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Geology and Hydrology, Alice Springs Town and Inner Farm Basins, Northern Territory

BY

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GEOLOGY AND HYDROLOGY, ALICE SPRINGS TOWN AND INNER FARM BASINS, NORTHERN TERRITORY

CORRIGENDUM

(i) Page 30, paragraph 3, line 10, should read.
"509 million cubic feet" in lieu of
"507 million gallons."

(ii) Plate 13 inserted in the pocket at the back of book
Order of diagrams are:
Precambrian, Tertiary and Quaternary.

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SUMMARY

The Alice Springs Town Basin is a small basin filled with Quaternary alluvium, which has provided the town with water. The Inner Farm Basin is more complex, with aquifers in unconsolidated deposits of Quaternary and Tertiary age, and in Precambrian rocks. They provide groundwater for domestic and agricultural use.

The results of a geophysical survey were used to plan three drilling programmes which were undertaken to investigate the occurrence of groundwater and to construct production bores for the town water supply. Several methods have been tried to construct efficient bores.

The two basins contain groundwater of nine different chemical types; groundwater suitable for domestic use occurs in the vicinity of the Todd River.

The volume of water in storage in the Town Basin fell from 647 million gallons in 1953 to 357 million gallons in 1964, as a result of an increase in the amount of water pumped from the basin. Average values for the aquifer constants (30,000 gallons per day for the coefficient of transmissibility and 0.07 for the coefficient of storage) were calculated from aquifer performance tests. The volume of water stored in the Inner Farm Basin is not known.

Maximum use could be made of the water available as recharge if groundwater was withdrawn from the Town Basin at a rate of 20 million gallons per month for a period of 2 months following a flood in the Todd River, with a subsequent reduction in the rate of withdrawal by 3.5 million gallons per month until the next period of recharge.

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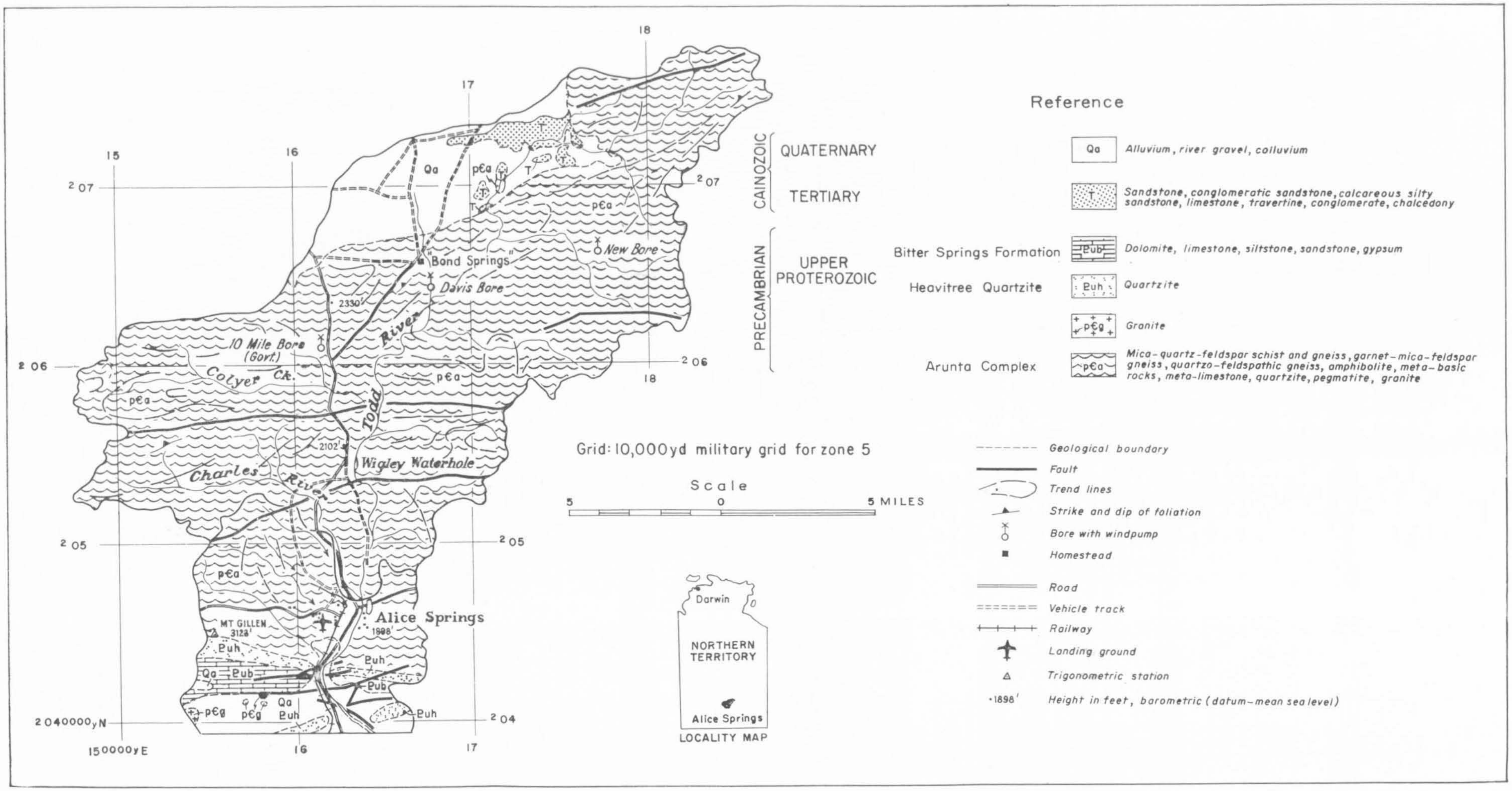

Fig. 1. Locality map and regional geological map of catchment of Todd and Charles Rivers.

INTRODUCTION

The Alice Springs Town Basin is a small alluvial basin with a maximum depth of about 75 feet and a surface area of about 3 square miles. Groundwater is withdrawn from the basin for the Alice Springs town supply, and until January 1964 this was the only source of supply. Some water for the town supply was imported from the Inner Farm Basin from January 1964 to April 1965. In the later part of 1964, pumping from the Town Basin virtually ceased when production from an alternative source of groundwater in Palaeozoic sandstone was started. The annual withdrawal at that date was about 250 million gallons, of which 200 million gallons was withdrawn by the town supply bores.

The Resident Geological Section, Northern Territory Administration, was requested by the Commonwealth Department of Works, in September 1959, to provide geological assistance in a programme of test drilling, the construction of 8 production bores, and long-term tests to determine the aquifer constants. This programme has been completed.

The Inner Farm Basin is a more complex basin, in which aquifers occur in Quaternary and Tertiary unconsolidated deposits and in Precambrian rocks. Groundwater is withdrawn from the basin to provide for domestic and irrigation use in the Farm Area. Some agriculture is carried on in the area, but is mainly confined to small market gardens. The bulk of the information on the geology and hydrology of the basin has been obtained as a result of investigatory drilling by Water Resources Branch, Northern Territory Administration. The Resident Geological Section provided geological assistance for this investigation.

The groundwater nomenclature used in this report follows that proposed by Jones (1965), and the relevant definitions are given in the Appendix.

Previous Investigations

Test drilling of the Town Basin was begun by the Australian Army in 1943, and was continued by the Department of Works from 1953 to 1961. The earliest reports are those of Owen (1952, 1954), who considered aspects of salinity, recharge, and groundwater movement. He used a bedrock contour map to arrive at an estimate of 900 million gallons for the amount of water stored in the basin.

Jones (1957) was able to refine Owen's ideas and to prepare a more accurate bedrock contour map with the aid of additional information. He estimated the amount of water stored in the basin to be 330 million gallons. This report was the first to consider the Inner Farm Basin, which was estimated to contain 180 million gallons.

The Bureau of Mineral Resources carried out resistivity and seismic surveys in the Town and Inner Farm Basins in 1956 (Dyson & Wiebenga, 1957). The results of their surveys were used in the planning of part of the Department of Works investigatory drilling programme.

Wilson (1958) conducted an investigation for the Department of Works, and examined groundwater movement, salinity distribution, and groundwater storage. He estimated that 1110 million gallons of water were stored in the Town Basin. He also carried out pumping tests on some of the production wells and measured some flows of the Todd River.

Forbes (1962) studied groundwater movement and salinity in both Town and Inner Farm Basins, and estimated that the annual safe yield from the Town Basin is 149 million gallons. He also estimated the average annual yield of surface runoff at Heavitree Gap to be 3180 million gallons.

Jephcott (1959) studied the relationship between groundwater salinity and river flow in the Town Basin, and concluded that sodium and bicarbonate are the most sensitive indicators of basin recharge.

Quinlan & Woolley (1962) discussed the occurrence of groundwater in the Town Basin, using the results of the drilling programme to 1960. They drew attention to the decline in the volume of groundwater in storage from 1953 to 1960, and made a preliminary interpretation of the results of some of the pumping tests.

Climate

Alice Springs lies within the arid zone: there are large diurnal and seasonal variations in temperature (Fig. 2), and the median annual rainfall of 10.58 inches (O'Mahoney, 1964) is much less than the potential free-water evaporation of 94.62 inches (Slatyer, 1962).

Rain is infrequent, and is dependent on the movement of moist air from north-west Australia, or South Australia, and the development of a pressure pattern that will produce sufficient uplift for rain to develop. 'More often than

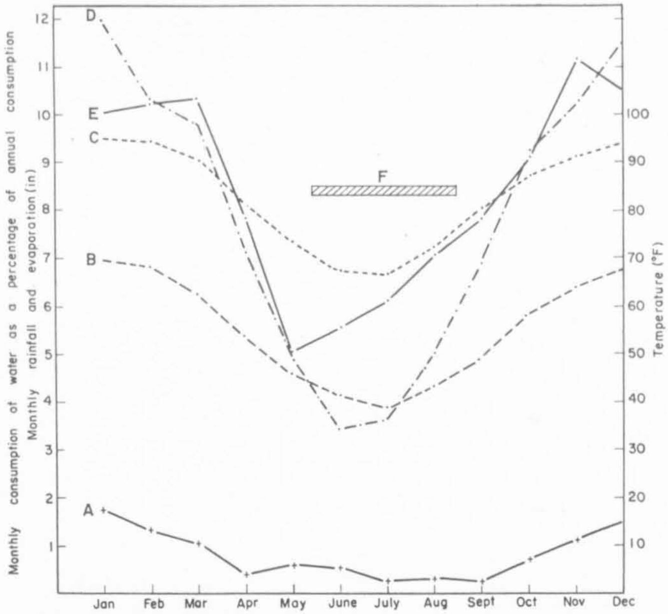

Fig. 2. Climatic data for Alice Springs, and its relation to consumption of water.

A: mean monthly rainfall, 1911-40 (Ashton, 1961); B: mean daily minimum temperature, 1911-40 (ibid.); C: mean daily maximum temperature, 1911-40 (ibid.); D: mean monthly evaporation, 1956-9 (Slatyer, 1962); E: main monthly consumption as a percentage of annual consumption, 1960-4; F: frost season.

not this is in the summer, but it can occur at any season. In any case it is rare, and such situations frequently have air masses from both north and south interacting' (Ashton, 1961).

Twenty-four-hour rainfall totals are measured at seven stations by the Water Resources Branch, Northern Territory Administration, the Commonwealth Bureau of Meteorology, and the Alice Springs Post Office. The records show that rain usually persists for 1 to 3 days, as light steady rain, with occasional heavy showers. Values for the mean monthly totals are higher for the summer than for the winter months, but as the rainfall varies so much these averages may have little real significance.

The use of water is closely related to the climate, as is shown in Figure 2 by the changes in the average monthly consumption, expressed as a percentage of the annual consumption. In spite of lower rates of potential evaporation, more water is used in June and July than in May, presumably because more is used on gardens in June and July to promote growth during the frost season.

GEOLOGY

Fluviatile sediment assigned to the Quaternary Period and unconsolidated sediment of Tertiary age are preserved in the Town and Inner Farm Basins. They rest unconformably on Precambrian sedimentary, igneous, and metamorphic rocks.

Because of the presence of regolith on the surface of the Precambrian rocks, it is often difficult to determine the position of the contact with the alluvium or the Tertiary sediment within a few feet from bore samples.

Precambrian Igneous and Metamorphic Rocks

The bedrock of the two basins consists of schist, gneiss, and granite, which are intruded by dolerite and pegmatite dykes. The rocks form part of the Arunta Complex (Joklik, 1955) of Precambrian age.

The metamorphic rocks are predominant, and consist of medium-grained to coarse-grained quartz-feldspar-mica gneiss, and fine-grained quartz-mica schist, with minor quartzite and amphibolite. They were probably formed by the regional metamorphism of a sequence of sedimentary rocks with some interbeds of volcanic rocks. They have been folded into an anticline whose axis trends north-west through Meyers Hill and Billygoat Hill. The predominant trend of the foliation is north-west, and is reflected in the trend of the bedrock 'highs' within the Town Basin (Pl. 7), although locally it is disturbed by minor folds and faulting.

Dolerite is the youngest intrusive rock in the area. To the north and west of the area of Plate 6 it forms vertical dykes 5-10 feet wide and thousands of feet long, which show up prominently on the air-photographs.

The granite intrudes the metamorphic rocks, and crops out on the northern edge of the area covered by Plate 6; deeply weathered granite has been intersected in holes drilled in the Inner Farm area (Pl. 6). Bore WRB/AK intersected 42 feet of weathered granite below the base of the Tertiary sediment; the top 6 feet of the granite are weathered and silicified and in the granite below the feldspars are kaolinized.

Pegmatites ranging from a few inches to 20 feet wide intrude the metamorphic rocks. Some of them are conformable with the foliation and others are discordant. They are generally very coarse-grained and contain quartz, feldspar, and a little mica.

Precambrian Sedimentary Rocks

Of the sedimentary rock units in the Amadeus Basin, the Heavitree Quartzite is the oldest, followed by the Bitter Springs Formation. Both are of Upper Proterozoic age.

Heavitree Quartzite

The Heavitree Quartzite (Joklik, 1955) is the sequence of medium-grained quartz sandstone, with some thin stringers of coarse-grained to very coarse-grained sandstone and very thin interbeds of pale grey shale, which rests unconformably on the Arunta Complex. At the surface the sandstone is commonly strongly cemented to quartzite. At Heavitree Gap there is a siltstone at the base of the formation which is not known to crop out elsewhere. It is about 30 feet thick, and the sandstone is about 500 feet thick (M. A. Condon in Prichard & Quinlan, 1962). A little disseminated pyrite occurs in the upper part of the formation, but it has not been observed in the Alice Springs area. In the Heavitree Range, from which the unit derives its name, the dip is about 80° to the south, with an east-west strike. In the Mount Blatherskite area the dip is vertical.

Bitter Springs Formation

The Bitter Springs Formation (Joklik, 1955; Ranford, Cook, & Wells, 1965) is a sequence of hard dark grey well bedded commonly laminated dolomitic and cherty limestone, interbedded with dark grey or black shale and siltstone, and dull red argillaceous limestone. Intraformational breccias, algal biostromes, and *Collenia* bioherms are common. The formation is 2500 feet thick at Ellery Creek, and rests conformably on the Heavitree Quartzite (Prichard & Quinlan, 1962).

Within the area of Plate 6, the unit comprises a basal sequence of pyritic grey siltstone and shale, overlain by grey, pink and purple fine-grained carbonate rocks which are dolomitic in part. Secondary gypsum is common in areas underlain by pyritic siltstone and shale. The shale is laminated to thin-bedded, and the carbonate sequence is thin-bedded to thick-bedded. The formation has been complexly folded and faulted, and the thickness of the unit is unknown.

Pyrite has been observed in samples from several bores, and the results of spectographic analyses of some of the samples are given in Table 1.

TABLE 1: SPECTROGRAPHIC ANALYSES, BITTER SPRINGS FORMATION

Bore	*Depth* (ft)	*Cu* (ppm)	*Co* (ppm)	*Ni* (ppm)	*Zn* (ppm)	*Sn* (ppm)	*Pb* (ppm)
WRB/O (F157)	74	20	n.d.	n.d.	n.d.	n.d.	n.d.
	76-86	10	10	10	n.d.	n.d.	10
	88-94	10	10	10	n.d.	n.d.	10
	96-102	10	10	10	n.d.	n.d.	10
(Sludge)	102	10	10	10	n.d.	30	20
	104-106	10	10	10	n.d.	n.d.	10
	108-114	10	10	10	n.d.	10	10
	116-122	10	10	10	n.d.	10	10
	124-130	10	10	10	n.d.	n.d.	10
	133-135	10	10	n.d.	n.d.	n.d.	10
(Sludge)	100-135	10	10	10	n.d.	n.d.	10
WRB/U (F163)	202-218	10	10	10	n.d.	n.d.	50
	238	10	10	10	n.d.	n.d.	40
	240-250	10	10	10	n.d.	n.d.	10
	250-260	10	10	10	n.d.	n.d.	20
WRB/X	150	10	220	150	n.d.	n.d.	40

n.d. = not detected. Detection limit for Zn is 50 ppm

Gypsum and anhydrite have been noted in several bore samples, particularly from bores WRB/BC and WRB/X, and the cuttings from between 130 and 170 feet in borehole WRB/BC consisted almost entirely of gypsum.

The analyses of four samples of the purest limestones collected by Hossfeld (1941) at various stratigraphical levels over an outcrop width of 210 feet are listed in Table 2.

A weathered zone has been developed over part of the formation; it is known from bore samples (e.g. WRB/BA, WRB/AR), and is exposed in the outcrop south-west of Mount Blatherskite. The weathered zone consists of yellow and red clay up to about 40 feet thick. Solution cavities and open ironstained joints are common in the lower part of the limestone. The weathered zone is older than the Tertiary sediments of the Inner Farm Basin.

Tertiary Sediments

The Tertiary sediments in the Inner Farm Basin (Pl. 6) have a limited distribution, and are continuous with more extensive deposits to the south in

TABLE 2: ANALYSES OF LIMESTONES, BITTER SPRINGS FORMATION
(after Hossfeld, 1941)

Sample No.	*Assay Results*	*(%)*	*Width of Sample Across Strike* (ft)
T301	$CaCO_3$	74.42	50
	SiO_2	10.2	
	Fe_2O_3	0.9	
T302	$CaCO_3$	87.5	80
	SiO_2	8.5	
	Fe_2O_3	0.3	
T303	$CaCO_3$	91.0	40
	SiO_2	6.2	
	Fe_2O_3	0.25	
T304	$CaCO_3$	99.26	40
	SiO_2	0.5	
	Fe_2O_3	Nil	

the Outer Farm Basin, which contain Tertiary fossils (P. R. Evans, BMR, pers. comm.). The maximum thickness in the Inner Farm Basin is 150 feet in bore WRB/BI, at the southern end of the basin. The contours representing the base of the Tertiary sediments are shown on Plate 8. The dominant rock type is white to pale grey fine sandy clay, commonly mottled with yellow and reddish brown streaks. Pale grey, yellow, khaki, brown, purple, and reddish brown clay, silty clay, and clayey silt, with varying amounts of fine to coarse sand, are also present. Beds of clean sand form only a small proportion of the total thickness, and individual beds are all less than 10 feet thick. The typical Tertiary sands consist of white translucent angular to subangular quartz grains, with rare grains of other minerals. The grainsize ranges from fine to very coarse, but individual beds are generally fairly well sorted. Some of the sands in the upper part of the Tertiary sequence are polymict, and are similar to the Quaternary sands; they are more common to the south in the Outer Farm Basin.

In the few outcrops of Tertiary sediments the lithology is generally obscured by weathering. The top zone of the profile of weathering is a siliceous 'billy' from 10 to 20 feet thick. It is underlain by a dazzling white leached zone, which grades down into the parent rock of white sandy clay. In the vicinity of bore WRB/BG there is a hard cap of silicified sandy clay at the top of the Tertiary sequence, buried under 70 feet of Quaternary sediments. This material looks like the billy which occurs in outcrop, but it is not as strongly silicified and not as hard. It is about 5 feet thick, and is underlain by a coarse to very coarse angular quartz sand. The same succession was also intersected in bore WRB/CR, 700 feet to the north-east.

Quaternary Alluvium

The Quaternary deposits are directly associated with the present and past channels of the Todd River. The maximum thickness recorded is 90 feet in the gap at Mount Blatherskite, through which the Todd River flowed until about 1880, when it changed to its present course during a particularly large flood. The fluviatile sediments are not everywhere thickest under the present channel of the Todd River.

The fluviatile sediments consist of a mixture of gravel, sand, silt, and clay, and can be divided into four main lithological types:

1. Brown sand
2. Brown and grey clayey sand
3. Brown and grey silt and clay
4. Regolith and colluvium

Brown Sand: Sieve analyses (Fig. 4, Table 3) show that the sand has a wide range in grainsize. Quartz is predominant, but some of the beds contain sufficient feldspar grains to warrant the use of the term arkose. Fragments of gneiss and schist, and aggregates of quartz, are common; they range from sand to boulder size. The silt fraction consists mainly of quartz and mica. The sieve analyses of samples from closely spaced intervals in any one bore may show differences in the degree of sorting. This is probably because the sediments are thinly bedded (from 6 to 12 inches thick).

Test drilling has shown that the beds of sand are long, narrow bodies with a lenticular cross-section. The lenses are from 2 to 25 feet thick, and they anastomose both vertically and horizontally through the body of alluvium.

This type of sediment forms about 15 percent of the total volume of the saturated alluvium in the Town Basin.

Brown and Grey Clayey Sand: The brown and grey clayey sand contains the same minerals as the brown sand, but much more matrix, and in places the proportion of silt and clay exceeds that of sand.

Brown and Grey Silty Clay: Probably 80 percent of the sediment in the basin is silty clay. It consists of blue or grey silty clay, very thinly interbedded or laminated

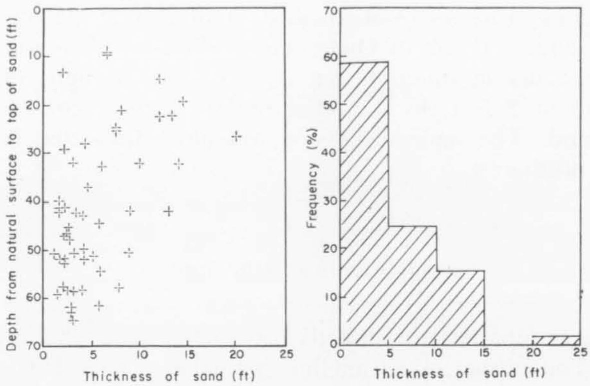

Fig. 3. Thickness of beds of channel sand in the vicinity of Bent Tree Well.

with brown clayey silt. Black carbonaceous (?) laminae are common, and it may contain variable but appreciable quantities of very fine to medium-sized sand. The clay content is estimated to range from 10 to 40 percent, and where it exceeds 30 percent the wet sediment is greasy and plastic. The silt fraction consists mainly of flakes of mica, and the sand fraction of subangular or subrounded grains of quartz, with up to 20 percent angular grains of feldspar.

Regolith and Colluvium: The regolith overlying the Arunta Complex is a stiff blue sandy clay, with cobbles and boulders of both weathered and relatively fresh metamorphic and igneous rocks. In some bores thin lenses of brown coarse sand are interbedded with the blue sandy clay. The sand-size material consists of angular grains of quartz and up to 25 percent of subangular grains of feldspar. Some of the cobbles, pebbles, and coarse sand grains are well rounded and waterworn. The sandy clay shows no sign of bedding or relict foliation.

The steeper slopes on the outcrops of the Precambrian rocks are commonly covered by coarse scree and rubble. Similar deposits are present on the steeper surfaces of the unconformity at the base of the alluvium in the two basins. The buried scree deposits form only a small portion of the total volume of saturated alluvium, but many of the boulders and cobbles in the alluvium may have been derived from them.

Stratigraphy of the Quaternary Alluvium

It is difficult to correlate the stratigraphic succession in alluvial deposits from bore to bore because of the irregular shape of individual beds, and the presence of cut-and-fill structures resulting from sudden changes in the position of the river channel. The correlations in the southern portion of the Town Basin which were used to compile Plate 10 are subjective; they were made by using basic assumptions and theory applicable to the fluvial environment (see p. 19).

These correlations were extended through the Town Basin and were used to recognize six aquifer systems which have been informally named the 'wedge', the '1810', '1820', '1830', '1840', and '1850' aquifers. The upper and lower boundaries of the aquifers correspond with what appear to be prominent changes in the location and depositional environment of the ancestral Todd and Charles Rivers.

The aerial distribution of the main textural types of alluvium for five of the aquifers is as shown on Plate 10. The areas of silty sand are considered to represent the meander belts of the river channels, and do not necessarily represent the actual extent of a bank-full stage of the river.

Texture

Samples of the fluvial sediments in the Town Basin were collected in a chop pump during the drilling of some of the test holes. The chop pump was emptied into a 20-gallon drum, and the sample obtained was passed through a Jones sample splitter to reduce its size. After allowing the silt and very fine sand to settle, the excess fluid was removed from the sample by decanting. Finally, the sample was dried and sieved in the Soils Laboratory of the Department of Works in Alice Springs.

The results of the sieve analyses have been used to plot cumulative size distribution curves on logarithmic probability paper, and some of the curves are shown in Figure 4. The curves indicate how closely the observed size distribution follows a theoretical log-normal law.

The assumption that the particle size distribution of a sediment is governed by either the normal or the log-normal law is a matter of convenience. It is adopted because the differences in particle size are not accounted for by definite assignable causes, but only by a number of unknown factors (Herdan, 1953).

The cumulative curves shown in Figure 4 are sigmoidal rather than straight lines, but it has been shown that many sets of data plot in this way. It has been suggested (Tanner, 1958; Doeglass, 1946) that such curves may be composed of two or more log-normal components. The method of Tanner (1959) has been used to separate components from the sets of data on samples from the Town Basin. These components are shown as broken lines in Figure 4.

Three parameters are necessary to define each component: the proportion of the weight of the component to the total weight of the sample, expressed as a percentage; the mean; and the standard deviation of the component. In general it was found that the original sample consisted of three components. The mean of the first falls in the silt to fine sand-size interval, the mean of the second falls in the medium to coarse sand-size interval, and the third, if present, falls in the fine pebble-size interval.

TABLE 3: TEXTURE OF THE QUATERNARY SILTY SAND, ALICE SPRINGS TOWN BASIN

	1			2			3		
Component	Pebble	Sand	Silt	Pebble	Sand	Silt	Pebble	Sand	Silt
Mean (mm)	—	0.87	—	—	0.73	—	—	0.55	—
Standard Deviation .	—	1.3	—	—	1.0	—	—	0.9	—
Proportion(%) . . .	1	91	8	<1	50	49	3	52	45

	4			5			6		
Component	Pebble	Sand	Silt	Pebble	Sand	Silt	Pebble	Sand	Silt
Mean (mm)	12.55	0.90	—	37.27	1.14	—	16.15	0.78	—
Standard Deviation .	0.8	1.35	—	0.9	1.25	—	3.5	1.0	—
Proportion(%) . . .	10	86	4	23	65	12	25	45	30

	7			8			9		
Component	Pebble	Sand	Silt	Pebble	Sand	Silt	Pebble	Sand	Silt
Mean (mm)	5.50	1.32	—	2.55	0.68	—	27.86	1.04	—
Standard Deviation .	0.8	1.0	—	1.3	1.0	—	1.7	1.3	—
Proportion(%) . . .	50	40	10	48	28	24	35	52	13

1. Bore 59/1, 29′8″-31′2″, '1840' aquifer
2. Bore 60/3, 54′-54′7″, 'wedge' aquifer
3. Bore 61/9, 19′, '1850' aquifer
4. Bore 60/12, 46′7″-48′8″, '1820' aquifer
5. Bore 60/10, 28′4″-29′1″, '1840' aquifer
6. Bore 60/20, 55′8″-57′6″, '1810' aquifer
7. Bore 60/11, 63′8″-64′7″, '1810' aquifer
8. Bore 60/1, 59′3″-61′2″, '1810' aquifer
9. Bore 61/17, 66′-66′10″, '1810' aquifer

Nine parameters are thus necessary to describe fully the cumulative size-distribution curve. The mean and the standard deviation of the first and third components cannot always be derived because of the limitations of the sizing method used. The seven parameters which could be determined for the examples illustrated in Figure 4 are shown against the appropriate curves.

The spatial distribution of the three parameters of the second component was examined, using nested analysis of variance (Miller & Kahn, 1962) to determine if there is a systematic variation in the texture of the sediments within the Town Basin.

Seventy-seven values of each of the three parameters derived from samples taken from the '1810' aquifer and 24 from the '1820' aquifer were used for an analysis of variance. This analysis shows that there is no significant variation in the median grain size, the standard deviations, and the proportions of the second component to the total samples, throughout the basin. The proportion of the second component in the total samples ranged from 40 to 90 percent, but this is no greater than could be expected.

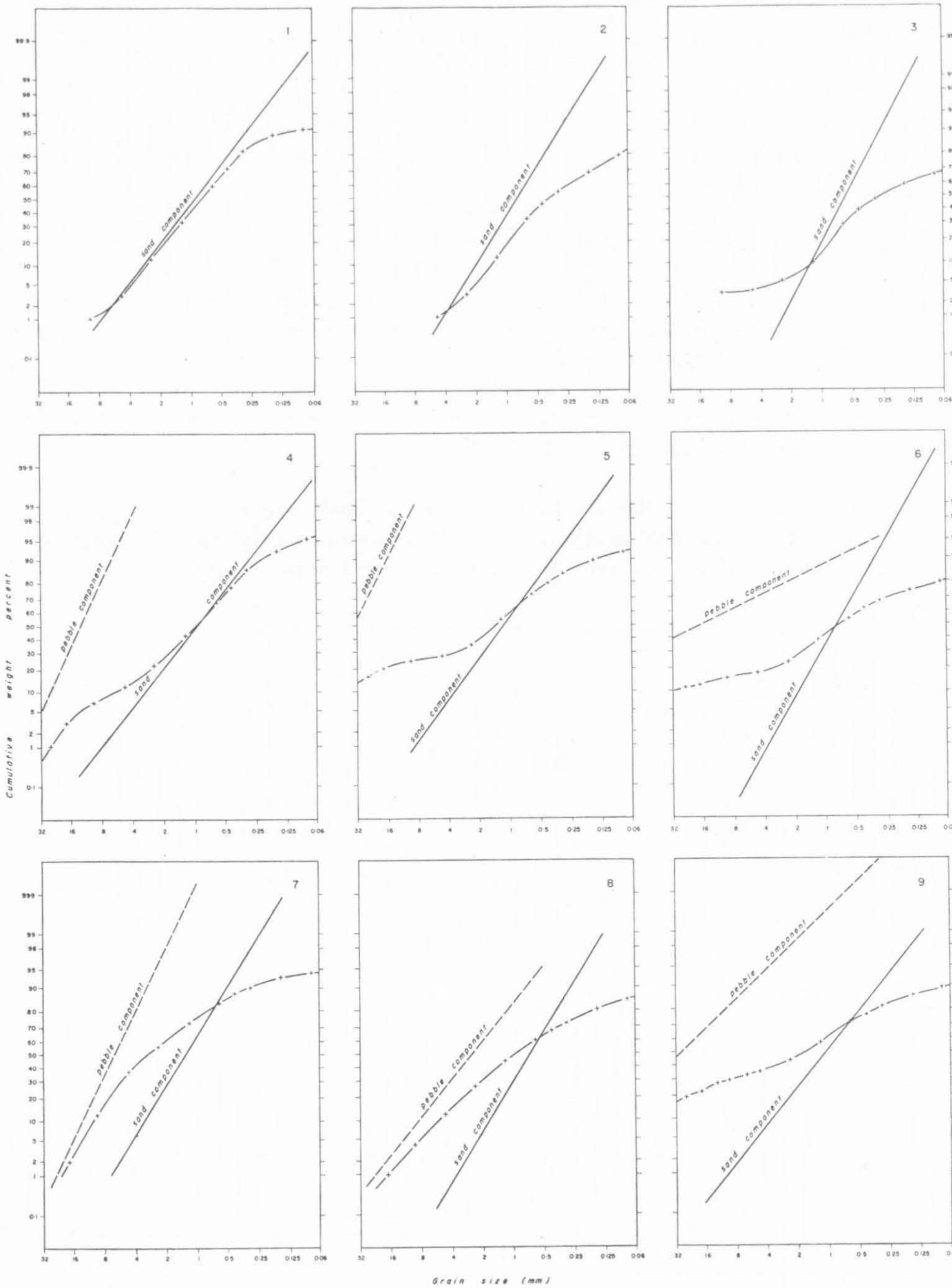

Fig. 4. Texture of the Quaternary silty sand, Town Basin, Alice Springs.

An analysis of linear regression was used to determine if the variation in the seven parameters is systematic. For the means and standard deviations of the second component and the proportion of the third component it was not. The proportion of the second component varies between wide limits and decreases from an average value of 80 percent at the Todd Well to 60 percent at Heavitree Gap; the proportion of the first component shows a corresponding increase. This change in texture can be illustrated by a comparison of the curves shown in Figure 4 D, E, and J.

These facts can be interpreted to indicate that:

1. The physical processes which controlled the transport and deposition of sediment within the Town Basin were similar during the deposition of the '1810' and the '1820' aquifers.

2. The three components represent the bed, saltation, and suspended loads respectively of the ancient Todd River.

3. The sediments in the southern end of the basin are more poorly sorted than those in the northern end. The more poorly sorted sediments presumably have a lower effective porosity and permeability.

GEOLOGICAL HISTORY

The Upper Proterozoic Heavitree Quartzite and Bitter Springs Formation are the oldest units of the sedimentary sequence in the Amadeus Basin. The basement underlying the basin consists of igneous and metamorphic rocks of the Arunta Complex. The youngest sedimentary unit, the Pertnjara Formation, is of Devonian to Carboniferous age (Hodgson, 1967; Ranford et al., 1965), and is a synorogenic sediment (Quinlan, 1962). The conglomerate member of the formation was deposited as a wedge-shaped body against the southern flank of an area of uplift to the north and east of Alice Springs. As a result of this uplift, the Alice Springs Orogeny of Forman et al. (1967), the sedimentary rocks were folded and faulted into the MacDonnell Range monocline.

The present landform, of parallel strike ridges and valleys with a transverse drainage pattern, is the result of at least two periods of erosion and two periods of deposition which followed the Alice Springs Orogeny. The probable sequence of geological events outlined below is based on numerous observations made outside of the area shown on Plate 1. The terminology used is that of Leopold et al. (1964).

Pre-Permian Erosion

The first period of erosion produced strike valleys with a relief in the order of 800 to 2000 feet before the Upper Permian. Spores of Upper Permian age have been identified (P. R. Evans, unpubl. data) in cuttings from a bore (F53/14-224) drilled in valley-fill sediments on the margin of the bolson to the north of the MacDonnell Ranges (Perry et al., 1963).

Erosion of the tops of the strike ridges to produce the Summit Surface of Mabbutt (1965) also dates from this time.

The results of seismic surveys and of test drilling, and the distribution of the Tertiary sediments in the western MacDonnell Ranges indicate that the drainage system was longitudinal, and that the master channel occupied the strike valley between the Arumbera Sandstone and Pacoota Sandstone. The bed of the channel was 1640 feet above sea level at a point south of Mount Blatherskite. Headward erosion of a tributary through the gap at Mount Blatherskite allowed the excavation of the valley to the south of the Heavitree Ridge. This erosion was controlled by a local base level of erosion in the gap, at a height greater than 1750 feet above sea level (Pl. 8).

The Precambrian rocks were deeply weathered during this period, and 42 feet of weathered granite were intersected in bore WRB/AK below the base of the Tertiary sediment in the Inner Farm Basin. The top 6 feet of the granite are weathered and silicified, and in the granite below the feldspars are kaolinized. The base of the weathering is at 1644 feet above sea level. The granite exposed on the north side of Anzac Hill is not weathered at an elevation of 2041 feet above sea level. Tertiary sediment overlies the mottled and pallid zones of weathered Bitter Springs Formation in an outcrop to the south-west of Mount Blatherskite.

It is inferred that the Heavitree Range was not breached at this stage, or if it was, it was at the level of the crest slope of the summit surface (Pl. 2, fig. 2), as no early Tertiary sediment is preserved within the MacDonnell Ranges to the north of the Heavitree Range, and because of the difference in elevation of the contact between weathered and fresh rock of Precambrian age, on either side of the range.

Early Tertiary Sedimentation

Sediment of Tertiary age was deposited in the strike valleys. It is considered to be largely of lacustrine origin, because of its texture and the presence of thin beds of lignite. The strike valleys were filled to the level of the crest slope of the summit surface (Pl. 4, fig. 1).

Weathering and erosion of the exposed portions of the strike ridges was continued.

Tertiary Deep Weathering

A long period of subaerial weathering followed, and as a result silicified and leached zones of grey billy were formed on the Tertiary sediment. Silicification of the summit surface continued, and by this time it was sufficiently thick to ensure that the segments of the surface would be preserved.

Lloyd (1967) has concluded that the stratigraphical relationships indicate that the period of weathering extended from the Eocene to the Miocene. Quinlan (1962) has concluded that the grey billy profiles and the laterite profiles, developed elsewhere in central Australia, are complementary: grey billy was formed on parent rocks with a low iron content, and laterite on parent rocks with a high iron content.

Quaternary Erosion

The upper surface of deep weathering, as preserved in central Australia, is a broad regional dome with superimposed local relief of about 100 feet; residuals of Precambrian rocks stand above the surface in the MacDonnell and Harts Ranges. The warping which produced the regional doming is considered to be partly of Quaternary age. It has been responsible for the rejuvenation of the streams which have exhumed much of the pre-Permian land surface.

The rejuvenated drainage system was still largely longitudinal, and undercutting resulted in the erosion of the Tertiary sediments at a much faster rate than the downcutting required to produce Heavitree Gap.

The final result of this second period of erosion was the excavation of the depression known as the Town Basin and the removal of a large volume of Tertiary sediment from the Inner Farm Basin. The stepped longitudinal profile of the ancestral Todd River is considered to be an equilibrium profile, resulting from the resistance of the Heavitree Quartzite and its control on the local base level of erosion.

Quaternary Deposition

It is difficult to determine the climatic conditions prevailing during the deposition of the Quaternary sediments. The texture of the sediments and the distribution of the lithological types suggest that they were deposited by an intermittent stream. It is possible that there has been no marked change in climate since then.

The five main lithological types of alluvium are thought to have been deposited in different environments (Table 4), and the distribution of four of them within the Town Basin is shown on Plate 10.

The broad principles controlling deposition in the basin are discussed below. They are based on the assumption of deposition by an intermittent stream, scale-model studies by Bain (1953), and the spatial distribution of the lithological units inferred from the results of test drilling.

Sediment is deposited from the suspended and bed loads of a river as a result of a reduction in velocity. Initially it is deposited to form an alluvial fan at the head of the basin. The channels on the face of the fan shift their position rapidly from one side to the other, to build the characteristic shape. At high-water stages sheet-flow extends across the fan between the channels, depositing fine-textured material. The channel sands are thin and markedly lenticular in cross-section, as the braided pattern may change with each flood stage. The system of drainage channels rapidly becomes graded with the drainage system in the catchment, and the front of the fan moves downstream.

TABLE 4: ENVIRONMENT OF DEPOSITION OF THE QUATERNARY ALLUVIUM

Lithological Type of Alluvium	*Postulated Environment*
1. Brown sand	(a) Main river channels (b) Braided channels on alluvial fans
2. Brown and grey clayey sand	Natural levee banks
3. Brown and grey silty clay	(a) Backswamp areas and flood plains behind the natural levee banks (b) Sheet flow deposits on the front of alluvial fans
4. Regolith	The surface of older rocks
5. Colluvium	Adjacent to steep slopes Developed on older rocks

The suspended load of clay and silt, together with detrital material carried by tributaries from the edge of the basin, is deposited in back swamps and flood plains.

Upstream from the head of the fan there are usually fewer channels, because they are confined by natural levees, built when the stream overflows, or because they are entrenched in older deposits. The sands in the channels are consequently thinner than those on the face of the fan, and their margins are well defined. As deposition continues channels become fewer and their grade lower, tending ultimately to the development of a single channel, which can transport more material than a system of braided channels. The thickness of channel sands, therefore, will generally decrease as the basin is filled, as illustrated by the scatter diagram of Figure 3.

Intermittent flow results in a variable degree of vertical sorting, but there is very little improvement in sorting along the length of the channel (cf. p. 14). The proportion of silt and clay in the sand is greater than in the channel of a perennial stream. At low-water stages the channel is not wholly occupied and the stream is deflected from one side to the other, depositing a layer of fine-textured material on top of the previous channel deposit. The average thickness of sand deposited in the channel during any one cycle of deposition in the Town Basin was probably between 2 and 5 feet (Fig. 3). The bodies of sand over 5 feet thick probably represent two or more cycles. Sand was re-sorted to a small degree at high-water stages or during periods of prolonged flow.

These principles have been used to postulate a sequence of events in the filling of the Town Basin, the main features of which are shown on Plate 9 and are summarized below:

(a) In stage 1 the channel of the Todd River occupied the deeepest portion of the basin. Alluvium was deposited to form an alluvial fan, which is shown below the '1810' aquifer in the longitudinal profile on Plate 6.

(b) In stage 2 the front of the alluvial fan had moved to a position south of Army Well No. 2. Upstream from the apex of the fan graded channels had been developed, to form the '1810' aquifer, with natural levees along its length. It is assumed that the external tributaries began to build up small fans on the margin of the basin. Back swamps developed where the levees impounded the flood waters from the tributaries.

(c) Stage 3 began when the head of the alluvial fan had passed through Heavitree Gap, and the channels which had developed on the top of the fan were graded to a slope of about 20 feet per mile. Deposition of material from the suspended and bed loads continued, to form the '1820' and '1830' aquifers. The distribution of silty sand, shown on Plate 10, indicates that the Todd River probably occupied several braided channels which migrated laterally from one side of the basin to the other. The Charles River began to deposit alluvium in the basin, entering it to the west of Billy Goat Hill.

(d) In stage 4 the area occupied by the channel shrank, and gradient dropped to 17 feet per mile. The northern boundary to the '1840' aquifer shown on Plate 10 marks the northern limit of deposition, and it is assumed that the Todd River was degrading its channel upstream.

(e) In stage 5 fine-grained sediment was deposited over large areas in the western part of the basin. The western channels were covered by sediment and the Charles River was diverted to join the Todd at the head of the basin. A comparison of the areal distribution of the silty sand shown on Plate 10 for the '1840' and the '1850' aquifers illustrates the tendency for the Todd River to develop a single channel.

(f) At the present time (stage 6) the Todd River occupies an incised channel on the eastern side of the basin. The degradation-aggradation boundary is considered to be at Heavitree Gap. Local residents point out that the bed of the river has risen between 5 and 10 feet within the last 20 years. The rate of deposition has probably been accelerated by grazing in the catchment area.

GEOPHYSICAL INVESTIGATIONS

Seismic and resistivity surveys were undertaken by Dyson & Wiebenga (1957).

Resistivity Method

The apparent resistance is influenced by vertical differences in lithology and the composition of the pore fluids. These differences are pronounced in the two basins (Pl. 11, 13), and only prominent geological and hydrological features are reflected in the areal distribution of the apparent resistivity measurements.

If it is assumed that the depth of penetration of the current is 60 percent of the distance between the electrodes, then the apparent resistance measured with a separation of 200 feet between electrodes is largely influenced by the resistance of the Precambrian rocks. With a separation of 100 feet the apparent resistance will be influenced by both the Precambrian and Quaternary rocks. This is illustrated by the general similarity of the two sets of results shown on the resistivity profiles and contour maps by Dyson & Wiebenga (1957).

The contour maps for the two electrode spacings show a major high-resistivity zone on the eastern side of the Town Basin (Pl. 18). Readings in excess of 100 ohm-metres in this zone, measured with a 100-foot spacing of the electrodes, are not considered to indicate a thin section of alluvium, and the lower readings to the east of the zone do not indicate the presence of saline water (over 5000 ppm total dissolved solids) in the Precambrian rocks. Good-quality water, with less than 500 ppm total dissolved solids and a predominance of the bicarbonate ion, is stored in permeable sand in the area bounded by the 40 and 100-ohm-metre contours on the western margin of the zone.

The measured values of the apparent resistance are higher at the western ends of traverses C and E close to the western margin of the basin, where the alluvium is not saturated and is less than 30 feet thick.

The ancient channels of the Charles River (Pl. 10) coincide with the minor high-resistivity zone on the western side of the basin; the permeable sands associated with the channels contain water with a salinity greater than 1000 ppm.

An attempt was made to estimate the porosity of the alluvium by using the nomogram of Dyson & Wiebenga (1957, fig. A1). Values of the resistance of the saturated alluvium obtained by them, using the depth probe technique, were compared with values of the salinity of the pore fluid, estimated from the contour maps of Plate 10. Most of the estimates for the porosity were found to be greater than 30 percent, and are not considered to be realistic.

Seismic Method

Using the seismic refraction method, Dyson & Wiebenga (1957) distinguished two discontinuities which they considered to be (a) the top of the zone of saturation, and (b) the base of the weathered zone in the Precambrian rocks.

The depth to the top of the zone of saturated sediment is variable, and is greater in the areas farthest from the river. It is of the same order as the depth to the piezometric surface, but the two do not correspond, because individual aquifers in the Quaternary alluvium normally contain groundwater under confined conditions. The zone of unsaturated sediment has a seismic velocity between 2100 and 2700 feet per second, except along traverses G and Q-R, in the bed of the river, where it is between 1100 and 1400 feet per second. The presence of permeable sand and the absence of silt (Pl. 10) may be responsible for the lower velocity in these areas.

The average seismic velocities in the lithological units below the top of the zone of saturation are 5000 feet per second for the Quaternary alluvium, 6000 to 7000 feet per second for the Tertiary sediment, 9000 feet per second for weathered granite, and 6500 to 8500 feet per second for the weathered metamorphic rocks. It has not been possible to identify the individual refractors, above the base of the zone of weathering, in traverse Q-R.

The base of the zone of weathering is irregular and its thickness is influenced by the lithology of the parent rock and its susceptibility to weathering. Assuming that these two factors are constant, the base of the weathered zone will be at about the same depth below surface. The elevation of the base of the weathered granite of the Arunta Complex (Pl. 6) in the Town Basin is markedly different from that in the Inner Farm Basin, and the two basins are considered to be of different ages.

The bedrock bars postulated by Dyson & Wiebenga (1957), at Heavitree Gap and at Point Q on the traverse in the Inner Farm Area, were not found. The longitudinal profile indicated by subsequent drilling (Pl. 6) shows that the contact between the unconsolidated sediments and the Precambrian rocks consists of a series of thalwegs uninterrupted by bedrock bars.

HYDROLOGY

Availability of Groundwater

Groundwater has been obtained from Quaternary alluvium, Tertiary sediment, Bitter Springs Formation, Precambrian granite, and Precambrian metamorphic rocks. It has not been obtained from the Heavitree Quartzite, which probably contains some aquifers, and the hard silicified sandstone is generally regarded as bedrock.

Quaternary Alluvium

Groundwater can be extracted from bores and wells which intersect permeable beds of silty sand below the piezometric surface. In the Town Basin, aquifers occur mainly in the areas shown as silty sand on Plate 10. The specific capacities of the bores in these areas may be over 1000 gallons per hour per foot of drawdown, but the capacities of the bores outside these areas are variable, and will probably be less than 300 gallons per hour per foot of drawdown.

Similar maps cannot be drawn for the Inner Farm Basin, for lack of data, but the same principles apply.

Many bores and wells near the present course of the Todd River were constructed to intersect shallow aquifers, in which the piezometric surface fluctuates considerably following river flow (Pl. 15), and the available drawdown is frequently insufficient to provide an adequate supply. To the north of the Heavitree Range, deeper aquifers could be developed, but in the Farm Basin they are not always available.

The fall in water levels during the period 1957-64 was sufficient to cause a significant reduction in the area of the saturated alluvium and volume of groundwater available (Pl. 16).

Tertiary Sediment

Groundwater is available from two types of aquifers in the Tertiary sediment preserved in the Inner Farm Basin. The first type consists of beds of quartz sand less than 10 feet thick, which will yield less than 1000 gallons per hour. It has not been possible to correlate the aquifers from bore to bore, nor to predict their presence. They are best developed in the south-eastern end of the basin.

The second type consists of one or more bodies of regolith overlying buried strike ridges of deformed and brecciated dolomitic limestone and siltstone of the Bitter Springs Formation. The limestone and siltstone are also porous and permeable, and together with the regolith they probably act as a single aquifer system. Both WRB/AI, F106 and WRB/AB were completed in this aquifer, and have specific capacities in excess of 1000 gallons per hour per foot of drawdown.

Bitter Springs Formation

Two of the rock types in the Bitter Springs Formation are porous and permeable, and the yield from bores may be over 3000 gallons per hour. The first type is black pyritic shale and siltstone which does not crop out. The pyrite occurs as small crystals disseminated in the siltstone and as large porous aggregates of small euhedral crystals. The porosity of the aquifer may be intergranular and associated with zones of mineralization or fracture porosity. The groundwater in the pyritic aquifers generally contains more than 2500 ppm total dissolved solids, as in bores F125 and WRB/O. It may be of better quality in these situations wherever there is an opportunity for recharge, as in the vicinity of bore WRB/X, but it always contains appreciable amounts of the sulphate radical.

The second type consists of very thick units of strongly deformed and contorted dolomitic limestone and siltstone in which intraformational breccias are common. Many of the dolomitic limestones are cherty and contain ankerite. The porosity is due to the presence of vugs lined with calcite, and numerous fractures, and if they are interconnected the permeability is very high. Large quantities of groundwater with a salinity of less than 2000 ppm are stored in these aquifers, and much of the water contains less than 1000 ppm.

Yields of less than 200 gallons per hour have been obtained from beds of grey fractured siltstone and shale, but these aquifers are not considered to be of importance.

Precambrian Granite

Several bores have been drilled into the Precambrian granite in the Inner Farm area where it has been softened by weathering. In bore WRB/AJ a supply of 2000 to 3000 gallons per hour of good-quality water was obtained; all other bores were unsuccessful in that they produced less than 500 gallons per hour of saline water.

Precambrian Metamorphic Rocks

Aquifers are not readily available in the Precambrian metamorphic rocks. Less than 200 gallons per hour of good-quality water was obtained from bore A125 in the East Side subdivision of the Town; other bores have produced variable supplies of saline water, ranging from 2000 ppm in bore A81 west of Billy Goat Hill, to 21,207 ppm in bore 64 to the north of Myers Hill.

Methods of Construction and Development of Bores

About 186 test holes were drilled in the Town and Inner Farm Basins during the period 1958-64. The test holes were drilled to obtain information on the rapid lateral and vertical changes in lithology, to evaluate the resources of the two basins, and to find suitable sites for the construction of production bores.

Contractors with percussion rigs were engaged to drill in the Town Basin, under the supervision of a geologist. The holes were drilled with a chisel bit and without casing to the first aquifer. A string of 6-inch blank casing was then run into the hole, and casing measurements were kept to check on the position of the casing shoe in relation to the bottom of the hole. Below the piezometric surface the casing shoe was driven ahead of the hole, except when in thick intervals of clay or silt, where an open hole was drilled ahead of the shoe for 2 or 3 feet to free the casing.

Samples were obtained with a 6-inch chop pump, which was emptied into a 20-gallon drum at the end of each run of 1 to 2 feet. The samples were quartered with a Jones sample splitter and stored in 3-lb tins. Depths were measured with a weighted steel tape from the top of the collar.

When clays and silts were being drilled the hole had to be cleaned out regularly with the sand pump before an uncontaminated sample could be obtained, and water was added to the hole to minimize the risk of sand entering the hole around the casing shoe together with water from aquifers behind the blank casing. This practice, and the driving of the casing ahead, made it difficult to obtain a true sample of the water from an aquifer, and to estimate the yield, but these precautions were necessary to obtain an accurate log of the hole.

Most of the production bores were completed with sandscreens, swedged inside 8-inch casing. In the earlier production holes, a screen-slot opening was selected which would allow about 50 percent of the aquifer material to pass through. Two lengths of screen were generally placed opposite the deepest and thickest aquifer located by the test drilling. The hole was drilled and cased to just below the bottom of the aquifer, and the casing was then withdrawn to expose the screen. Eight-inch casing was necessary to accommodate the pumping equipment.

The early holes were developed by means of mechanical surging, using both solid and valve surge tools. Silt and clay frequently sloughed from the walls of the holes, because in most of the holes there are several thin aquifers separated by silt or silty clay, and because it was impracticable to provide screens opposite each aquifer. In some cases onlv an upper aquifer was sealed off.

Attempts were made to prevent collapse by using gravel packing techniques, but these were not successful in stabilizing all the aquifers in a particular hole. Where separate gravel feed holes were used (Town Bore, 60/19), the emplacement of the gravel could not be controlled with sufficient accuracy. An attempt to provide a gravel envelope in the annulus between the production casing and the drill casing in bore 61/22 failed, probably because it was impracticable to use casing large enough to provide a sufficiently wide annulus.

In some of the later bores screens with larger slot openings were used and development was restricted to pumping only, to avoid collapse of the aquifer. This was only partly successful, although it was quite successful in developing the screened aquifer. Bore 61/42 (Bent Tree No. 2 Bore) included two aquifers at 38 to 40 feet and 54 to 58 feet; the upper aquifer was cut off by sloughing of clay in the interval 40 to 54 feet during the initial pumping period, but the lower screened aquifer was well developed. Bore 61/33, with only one aquifer at 46 to 52 feet, was also developed successfully by pumping only, with the entire aquifer screened. The successful development of this bore was probably partly due to the large slot openings used (0.090 inch).

As the annular space between the wale of the hole and the screen may be sufficient to start collapse, two methods were tried in which the openings in the production string were set opposite the aquifer without withdrawing the blank casing. In the first method 8-inch casing with ⅛-inch diameter holes drilled on a 1½-inch square grid was used. In Bore 61/24 (Colocag Park), 40 feet of this perforated casing was undercut into position between 30 and 70 feet. Aquifers were known to exist at 28 to 30 feet, 56 to 61 feet, and possibly at 49 to 51 feet. The bore produced a good supply with the relatively high capacity of 450 gallons per hour per foot drawdown. This was probably due to production from two or more aquifers. However, the well loss is considerably higher than in bores completed with sand screens (see Table 5).

TABLE 5: SPECIFIC CAPACITY OF BORES, ALICE SPRINGS TOWN BASIN

Bore	*Specific Capacity* (gph/ft drawdown)	*Well Loss* (% of drawdown at 3000 gph)
Town 60/19	120	20
Bent Tree No. 2 61/42	270	10
62/9	1000	14
Gap 59	300	5
61/33	450	14
Colocag Park 61/24	430	29

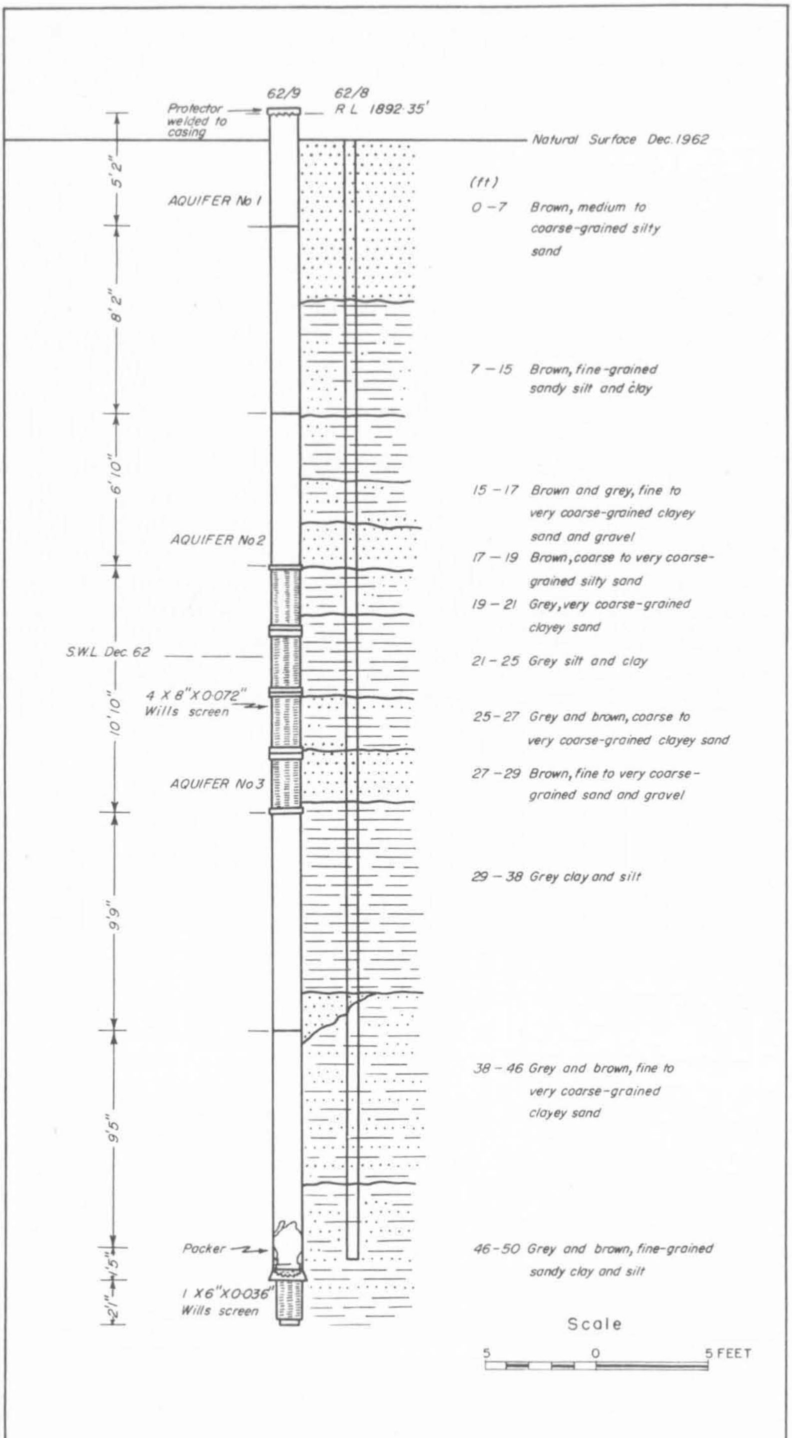

Fig. 5. Lithological log and completion details of bores 62/9, 62/8.

Bore 62/9 was constructed by undercutting into place a production string of screens screwed to 8-inch casing. Four lengths of 0.072-inch screen were used, with 20 feet of casing below; the screens were set at a predetermined depth indicated by test drilling (Fig. 5). By this means the screens were set directly against the aquifers with a minimum risk of collapse. By using four lengths of screen it was intended to obtain water from all available aquifers. The bore was developed by pumping with an axial-flow turbine pump, with backwashing by stopping the pump. This bore has the relatively high specific capacity of about 1000 gallons per hour per foot drawdown, and a low well loss (Table 4) indicates that development was satisfactory. The specific capacity, and well loss as a percentage of total drawdown at a pumping rate of 3000 gallons per hour, of the different types of bores are listed in Table 4.

Runoff and River Flow

A certain amount of rain must fall on the catchment within a given time before runoff will begin; this is variable, and depends on the intensity of the rain and the history of previous rainfall. Two qualitative estimates of this amount have been made: Wilson (1958) considers that 'the Todd River appears to flow only after about 1½″ of rain of an intensity approximately to 2″ per hour', and Forbes (1962) concluded 'that an average rain of 40-50 points in one day will bring the river down' provided it is of sufficient intensity.

These figures, and the daily rainfall totals and recorded volumes of river flows have been manipulated to estimate the yield of surface runoff from the catchments of the Todd and the Charles Rivers. Wilson (1958) considered that an average of three medium flows per annum crossed the East Side Causeway, during the period 1937-57, with a total average yield of 600 million gallons per year. He considered that on two occasions (1927-29 and 1901-02), the river probably did not run for 2 years. Forbes (1962) extrapolated a relation between average annual rainfall and surface flow through Heavitree Gap to derive an average yield of 507 million gallons per year. It is inferred from his Table 14 that the longest period between river flows was less than 2 years.

The cumulative frequency distribution of the number of days between successive river flows (Table 6) over the East Side Causeway for the period 1952-64 is plotted in Figure 6, using logarithmetic and normal probability scales. This plot indicates that the probability of the interval between successive river flows being less than 1 year is 91 percent, and less than 2 years is 96 percent. These estimates are not precise because they are based on the assumption that the distribution is of the log-normal type. An indication of their reliability is the departure of the points plotted on the right-hand side of Figure 6 from the 'straight line of best fit'.

TABLE 6: SUMMARY OF RAINFALL AND RIVER FLOW, TODD RIVER, 1952-64

Date of Commencement of River Flow at East Side Causeway[a]	Date of Cessation of River Flow at East Side Causeway[a]	Total Discharge at East Side Causeway[b] (million cu. ft)	Total Discharge at Heavitree Gap[b] (million cu. ft)	Number of Days Since Previous River Flow	Weighted Average of Rainfall on the Catchment (ins)[b]
1952					
26th January	NA			273	
26th October					
1953	1953				
2nd January	2nd January			68	
5th January	6th January			3	
3rd February	9th February			29	
29th April	2nd May			85	
27th December	29th December			242	
1954	1954				
25th January	NA			29	
14th October	16th October			262	
24th October	29th October			10	
1955	1955				
4th March	7th March			131	
22nd March	24th March			18	
27th July	NA			126	
1956	1956				
22nd February	1st March	211.0		211	
6th July	8th July			134	
1957	1957				
20th April		200.0		288	
25th April	29th April	220.0		5	1.14
19th June	22nd June	230.0		55	1.76
9th December	12th December			173	
26th December	5th January			17	
1958	1958				
8th March	11th March	0		72	
29th March	29th March			17	
15th May	16th May			68	
20th May	25th May			5	
1959	1959				
21st May	22nd May	1.0	0	366	
1960	1960				
11th January	11th January		0	235	0.56
17th January	19th January			6	1.09
29th January	31st January		92.8	12	1.43
11th February	15th February			13	0.54
11th October	12th October			242	1.03
15th November	18th November		5.3	35	0.36
1961	1961				
7th February	8th February			84	
18th April	24th April		355.9	70	2.08
6th November				214	
9th November				3	
1962	1962				
11th January	12th January		13.4	63	
14th January	19th January		71.2	3	
2nd March	5th March			47	
14th August	15th August			185	
23rd October	26th October			70	
19th November	21st November			27	
26th December	28th December			31	
1963	1963				
8th January	9th January			13	
14th May	19th May			126	
26th October	27th October			165	
29th December	30th December			64	
1964	1964				
13th January	13th January			15	
26th September				256	
14th October				18	
22nd December				69	
27th December				5	

a. Sources of Data: J. B. Owen, Alice Springs, Water Resources Branch, N.T. Administration, Commonwealth Department of Works, Resident Geologist.

b. Source of Data: Water Resources Branch, N.T. Administration.

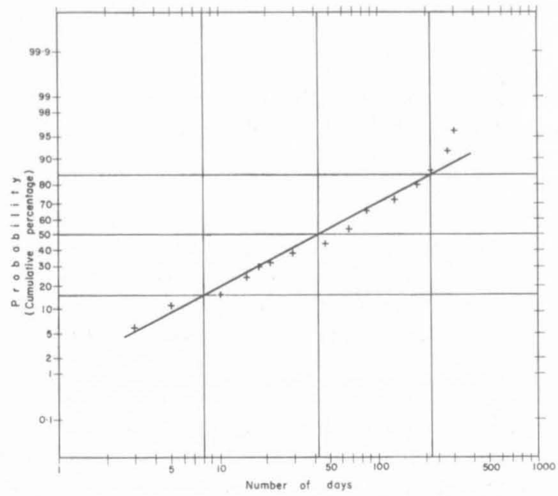

Fig. 6. Probable number of days between the beginning of successive flows in the Todd River.

Chemical Character of the Groundwater

Natural waters, such as rainwater and groundwater, are complex ionic solutions of the elements of the Earth's crust. 'They acquire some of the chemical characteristics through direct solution of some of the solids, liquids, and gases with which they may come in contact in the various parts of the hydrologic cycle where water is in the liquid state' (Hem, 1959).

The ten most common ions in natural waters are chlorite, sulphate, fluoride, calcium, bicarbonate, carbonate (if the pH is greater than 8.3), sodium, potassium, magnesium, and nitrate. The concentration of these ions in 860 water samples collected from bores and wells in the Town and Inner Farm Basins was determined in the chemical laboratory of the Animal Industry Branch, N.T. Administration, Alice Springs. The samples were collected during the years 1954-64. In addition, the conductivity of 1292 samples, taken at weekly intervals from the production bores and wells, was determined in the Resident Geologist's Office. The results form the basis for this discussion of the chemical character of the groundwater.

Two approaches were used to examine the data. Firstly, the variation in the areal distribution of the cations (calcium, magnesium, sodium, and potassium) and anions (bicarbonate, carbonate, chloride, sulphate, and nitrate) has been considered in relation to the aquifers which have been recognized. Changes in the hydraulic regime during the period 1954-64 must have been responsible for some changes in the areal variation, but have had to be ignored for lack of data. Secondly, the variation in chemical character with time has been considered where sufficient data are available.

The five aquifer systems in the Quaternary sediments of the Town Basin have been considered separately from the Quaternary, Tertiary, and Precambrian aquifers in the Inner Farm Basin.

The method adopted for the presentation of the chemical data is a modification of the trilinear plotting system of Piper (1944) using the classifying or 'D' function of Pelto (1954). Other methods which have been used include the mapping of absolute values or relative values of selected ions (Schoeller, 1959), and the mapping of geochemical facies (Back, 1961).

The 'D' function divides a continuous 3-component system into seven classes, three in which one of the end members is the dominant component, three in which two of the end members are the dominant components, and one in which none of the three end members is dominant. It is often possible to contour the values of 'D' within each class. This function was used because the division into the seven classes is logical and not arbitrary, and because values of the function 'D' seem to readily describe three variables simultaneously. The areal variation of the chemical character of groundwater in the Town and Inner Farm Basins, and in the Precambrian rocks below the Inner Farm Basin is shown on Plates 10, 11, 12, 13, and 14.

Contours of the content of total dissolved solids of the groundwater in the same aquifers are shown on Plates 10 and 13. The water in the Tertiary and Quaternary aquifers contains less than 3000 ppm and that in the Precambrian rocks may contain up to 10,000 ppm.

Quaternary Aquifers of the Town Basin.

The salinity of the water increases from 250 to 3000 ppm with depth and with the distance from the Todd River, the source of recharge. A feature of the contour maps (Pl. 10) is the close spacing of the 500, 750, and 1000 ppm lines, to form a narrow zone marking the boundary of the area of good-quality water associated with the recharge mound (Pl. 16), and the poorer-quality water in the western half of the basin. The gradient of the contours in this zone is particularly steep in the shallow aquifers in the vicinity of Heavitree Gap, where water of both types moves through the constriction.

The increase in salinity is generally accompanied by a change in chemical composition, from water in which bicarbonate is the predominant anion to water in which no anion is dominant (the mixed type), or to water in which chloride is predominant.

Sodium is the dominant cation throughout. Contours were drawn of values of the 'D' function. The contours for the '1830' and '1840' aquifers in the southern part of the Town Basin are shown on Plate 12; they do not show well defined trends, and it is concluded that the analyses fail to show a systematic variation.

The chemical character of the groundwater in an aquifer is influenced by its proximity to a source of recharge. This is illustrated by the closure of the 250-ppm contour (Pl. 10) and the contour lines of values of the 'D' function in the '1830' and '1840' aquifers in the southern part of the basin (Pl. 11); the contours are closed around areas which are interconnected with channel sands in the overlying aquifers. The absence of interconnexion in the vicinity of bores 110 and A131 prevents the vertical movement of groundwater, and the diffusion of chemical ions from the '1830' to the '1820' aquifers; this is reflected in the increase in the proportion of chloride and sulphate ions in the '1820' aquifer.

Quaternary Aquifers of the Inner Farm Basin

The groundwater moving through the Quaternary aquifers in the Inner Farm Basin originates as outflow from the Town Basin and as flood water in the Todd River. Most of the water from the Town Basin contains more than 1000 ppm total dissolved solids (TDS) and is of the mixed type. The water moves through the deeper aquifers on the western side of the basin (Pl. 13).

The shallow aquifers on the eastern side of the basin are largely supplied by water passing through the shallow aquifers in Heavitree Gap and by recharge water from the Todd River. The 500-ppm contour in the central part of the basin and the 250-ppm contours in the northern and southern ends of the basin are thought to enclose recharge areas.

Since 1957 the fall in the piezometric surface of the Quaternary aquifers has been sufficient to allow sulphate water to move into them from directly interconnected aquifers in beds of pyritic siltstone and shale of the Bitter Springs Formation, within the area bounded by the wells F13 and F16. If the piezometric surface rises this movement would presumably be reversed.

The variation in the proportions of the cations is shown on Plate 14. As in the Town Basin, sodium is the dominant radical close to sources of recharge, and in areas where chemical equilibrium has been reached between the groundwater and the rock minerals of the aquifer. The reason for the occurrence of two types of water, one in which sodium and calcium are predominant and one in which no single cation is predominant, is unknown. Presumably the Quaternary alluvium in the Inner Farm Basin is chemically and mineralogically different from that in the Town Basin.

Tertiary Aquifers of the Inner Farm Basin

The limited opportunity for recharge and movement of groundwater in the Tertiary aquifers throughout most of the Inner Farm Basin is reflected in the chemical quality of the water. The groundwater, which enters the regolith aquifers on the northern margin of the basin from the deeper Quaternary aquifers, is of the bicarbonate and mixed types. The salinity of the bicarbonate water does not increase appreciably in the Tertiary aquifers, but the proportion of chloride and sulphate ions increases and the water becomes of the mixed type.

The interconnexion with the Bitter Springs Formation in the embayment about bore F111 is reflected in the abundance of chloride and sulphate ions.

In the southern portion of the basin the gently dipping Tertiary aquifers are truncated by those of Quaternary age, and good-quality water is able to move from them into the Tertiary aquifers. This water is stored down-dip from the area of interconnexion, with little change in its chemical composition.

Precambrian Aquifers

The Precambrian rocks beneath the Inner Farm Basin contain groundwater with salinities ranging from 450 to 13,800 ppm (Pl. 13).

The better-quality water is of the bicarbonate type, and is associated with aquifers which are directly connected with the shallow Quaternary channel sands. The sulphate radical predominates in the saline water associated with the black pyritic siltstone and shale of the Bitter Springs Formation and the Precambrian granite. Sulphides are unknown in the granite, and the predominance of the sulphate radical may be due to the poor permeability of the rock and to its proximity to the sulphide of the Bitter Springs Formation.

No systematic variation is apparent in the areal distribution of the cations, and the dominant radical is commonly different in water from adjacent bores. This is logical if the mineralogical composition of the aquifer determines the degree of exchange of cations between it and the contained groundwater (Schoeller, 1959) because of the rapid variation in lithology of the Precambrian rocks.

Varition in Chemical Character With Time

The composition of groundwater stored in an aquifer is modified by solution and absorption until it is in chemical equilibrium with its environment. The addition of recharge water from the Todd River lowers the salinity and changes its composition until equilibrium has been re-established. In this case it is assumed that the diffusion of ions from the groundwater to the recharge water is an important mechanism in the process.

The rates of diffusion of ions are low, and a considerable time may elapse between the start of river flow and the resultant changes in the composition of the groundwater some distance from the river. The changes can be expected to decrease with the distance from the river.

Composition of the Recharge Water

Seven samples of floodwater were collected from the Todd River between 1957 and 1962; the salinity ranged from 65 to 202 ppm, and the ionic ratios vary considerably. The cations and anions have been plotted on two triangular diagrams (Fig. 8A, B); the points are widely scattered, but the reason for the wide variation in composition is unknown.

Composition of Water Pumped from the Todd Well

The conductivity of water samples collected from the Todd Well during 1963 and the early part of 1964 has been plotted on Figure 7 against the time elapsed in days since the beginning of individual river flows. The response to river flow is rapid and occurs in less than a day as the well is in the river bed. The rise in conductivity above 200 mhos is probably due to a decrease in the proportion of the sulphate ion relative to the chloride ion, rather than to an increase in salinity.

A similar plot of total dissolved solids of samples collected from 1953 to 1964 does not show such a systematic variation. The character of similar plots

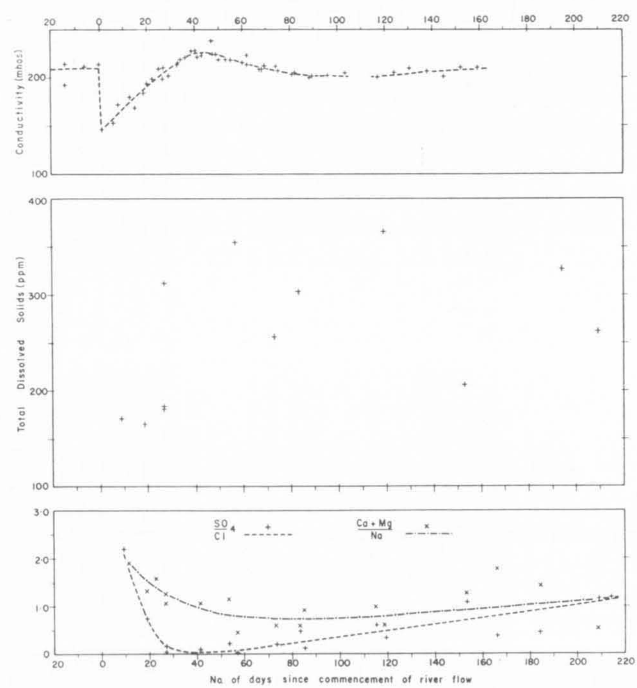

Fig. 7. Variation in the salinity and chemical composition of water pumped from the Todd Well following river flow.

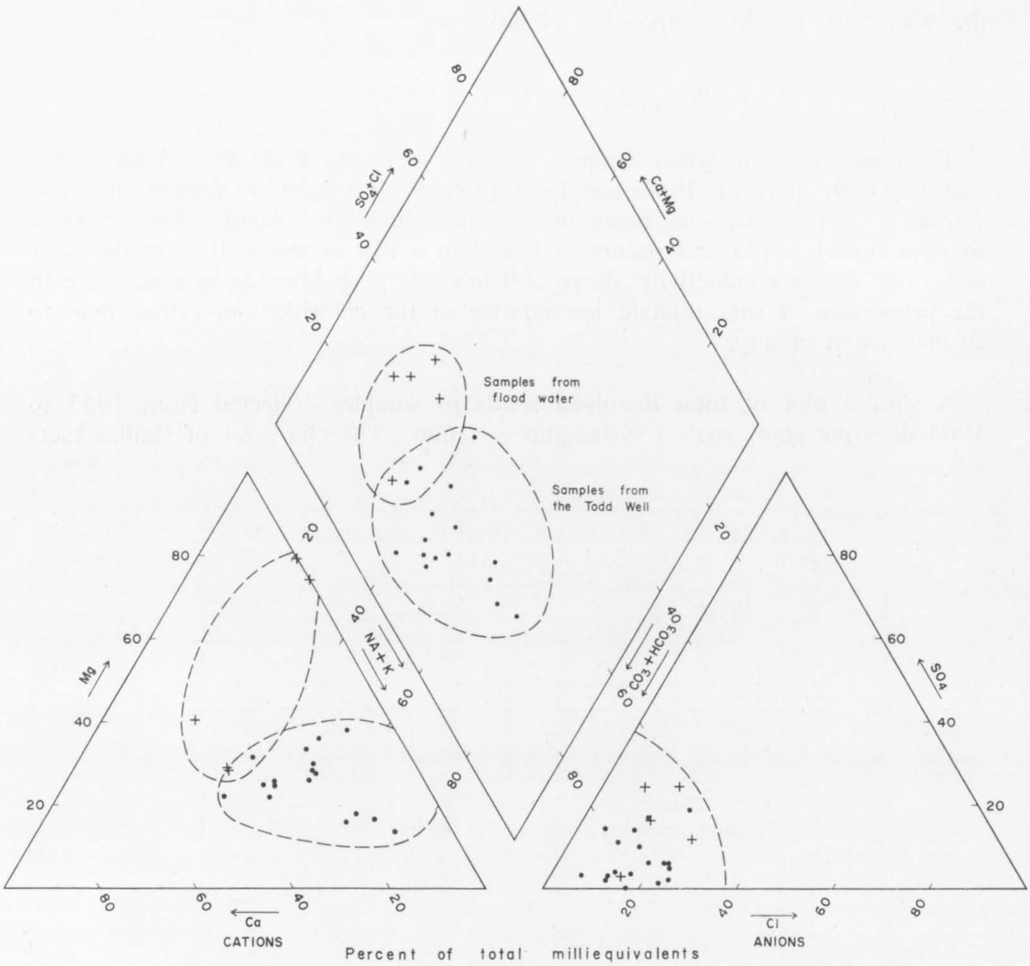

Fig. 8. Chemical character of water from Todd River and flood water, Todd Well.

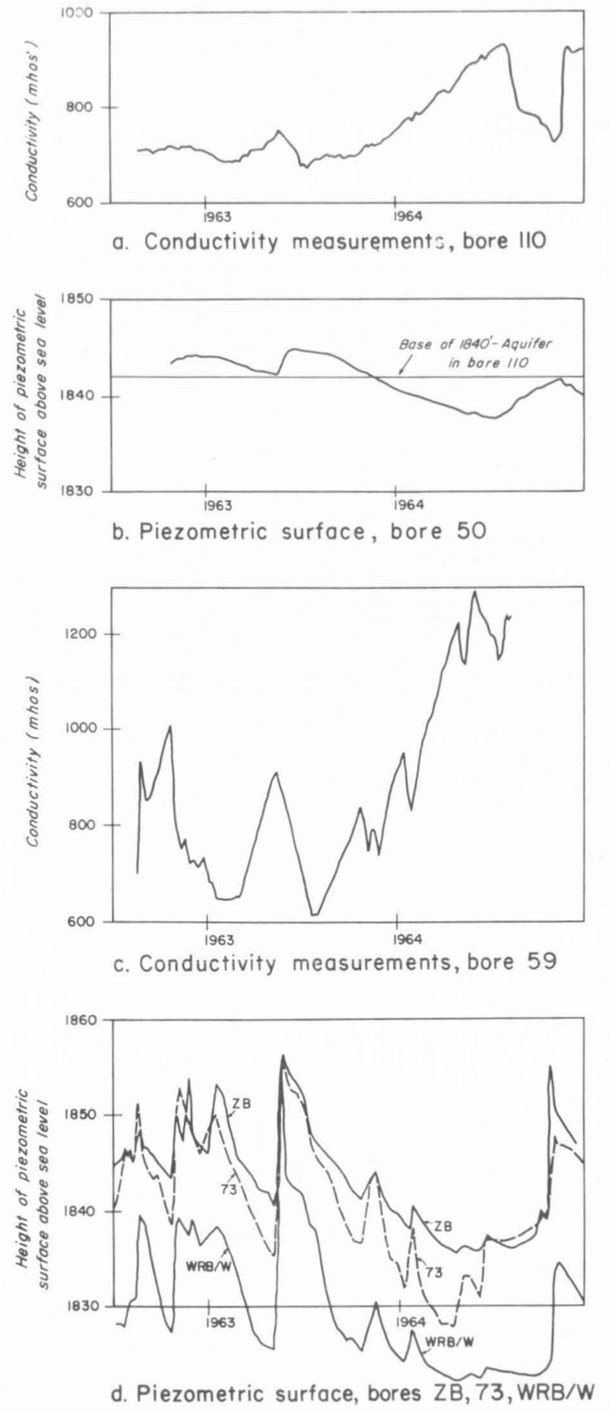

Fig. 9. Conductivity and piezometric surface bores 50, 59, 28, 73 and WRB/W.

of three of the ionic ratios (Fig. 9) indicates that this is probably due to differences in the handling and storage of the samples, which has resulted in the loss of varying amounts of bicarbonate. In contrast, the conditions of sampling, storage, and analysis of the samples used for the conductivity measurements were constant.

In spite of the wide range in composition of the samples from the two sources, it appears that the concentration of the bicarbonate, sodium, and potassium ions (Fig. 8) is greater in the Todd Well than in the floodwater. The bicarbonate or carbonate ion is not normally a component of the minerals in alluvium, and the most probable source appears to be the carbon dioxide in the air trapped in the pores of the alluvium. The additional sodium and potassium ions have presumably been derived from the minerals of the aquifer by solution.

Salinity of Water Pumped from Bore 110

Bore 110 was completed so that it is able to withdraw water from both the '1840' and the '1810' aquifers, which in this area contain groundwater with a TDS of about 500 to 750 ppm respectively (Pl. 10). It is expected that the salinity of the water pumped from this bore will vary within these limits according to the proportion of water extracted from each aquifer. The variation is illustrated by the changes in the conductivity of water samples collected during 1962 to 1964 (Fig. 9a). The increases in conductivity in 1963 and 1964 were accompanied by falls in the piezometric surface as measured in bore 50 (Fig. 9b), 400 feet to the north (Fig. 11). On each occasion the fall was sufficient to dewater the '1840' aquifer in the vicinity of bore 110, which under these conditions withdrew water only from the '1810' aquifer.

Salinity of Water Pumped from Bore 59

The conductivity of water samples collected from bore 59 during the period 1962-64 has been plotted on Figure 9c. The variations in the conductivity can be related to the changes in the piezometric surface through Heavitree Gap, which have resulted from the addition of recharge water from the Todd River, and the depletion until early in 1964 of groundwater stored in the Basin. This depletion caused a gradual increase in gradient of the piezometric surface from bore Z_B to bore 73 (Fig 9d), which allowed more saline water in the '1810' aquifer system to move from the western part of the basin through Heavitree Gap. The gradual increase in salinity was interrupted for short periods following river flow, when there was sufficient water moving through the basin in recharge mounds to re-establish the normal gradient on the piezometric surface, and thus restricted the movement of the saline water through Heavitree Gap.

WITHDRAWAL OF GROUNDWATER

Records are maintained by the Commonwealth Department of Works on the quantity of water withdrawn from the Town Basin, and Wilson (1958) and Forbes (1962) have estimated the amount of water withdrawn from bores controlled by private individuals and the Trustees of the Recreation Reserves. The validity of these estimates can be challenged, but they are the most reliable figures available. No comparable estimates can be made for the Inner Farm Basin.

Inner Farm Basin

The construction of private wells began in 1942 or 1943 to supply market gardens and a piggery which were established to provide food for the Australian Army stationed in Alice Springs. Subsequent development has been hampered by the failure of shallow bores and wells in the Quaternary alluvium, and the difficulty of obtaining sufficient supplies of suitable water from the older rocks.

Since 1962 two bores have been constructed by the Commonwealth to augment the water available from the Town Basin. Both bores withdraw water which is not available to leaseholders in the area. The water from one of the bores (F176) is unsuitable for human consumption and is used for construction works; water from the other (WRB/AR) is used for domestic consumption in Alice Springs.

Town Basin

The demand for water has risen with the increase in population, and during the summer months it has exceeded the capacity of the withdrawal and reticulation system. In the summer the average daily consumption from the Town Supply has been maintained at less than 120 gallons per head per day by restrictions on the use of water for gardening.

The Town Wells, in the centre of the basin, were constructed in 1939 to provide water for the townspeople. Before 1939 many residents had their own wells. In 1942 and 1943 the Australian Army constructed the No. 1 and No. 2 Army Wells, and a reticulation system, to provide water for the troops stationed in the town. This system was adequate until 1956, when the Bent Tree Well and Todd Well were constructed. Six bores (Nos 21, 27, 28, 86, 59, and 110) were constructed in 1958 and 1959 during an investigation by the Department of Works (Wilson, 1958).

Not all of the bores and wells were available for use at any one time (Fig. 7), because the fall in the piezometric surface and the collapse of aquifers affected the efficiency of the wells and some of the bores. Since 1959 six bores have been constructed to replace those abandoned.

TABLE 7: POPULATION AND CONSUMPTION OF WATER

Year Ending	Population[b]	Estimated Daily Consumption per Head (gals)	Groundwater Withdrawn from Town Basin (million gals)			Total Consumption (million gals)	
			Town Supply Bores	Recreation Ovals	Private Bores and Wells	From Town Basin	External to Town Basin
30 June 1952	2,620						
30 June 1953	2,700						
30 June 1954	2,785[a]	106	108,250[c]		10.000(?)		
30 June 1955	2,980	104	113,900[c]				
30 Sep. 1956	3,100	110	125.109[c]		40.000(?)[g]		
30 June 1957	3,260	90	107.823[c]		13.000	121	
30 June 1958	3,320	112	136.392[c]	0			
31 Dec. 1958			144.111[d]	2.762[d]	15.000	162	
30 June 1959	3,560	116	151.132[c]				
31 Dec. 1959			159.041[d]	9.552[d]	16.000	184	
30 June 1960	4,340	101	161.132[c]				
31 Dec. 1960			168.674[d]	14.448[d]	16.500	200	
30 June 1961	4.668[a]	105	174.340[e]				
31 Dec. 1961			199.996[d]	22.469[d]	18.000[d]	240	
30 June 1962	4,720	121	206.077[e]				
31 Dec. 1962			204.431[e]	25.000	22.000	251	
30 June 1963	5,000	120	216.576[e]				
31 Dec. 1963			223.862[c]	27.000	26.000	276	0.000
30 June 1964	5,500	108	210.209[e]				7.039[e]
31 Dec. 1964		109	124.804[e]	30.000	30.000	185	103.915[e]

Sources of Data:

a Census 1954, 1961

b Estimated at 17% of the estimated population of the Northern Territory published in Quarterly Summary of Australian Statistics, Commonwealth Bureau of Census and Statistics

c Annual Reports for Northern Territory, Department of Territories

d Forbes (1962)

e Water Resources Branch, Alice Springs

f Wilson (1958)

g Jones (1957)

The quantity of water pumped (Fig. 10 and Table 7) from the Town Supply bores and wells has risen from 108.2 million gallons in 1954 to 223.8 million gallons in 1963. A reduction in the quantity pumped has been possible since 1964, when water became available from the Mereenie Sandstone, 7 miles to the south, and from bore WRB/AR in the Inner Farm Basin.

Since 1958, water for the Anzac and Traeger Park ovals has been obtained from bores under the control of the Boards of Trustees. Forbes (1962) estimated that they used 22.5 million gallons in 1961, and the estimates shown in Table 7 are based on the assumption that they have continued to use the same amount.

Wilson (1958) estimated that 62 private wells and bores were in use in 1957, and that they pumped 13 million gallons per year. Forbes (1962) considered that

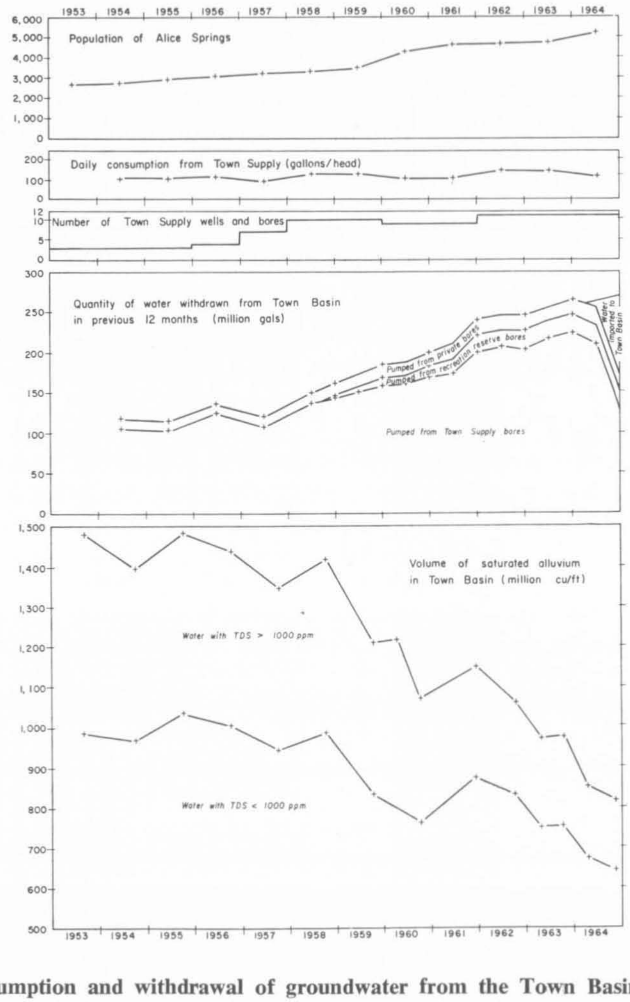

Fig. 10. Consumption and withdrawal of groundwater from the Town Basin, Alice Springs.

the amount pumped from private bores was 18 million gallons per year. The quantities shown on Table 7 for the intervening years were obtained by interpolation. About 58 bores were in use at the end of 1963, and it is considered reasonable to apply Forbes' estimate to the succeeding years.

The quantity of water transpired by trees in Alice Springs Town is extremely difficult to measure, and Wilson's (1958) estimate of 20 million gallons per year has been adopted.

RECHARGE

Recharge to all aquifers originates as floodwater in the Todd River. Certain portions of the river bed are known to be recharge areas which are interconnected with aquifers within the basins. They occur in the vicinity of the Todd Well, the East Side Causeway, Meyers Hill, bore 110, Mount Blatherskite, and the south and east of block 793 in the Inner Farm Area.

Observations on the rate of advance and recession of floodwaters in the recharge areas indicate that the rate of infiltration of water is significantly greater than in other parts of the channel. The rate of infiltration can be expected to decrease with time (Todd, 1959). Within the first two days the decrease is attributed to swelling of the clay matrix after wetting. The rate of infiltration may increase during the next 18 days, as entrapped air is dissolved by the recharge water. Wilson (1958) records initial infiltration rates for the Todd River as high as 180 gallons per hour per square foot, but within 24 hours this rate had dropped to 0.5 gallons per hour per square foot. It is doubtful if the river ever continues to run long enough to dissipate the air entrapped in the interstices of the sand.

It is inferred that groundwater moves from the sand in the bed of the present river into the Quaternary alluvium, where the river has truncated the gently dipping channel sands of the five aquifers. Within the alluvium, groundwater moves freely from one aquifer system to another where the individual channel sands are interconnected. The recharge mound in the piezometric surface adjacent to the Todd River (Pl. 16) encloses permeable alluvium in which recharge water is stored under unconfined conditions until it moves into confined aquifers.

The erosion of large quantities of Tertiary sediment from within the Inner Farm Basin after the period of Tertiary deep weathering resulted in interconnexion between the permeable Quaternary alluvium and the aquifers in the older rocks. The position of these areas has been inferred from the changes in the chemical character of the groundwater in the aquifers.

WATER LEVELS

Water level hydrographs for representative bores in each of the five Quaternary aquifers in the Town Basin are shown on Plate 15. They show that the water levels fluctuate after floods in the Todd River and in response to pumping near the observation bores. The magnitude of the fluctuation depends on the distance of the observation bore from the recharge areas in the Todd River. The water level in bore A25, which is 550 feet from the river, rises within 2 days after a flood, whereas that in well A142, 700 feet from the river, begins to rise within 4 days, and only rises half as far as in bore A25. Water levels in bore U, which is about 1500 feet from a recharge area, respond to a river flow within 6 days. The character of the hydrograph also changes with increasing distance from the river; the crests of the hydrographs become rounded, and the rate of decline in water levels is much less.

The permeability of the alluvium along the path of movement of the recharge mound also influences the shape of the hydrograph. The fluctuations of water level in bore A80 are much less than in well A29. Both observation points are completed in the '1850' aquifer, and A80 is closer to a recharge area than A29; but A80 is within an area of low permeability (Pl. 11).

The rise in water levels in response to a river flow, within 3 months of a previous flow, is generally not as great as the rise resulting from flows separated by a longer interval. A minimum period of 3 months is probably required for the recharge mound near the river to be sufficiently dissipated to permit significant quantities to infiltrate from surface flow. Considerable quantities of the water available for recharge are rejected if the return period of river flow is less than 6 months.

Water levels in the basin fell during the period 1958-64, as a result of the increased withdrawal in the same period (Pl. 15 and Fig. 10). The rate of decline was greatest in the south, and was not significant in the north. The decline has not apparently resulted in the increase in the amount of recharge to the basin predicted by Wilson (1958). The water levels in the bores in the areas of greatest decline (J and 59/8) showed a much smaller response to river flow in 1962 than in previous years; yet the river ran seven times in 1962. It follows that the rate of transfer of water from the recharge mound to the five aquifer systems must be less than the rate of movement of groundwater within the aquifers.

The fluctuations in water levels measured in the Quaternary alluvium of the Inner Farm Basin are similar to those observed in the Town Basin, in that the distance of the observation bore from the Todd River influences the magnitude and character of the hydrograph.

Water levels measured in bore Test 1 show no response to the occurrence of floods in the Todd River. This suggests that the aquifer system in the Tertiary regolith has impermeable boundaries on its western, southern, and eastern margins. The changes in level are attributed to pumping from the adjacent bore AI, and to the increase in withdrawal from the Town Basin during the period 1958-64.

Some aquifers in the Precambrian rocks are interconnected with those in the Quaternary alluvium, as shown by the similarity of the water-level hydrographs of bore Test 6 and well F15 (Pl. 15), and by the steady decline in the piezometric surface at bore HC.

Water Level Contours

Contours on the piezometric surface as it appeared on 16 October 1957, 14 October 1961, and 2 October 1964 are shown in Plate 16.

The contours for October 1957 show the basin in a relatively full state with only one zone of heavy pumping (Town Wells to East Side Bores). In the northern end of the basin (along the Todd River) two sets of contours have been drawn, in an attempt to define two surfaces associated with water in different aquifers. The main features indicated on this map are:

(a) The mounds in the northern part of the basin and in the south-east along the Todd River, where recharge has taken place;

(b) A less pronounced mound in the central and southern part of the basin, roughly along the railway;

(c) A pronounced trough due to pumping of the Town Wells and East Side Bores, with closed cones of depression around the bores. This trough disappears downstream between Billygoat Hill and Meyers Hill, and extends upstream only just past the most northerly of the East Side Bores.

The contours drawn for October 1961 reflect the increased pumping from the basin, particularly from the Gap Bore, Bore 110, and Bent Tree Bore. The main features apparent at this date are:

(a) Water levels are still high in the East Side area, and the mound is pronounced in the shallow aquifers in the northern part of the basin along the Todd River.

(b) The trough from the East Side Bores has expanded and a reflexion of it extends south-west through the gap between Billygoat and Meyers Hills to join the trough created by the Bent Tree Bore and Army Well.

(c) The recharge mound has contracted and now has a steeper gradient on its margins. In the southern part of the basin the mound has been replaced by a trough about the Gap Bore and Bore 110.

(d) The migration northwards for 5000 feet of the 1850 contour, from the position which it occupied within Heavitree Gap in 1961, illustrates the considerable depletion in storage in the south-west part of the basin.

The October 1964 contours illustrate the condition of severe depletion:

(a) There is a continuous trough from the Todd Well at the northern end to Heavitree Gap in the south.

(b) The shallow aquifers in the north (which created mounds on the contour map for 1957 and 1961) have been dewatered and only one set of contours has been drawn.

(c) The decline in storage in the western part and southern part of the basin is indicated by the position of the 1845-foot contour, which extends almost as far north as the Bent Tree area.

Aquifer Performance Tests

The results of 12 aquifer performance tests which have been conducted on the town supply bores and wells are shown in Table 8. Two of the results have been recalculated from data obtained by Wilson (1958). The aim of the tests was to investigate the hydraulic characteristics of the Quaternary aquifers in the Town Basin, under unconfined conditions. To achieve this, some of the tests were run for as long as 3 months.

Methods

The tests were conducted on bores pumping water for the town supply installation to avoid the need to install special pumps, and solved the problem of the disposal of discharge water. Several factors increase the probable error of the results:

1. Tests are possible only during the winter months, when adjacent production bores can be shut down to avoid interference between bores. The time available for testing was seldom long enough to measure the recovery of water levels on completion of pumping.

2. The discharge may fluctuate by 5 percent, because of variations in head in the rising main.

3. The observed drawdowns were adjusted to allow for the natural fall in water levels between recharge periods. These corrections were obtained by extrapolation from long-term trends in water levels at observation points, both inside and outside the area of influence.

Analysis of Data

Because of the irregular distribution and thickness of the channel sands it is not possible to treat them individually as confined aquifers, or more properly as infinite-strip leaky artesian aquifers.

On a long-term basis, groundwater can be considered to withdraw from the saturated alluvium under unconfined conditions. The alluvium, as a whole, could be considered as an anisotropic heterogeneous unconfined aquifer, but an exact solution to the differential equation which describes these conditions is difficult to obtain, and is of little practical value. It is expedient to examine first the

TABLE 8: COEFFICIENTS CALCULATED FROM AQUIFER PERFORMANCE TESTS, ALICE SPRINGS TOWN SPRINGS TOWN BASIN

	62/9	Colocag Park 61/24	Bent Tree No. 1 60/14	Todd Bore 60/5	61/33	110	Army Well No. 2	59	28	59/11	Town Wells *	Bent Tree Well *
Non-Equilibrium Method—												
Coefficient of Transmissibility (Imp. gals/day/ft)		—	—	—	—	22,000	17,000-66,000	11,000-150,000	20,000	5,000-42,000	30,000	12,000
Hydraulic Conductivity (ft/day)		—	—	—	—	111	150	—	93	130	120	92
Coefficient of Storage		—	—	—	—	0.03	0.07	0.004	0.07	0.002	0.16	0.17
Equilibrium Method—												
Coefficient of Transmissibility (Imp. gals/day/ft)	4,750	26,000	38,000	31,000	35,500	56,000	30,000	42,000		17,000	—	—
Hydraulic Conductivity (ft/day)	109	95	187	125	200	280	190	120	—	—	—	—
Coefficient of Storage	0.05	0.08	0.13	0.09	0.004	0.00014	0.43	0.02	—	0.0001-0.001	—	—

Probable values applicable to Town Basin:

Coefficient of transmissibility: 30,000 Imp. gals/day/ft

Hydraulic conductivity: 150 ft/day

Coefficient of storage: 0.07

*Recalculated from Wilson (1957)

drawdown data on the assumption that the saturated alluvium is an isotropic homogeneous unconfined aquifer of infinite lateral extent. The consistency of the result obtained from any one test can be taken as an indication of the differences between the ideal aquifer and the saturated alluvium.

The aquifer constants were calculated from the Theis non-equilibrium formulae (Wenzel, 1942), which in non-dimensional form are:

$$s = QW(u)/4\pi T$$
$$u = r^2S/4Tt$$

and from the equilibrium formulae (Jacob, 1950):

$$s_1 - s_2 = (Q/2\pi T)\log_e(r_2/r_1)$$
$$s = (Q/4\pi T)\log_e(2.25Tt/r^2S)$$

In terms of the units used for the aquifer tests the equations may be written as

$$S = 1.91QW(u)/T$$
$$u = 1.56r^2S/Tt$$
$$s_1 - s_2 = (8.79Q/T)\log_{10}(r_2/r_1)$$
$$s = (4.4Q/T)\log_{10}(0.36Tt/r^2S)$$

where s = drawdown, in feet, at the observation point

r = radial distance in feet of the observation point from the pumped bore

s_1 = drawdown, in feet, at an observation point which is at a distance r_1 from the pumped bore

Q = the discharge of the pumped bore in imperial gallons per hour

T = coefficient of transmissibility in imperial gallons per day per foot width of aquifer

$W(u)$ = the well function

S = coefficient of storage

t = time in days since pumping started.

The Theis non-equilibrium formula is applied by fitting a type curve for the well function $W(u)$ to the drawdown information obtained from the tests. The drawdown values and the matched curves of $W(u)$ for the pumping tests of bores 110, 28, 59/11, and 59 are shown on Plate 17.

The equilibrium equation is applied to the straight line of best fit to a plot of the values of drawdown and the logarithm of the distance of the observation point from the pumped bore. The method of analysis for the pumping tests of Army Well No. 2 and bore 61/33 is shown on Plate 17.

The values obtained for the coefficient of transmissibility, the hydraulic conductivity, and the coefficient of storage are given in Table 8. Individual values, calculated by the non-equilibrium method for each observation point, were used to obtain an average value of the constant for the alluvium in the vicinity of the pumping bore.

The appropriate values of the constants applicable to the saturated alluvium in the Town Basin are: 30,000 gallons per day per foot, with unit hydraulic gradient, for the coefficient of transmissibility; 140 feet per day under unit hydraulic gradient for the hydraulic conductivity; and 0.07 for the coefficient of storage.

Interpretation of Results

The results of the pumping tests shown on Plate 17 illustrate the two methods of analysis and the problems of interpretation.

Bore 28: The drawdown values at the observation points as plotted fall on simple exponential curves, which give mutually consistent values for the coefficient of transmissibility and storage.

Bore 110: The drawdown curves for observation bores 61/6 and 92 are simple exponential curves giving consistent values for the coefficients. The type curve of $W(u)$ was fitted initially to the early time portions of the drawdown curves for bores 49 and 50; the approximate values of the coefficients are: $T = 125{,}000$ gallons per day per foot, and $S = 0.003$ — values which are typical of confined conditions. The curve of $W(u)$ was then matched with the later time values of the drawdown, and the resultant values for the aquifer constants were consistent with those computed for the other two observation bores. These values were adopted.

Bore 59/11: The shape of the drawdown curves indicates that vertical leakage to the developed aquifer through overlying aquicludes occurred at an approximate value of 10 for r^2/t. The type curve of $W(u)$ was therefore fitted to the early time portions of the drawdown curves. The aquifer constants can be divided into two groups, the first with moderate coefficients of transmissibility and the second with low coefficients. The storage coefficients, as computed for confined conditions without leakage, are all low. The sharp increase in the drawdown on the tail of the curves was caused by interference from bore 59, which began pumping at this time.

Bore 61/33: The drawdowns measured in the four observation bores when plotted against the logarithm of the distance from bore 61/33 lie within an oval area. As a result the position of the straight line of 'best fit', which describes the distribution of drawdown in the vicinity of the pumping bore, is largely determined by the position of the point representing the corrected drawdown in bore 61/33. The correction applied is for the entry loss, as determined independently from step drawdown tests. The departure of the points plotted from the line of best fit is an indication of the lack of homogeneity of the alluvium.

Army Well No. 2: Values for the hydraulic constants for the saturated alluvium in the vicinity of Army Well No. 2 cannot be confidently determined because the plotted values of drawdown against distance are scattered and do not show a well defined relationship. The drawdown in the well cannot be used in the analysis because it was greater than 13 feet, of which at least 50 percent was entry loss.

Bore 59: Two drawdown curves for the observation bore ZB are shown on Plate 17; one is the result of an aquifer performance test in 1960 and the other on a test in 1962. The difference between the two curves is marked, even allowing for the different rates of pumping during the two tests. The shape of the 1962 curve indicates that additional quantities of groundwater were released from storage to bore 59 in response to the initial decline in head, but this apparently did not occur during the 1960 test. The reflection of impermeable boundaries in the later time portion of the 1960 curve indicates that neither a non-equilibrium nor a leaky artesian type of analysis alone is adequate. It is probable that an analysis based on the assumption of an infinite-strip leaky artesian aquifer (Hantush & Jacob, 1955) would be more appropriate, with allowance for interference from bore 61/33 during the 1962 test.

Application of the Results to the Town Basin

The application of the values of the coefficients in Table 8 to the saturated alluvium of the Town Basin is restricted by the nature of the fundamental assumptions used in the derivation of the Theis equation.

The assumptions are (Wenzel, 1942):

(i) the aquifer is confined;

(ii) the aquifer is homogeneous, isotropic, and of infinite areal extent;

(iii) the bore penetrates the entire thickness of the aquifer;

(iv) the coefficient of transmissibility is constant in all planes at all times;

(v) the bore is of negligible diameter; and

(vi) the water removed from storage is discharged instantaneously with decline in head.

These assumptions are valid, with the following qualifications:

1. The proposed mathematical model is for confined conditions. However, Boulton (1954) has shown that, providing sufficient time has elapsed and the

observation points are sufficiently far from the bore, then the exponential integral is an approximate solution to the differential equation which describes the unconfined condition. These two qualifications were used in selecting the results for analysis.

The coefficients of transmissibility computed for the tests are of the right order of magnitude for an unconfined aquifer; the lower values computed for bore 62/9 and Bent Tree Well reflect the smaller thickness of aquifer from which water was withdrawn during the period of the test. Values of the hydraulic conductivity provide a better basis for comparison between the tests, and the application of the results to the basin, as they are calculated from the coefficient of transmissibility and the thickness of the aquifer.

The coefficients of storage calculated for the tests of bores 110 (using the equilibrium method), 59/11, and 61/33 are small, and are typical of a confined aquifer.

2. The saturated alluvium in the Town Basin is not a homogeneous isotropic aquifer, nor is it of infinite areal extent.

However, 'in any case in which nonhomogeneity is so distributed that the flow field statistically fits the geometry of the mathematical model, the mathematical solution will provide a sound analysis' (Ferris et al., 1962). The results of the tests of bores 28 and 110 are consistent within the order of accuracy of the field measurements. This is not so for the tests on bore 59/11 and the Army No. 2 Well.

The transmissibility of an anisotropic aquifer is a vector property, with an elliptical law of addition. The values for the coefficient will then show a systematic and symmetrical variation in relation to two principal areas. The coefficient calculated for the observation bores about bore 110 show some systematic variation (Fig. 10), but more observation points are required to prove that the variations are symmetrical. Corrections for anisotropic conditions can be applied by distorting the dimensions of the mathematical model.

An aquifer may be regarded as of infinite areal extent, provided the drawdown curves have not been modified by vertical recharge, or by reflections from a hydraulic boundary. The shape of the drawdown curves for the observation points around bore 59/11 (Pl. 17) indicates that water was being added to the aquifer system during the later part of the test, and the type curve was therefore fitted to the early values of drawdown.

3. The observation bores and the bores pumped were completed by a variety of methods. The production bores 27, 110, and 61/24 were completed with perforated casing, and water was withdrawn from the full thickness of saturated alluvium during the period of the tests. Bores 60/5, 62/9, 60/14, 61/33, and 59/11 were completed with sand screens set opposite confined aquifers. The results from the tests on these bores would be applicable to the specific aquifers,

unless the test was of sufficient duration for water to be transmitted from the body of saturated alluvium to these aquifers. The same qualification applies to the results obtained by pumping the three wells, which in each case were not as deep as the thickness of alluvium. The observation bores were mainly completed with varying lengths of perforated water pipe; the remainder were cased with 6-inch casing. It was not considered necessary to apply corrections in the analysis to compensate for partial penetration of the observation points, as the tests were of sufficient duration for its effects to be neglected (Hantush, 1961).

4. The Theis type analysis is not strictly valid if water is released initially from elastic storage in a thin confined aquifer and subsequently released from the full thickness of saturated alluvium under unconfined conditions.

The drawdown curves of bores 49 and 50 (Pl. 17) are thought to reflect this change in conditions of withdrawal, because of their shape. This implies that bores 110, 49, and 50 intersect the same thin confined aquifer. The values calculated from the early time part of the curve for bore 49 are: $T = 125{,}000$, and $S = 0.003$ — values which are characteristic of confined conditions.

The coefficients for the later time portions are $T = 24{,}000$ and $S = 0.018$, which are characteristic of unconfined conditions. The values calculated with the equilibrium formula ($T = 56{,}000$ and $S = 0.00014$) are probably irrelevant.

5. The diameters of the bores are negligible in relation to the radial distances.

6. It is assumed that during the tests of bores 28 and 110 water is instantaneously released from storage with decline in head.

It is evident from the shape of the drawdown curves on Plate 17 that after a time t defined by $r^2/t = 10^7$, additional quantities of groundwater were released from storage to bore 59/11 in response to the initial decline in head. Accordingly, the type curve was fitted to the early time portion of the drawdown curves (Ferris, 1963).

It is concluded that representative values are as follows: 30,000 gallons per day per foot for the coefficient of transmissibility, 150 feet per day for the hydraulic conductivity, and 0.07 for the coefficient of storage.

These values are thought to be applicable to the full thickness of the saturated Quaternary alluvium in the Town Basin.

Volume of Saturated Alluvium in the Town Basin

A graphical method of integration has been used to estimate the volume of saturated alluvium in the Town Basin. A series of cross-sections, spaced at 1600-foot intervals, was drawn, each showing the bedrock and water-table profiles for a particular date. A planimeter was used to measure the areas of the cross-sections; these values were then plotted as ordinates, with the distance between sections as abscissae. The area under the resultant curve, which represents the volume of alluvium between the bedrock and the piezometric surface on a particular date, was then measured with the planimeter.

The volume has been calculated for a date in October for each year from 1953-64 inclusive, and for April in 1963 and 1964. The values are listed in Table 9, and also in Figure 9, which shows the marked drop in volume of saturated alluvium which started in 1957 and has continued to the present.

The estimates of the volume of groundwater stored in the Town Basin (Table 9) are based on the calculated volumes of saturated alluvium and a specific yield of 0.07 (Table 8). They range from 357 million gallons in October 1964 to 649 million gallons in October 1955, compared with the 900 million gallons estimated by Owen (1952, 1954), 1110 million gallons by Wilson (1958), and 300 million gallons by Jones (1957).

Safe Yield

The safe yield of the Alice Springs Town Basin has been calculated using an adaptation of the Hill method quoted by Todd (1959), in which the annual change in water level is plotted against the annual draft, and if the water supply to the basin is reasonably constant, the points can be fitted to a straight line. The draft corresponding to zero change in water level equals the safe yield. This method has been adapted by using the annual change in volume of saturated alluvium instead of the annual change in water level. The calculated values for the water years 1954-64 (1 October to 30 September) are shown in Table 8 and on a scatter diagram in Figure 11. The wide scatter of points is probably due to the erratic recharge to the basin. To compensate for this, estimates were made of the number of days in each year when there was no recharge; the estimates were made on the assumption that recharge will continue for 100 days, which is the average duration of the rise in water levels (Pl. 15) after a river flow.

An analysis of multiple regression was then used to derive a relation between the change in the volume of saturated alluvium (the dependent variable y), and the independent variables x (the total quantity of water pumped from the basin during the year) and t (the estimated number of days during the year without recharge). The basic assumption that a linear relation exists between the variables is probably not realistic, and the relation must be regarded as approximate only.

The relation obtained, $y = 372 - 1.23x - 1.35t$, is illustrated in Figure 11 for three values of t. The value of 0.89 for the coefficient of multiple correlation is relatively high, and there is close agreement between the total of the predicted change (668 million cubic feet) and the net of the observed change (665 million

TABLE 9: STORAGE AND WITHDRAWAL OF GROUNDWATER, ALICE SPRINGS TOWN BASIN

Year Ended	Volume of Saturated Alluvium (10^6 cu. ft)	Estimated Volume of Groundwater in Storage (million gals) (Specific Yield = 7%)	Estimated Volume of Groundwater Pumped from Basin (million gals)	Change in Volume of Saturated Alluvium (10^6 cu. ft)		Difference	Estimated Period Without Recharge (days)	Predicted Safe Yield (million gals)
				Calculated	Predicted			
1.9.53 . . .	1480	647.5					80	264
10.54	1392	609.0	120	—88	—94	6	236	43
10.55	1483	648.8	130	+91	117	—26	70	278
10.56	1440	630.0	141	—43	1	—44	146	176
16.10.57 . .	1349	590.2	152	—91	—75	—16	192	107
10.58	1420	621.2	160	+72	+35	+36	103	233
10.59	1213	530.7	175	—208	—20	—7	265	14
10.60 . . .	1074	469.9	192	—139	—182	43	235	55
14.10.61 . .	1167	510.6	206	+93	+15	+78	76	269
11.10.62 . .	1065	465.9	256	—102	—80	—22	101	236
18.10.63 . .	980	428.7	276	—82	—57	—25	66	283
2.10.64 . .	817	357.4	219	—166	—143	—23	182	126
TOTAL				—665	—670			

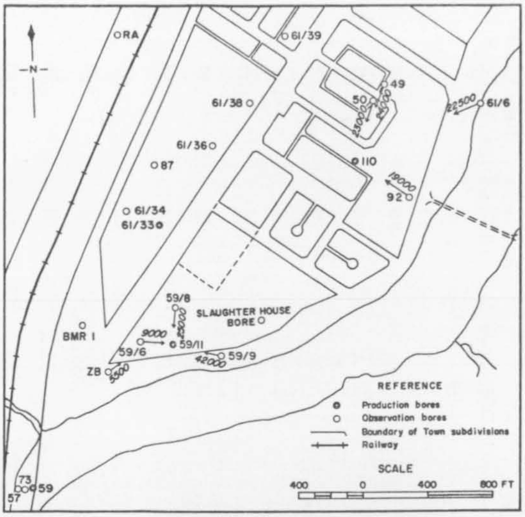

Fig. 11. Town Basin, Alice Springs, showing location of observation bores and valves of the coefficience of transmissibility for the aquifer tests of bores 110 and 59/11.

cubic feet) for the years 1953 to 1964. This equation, therefore, would be reasonably effective in predicting changes in the volume of saturated alluvium over long periods. The differences between the observed and predicted changes in volume for each year, as shown in Table 9, indicate that the efficiency of such a relation for the prediction of short-term changes could be improved if an allowance was made for the past history. Such an allowance would be made by the introduction of a third independent variable, the difference between the quantity of water withdrawn and the estimated safe yield, for the previous year.

The analysis shows that a single value cannot be assigned as the annual safe yield, as it is largely dependent on the number of river flows, separated by more than 100 days, which have occurred during the year. The safe yields which can be expected are illustrated in Table 9 and Figure 12(b).

It has been shown (Figs 6 & 13) that, within a period of 100 years, the Todd River can be expected to flow at least once during 91 of the years. If the basin is managed with this level of probability (0.91), then a value for the annual safe yield is insignificant (Fig. 12), as allowance must be made for 265 days per year without recharge. This is obviously impracticable as a basis for the management of the basin.

Management at the 50 percent level of probability would allow the withdrawal of groundwater at a rate of 156 million gallons per year (Fig. 12a). This estimate is based on the probability distribution of the number of days per annum when recharge does not occur (Fig. 13), for which the median is 126 days. In this case it would be expected that depletion would occur in 50 years of a 100-year period, which would be replaced during the other 50 years.

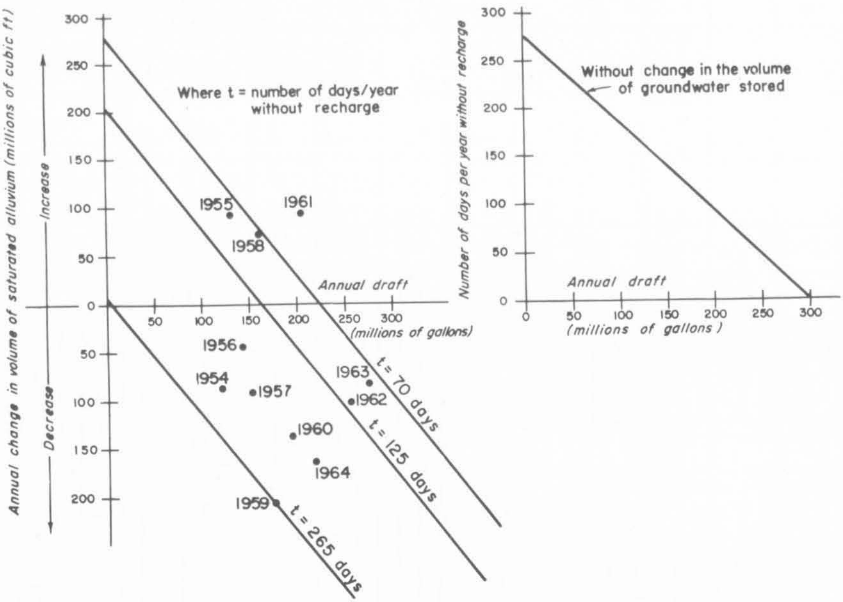

Fig. 12. Calculation of safe yield, Town Basin, Alice Springs.

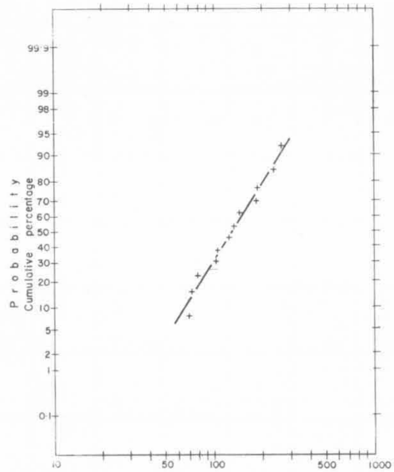

Fig. 13. Probability distribution of the number of days without recharge.

A third method by which the basin could be managed would be to take advantage of each recharge period as it occurred. This could be achieved by the withdrawal of groundwater at a rate of 20 million gallons per month for a period of 2 months following recharge, then reducing the withdrawal rate by 3.5 million gallons in each succeeding month, until the next period of recharge. The probability of failure of such a policy cannot be estimated at present.

CONCLUSION

1. Permeable sediments are the most significant aquifers in the two basins; they include Quaternary silty sands, Tertiary gravel and sand, and pyritic shale and weathered limestone of the Upper Proterozoic Bitter Springs Formation. The Quaternary sands contain the largest quantities of groundwater suitable for domestic and agricultural use.

2. The Tertiary aquifers in the Inner Farm Basin are of limited areal extent, and for practical purposes they and the aquifer of Quaternary age can be considered to behave as a single aquifer system.

3. The body of weathered and vuggy Bitter Springs limestone, to the south of Mount Blatherskite, is directly interconnected with the Quaternary aquifers; it appears to offer the best prospects for development in the Inner Farm Basin.

4. The most satisfactory method for the construction of bores is to place screens with oversize slot openings (which will pass up to 80 percent of the aquifer) against the full thickness of a bed of sand with a minimum of disturbance, even though part of it is of very low permeability.

5. Some disturbance of the alluvium and an increase in well loss will occur during development. This can be kept to a minimum if the bore is developed by pumping and backwashing with an axial flow turbine pump. Surging to remove clay and silt from aquifers can be disastrous, particularly if screen openings are less than 0.04 inches.

6. Recharge water for the two basins is derived from floodwater in the Todd River. It is estimated that recharge will continue for 100 days following a river flow. The probability that the interval of time between successive river flows will be less than 1 year is 0.91.

7. One of the factors on which the safe yield of the Town Basin depends is the period between successive river flows. The theoretical safe yield is a negative quantity for 9 years in each 100 years, and a constant rate of withdrawal of groundwater of 156 million gallons per year will result in depletion of storage for 50 years of a 100-year period.

8. Maximum use could be made of the water available as recharge if groundwater was withdrawn at a rate of 20 million gallons per month for a period of 2 months following a river flow, and then reducing the withdrawal rate by 3.5 million gallons per month until the next period of recharge.

9. Aquifer coefficients for the Quaternary alluvium of the Town Basin, acting as an unconfined, isotropic, homogeneous aquifer, were estimated to be 150 feet per day for the hydraulic conductivity (which is equivalent to a coefficient of transmissibility of 30,000 imperial gallons per day for the full thickness of alluvium) and 0.07 for the coefficient of storage.

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APPENDIX

GLOSSARY OF GROUNDWATER NOMENCLATURE

Aquiclude. A body of rock which contains an interconnected system of interstices saturated with water, but which will not yield groundwater at a sufficient rate to be of local consequence as a source of supply.

Aquifer. A body of rock containing a system of interstices that will yield groundwater at sufficient rate to be of local consequence as a source of supply.

Bedrock. Any solid rock exposed at the surface of the earth or overlain by unconsolidated material.

Specific Capacity. The capacity of a well or bore per unit drawdown.

Tested Capacity. The maximum rate at which withdrawal from a well or bore is known to have been sustained.

Total Capacity. The maximum rate of withdrawal from a well or bore that can be sustained for the greatest likely duration of discharge.

Cone of Depression. The depression in a potentiometric surface resulting from the withdrawal of water from a bore. It varies in size and shape with the rate and duration of withdrawal.

Confined Groundwater. Groundwater occupying the full thickness of an aquifer overlain by an aquifuge or saturated aquiclude.

Discharge. The removal of water from the zone of saturation, either to the ground surface or to the zone of aeration.

Drawdown. The lowering of potential at a given point in a groundwater body in or adjacent to a bore, resulting from the withdrawal of water from the bore.

Groundwater. The water in the zone of saturation.

Groundwater Basin. A body of rock containing a groundwater body or group of groundwater bodies, which has geological and hydraulic boundaries convenient for description and analysis. Generally both the recharge and discharge zones of the groundwater body lie within the basin.

Groundwater Budget. An accounting of the recharge to, discharge from, and storage of groundwater in, a subsurface hydrological unit such as an aquifer or groundwater basin.

Hydraulic Conductivity. The rate of flow of groundwater through a given rock under unit potential gradient at field temperature.

Infiltration. The movement of water through the ground surface into small interstices in either the zone of aeration or the zone of saturation.

Perched Groundwater. Groundwater separated from an underlying body of groundwater by unsaturated rock.

Permeability. The capacity of a rock to transmit fluids through its interstices.

Piezometric Surface. An imaginary surface defined by the potentials at all points on a given plane in a groundwater body.

Porosity. The property of a rock that defines the degree to which it contains interstices.

Potential. The sum of the pressure head of the groundwater at a given point and the elevation of that point above a selected horizontal datum.

Potential Gradient. The rate of change in potential at any point in a groundwater body: where no gradient direction is specified, the direction is that of maximum gradient.

Potentiometric Surface. An imaginary surface defined by the potentials at all points on a given plane in a groundwater body.

Pressure Head. The height of a column of pure water that can be supported by the hydrostatic pressure, against the pressure of the atmosphere, at a given point in a groundwater body.

Pumpage. The amount of water withdrawn from a bore or group of bores during a stated period.

Recharge. The addition of water to the zone of saturation, either directly from the ground surface or from the zone of aeration.

Safe Yield. The maximum rate at which water can be artificially withdrawn from a groundwater basin without causing depletion or deterioration to the extent that withdrawal at that rate is no longer economically feasible.

Salinity. The total content of dissolved solids of groundwater.

Storage Coefficient. The ratio of (1) the volume of water released from or taken into storage in a prism of aquifer of unit surface area and the full thickness of the aquifer to (2) the volume of the aquifer prism, per unit change in the component of pressure head normal to that surface.

Static Level. The level that passes through the top of a column of water that can be supported, against the pressure of the atmosphere, by the hydrostatic pressure of the water at a given point in a groundwater body, the water in the column having the same density as that in the groundwater body at that point.

Unconfined Groundwater. Groundwater of which the upper surface is formed by surface water or by permeable rock containing air at atmospheric pressure.

Underground Water. All water occurring below the ground surface.

Water Bore. A hole which is drilled, jetted, or augered to withdraw or replenish groundwater, or to obtain information about groundwater.

Water Table. The surface within a groundwater body at which the hydrostatic pressure is equal to atmospheric pressure.

Water Well. A hole which is dug, manually or mechanically, to withdraw or replenish groundwater, or to obtain information about groundwater.

Zone of Aeration. The zone in which interconnected interstices are filled with, or partly with, air and partly with water held or suspended by molecular forces.

Zone of Saturation. The zone in which interconnected interstices are filled with water.

PLATE 1

Fig. 1. Texture of Todd River bed, showing range of particle sizes, flakes of dried silt, and organic debris

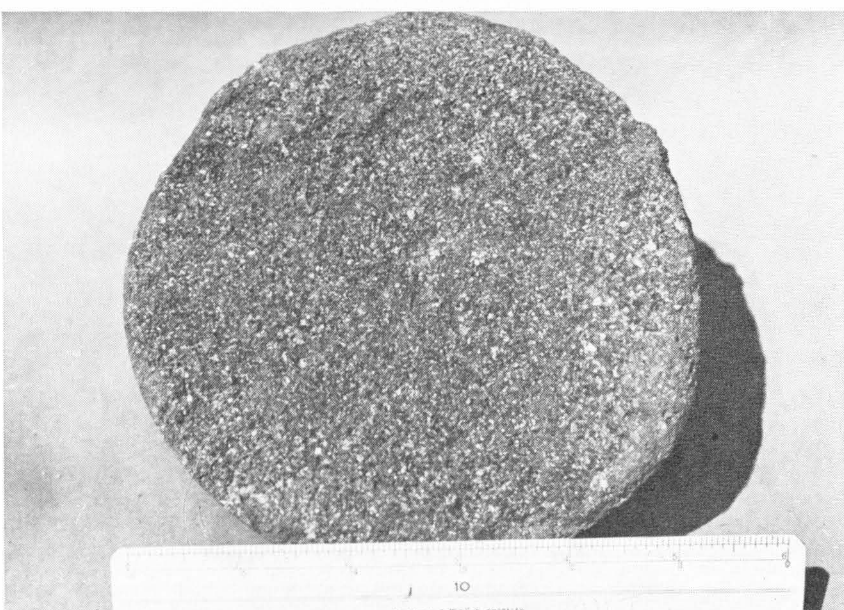


Fig. 2. Core from test hole 60/27, showing texture of brown clayey sand (Photo: J. Zawartko)

PLATE 2

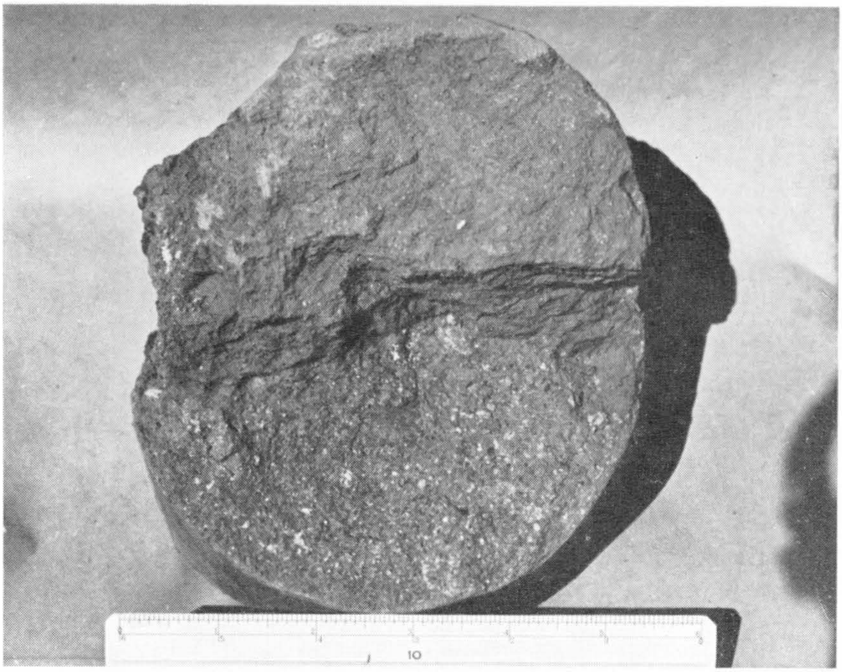


Fig. 1. Core from test hole 60/27 (opposite end of same core shown in Pl. 1, Fig. 2), showing boundary between brown clayey sand (below) and blue-grey silty clay (above) (Photo: J. Zawartko)

Fig. 2. Heavitree Gap, looking north from Mount Blatherskite, showing erosional levels (Photo: J. Zawartko)

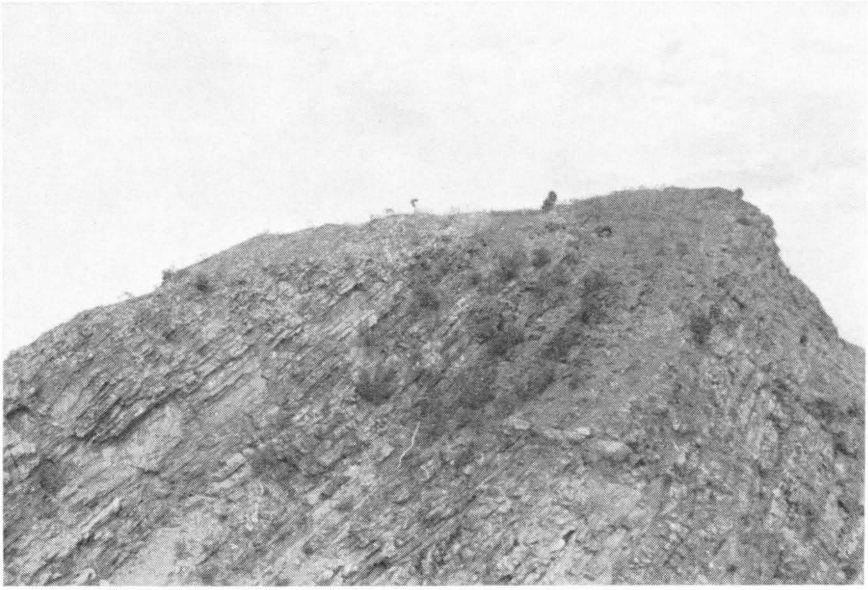


Fig. 1. Tertiary erosion surface, western side of Heavitree Gap

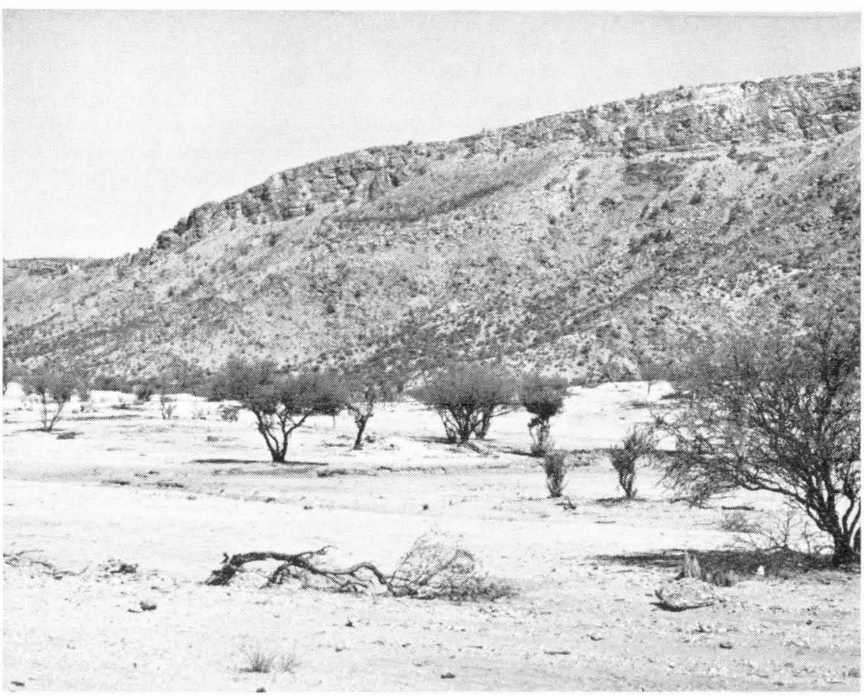


Fig. 2. Tertiary erosion surface, north side of Heavitree Ridge (Photo: J. Zawartko)

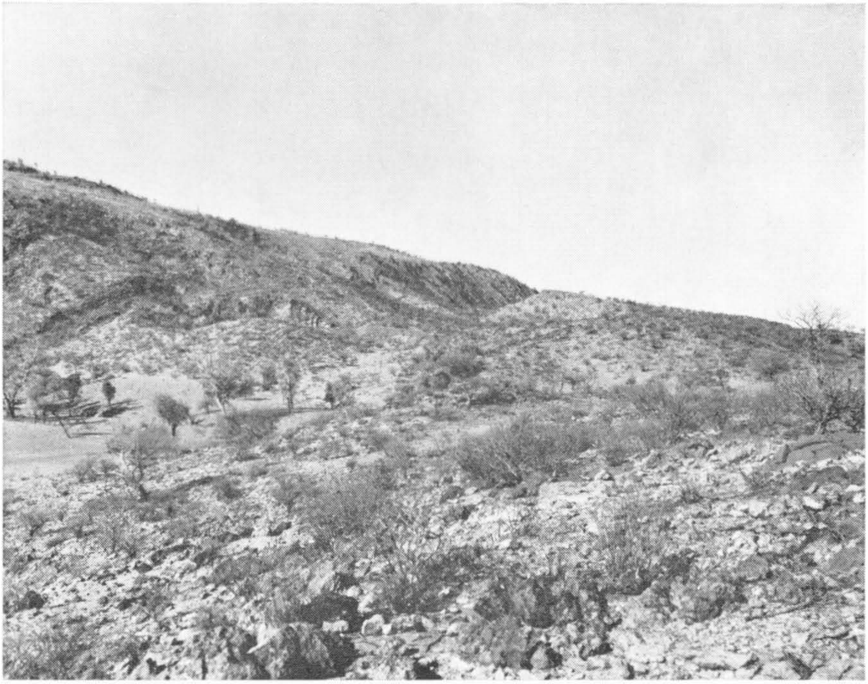


Fig. 1. Tertiary erosion surface remnant, in area south of Heavitree Ridge (Photo: J. Zawartko)

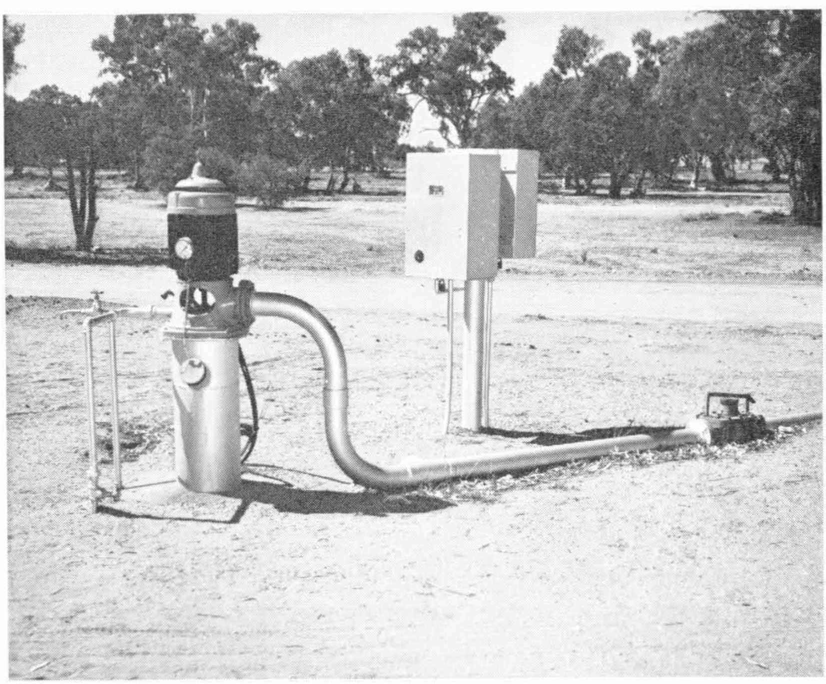


Fig. 2. Colocag Park Bore (61/24), showing pump, electrical, and meter installations. Todd River in background (Photo: J. Zawartko)

PLATE 5

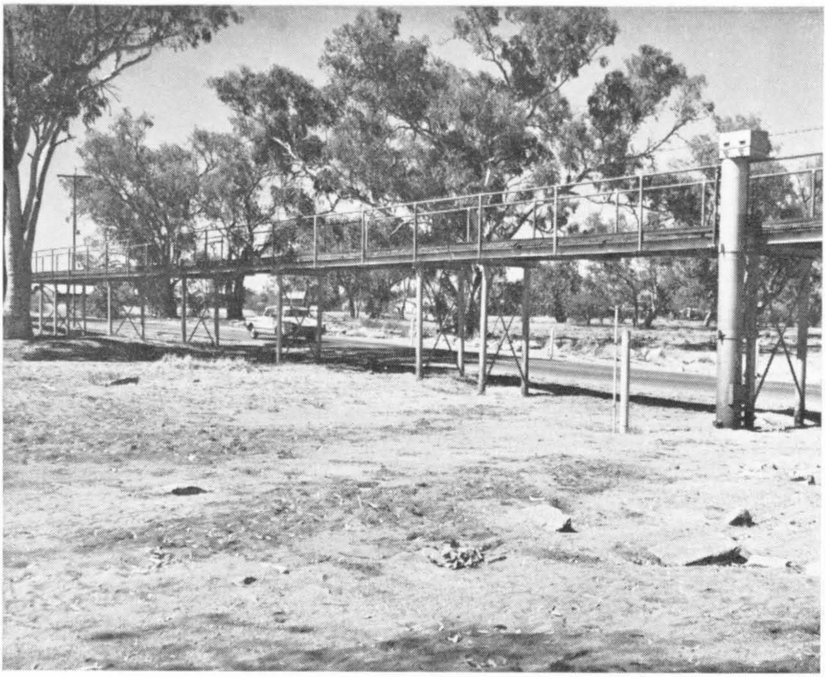
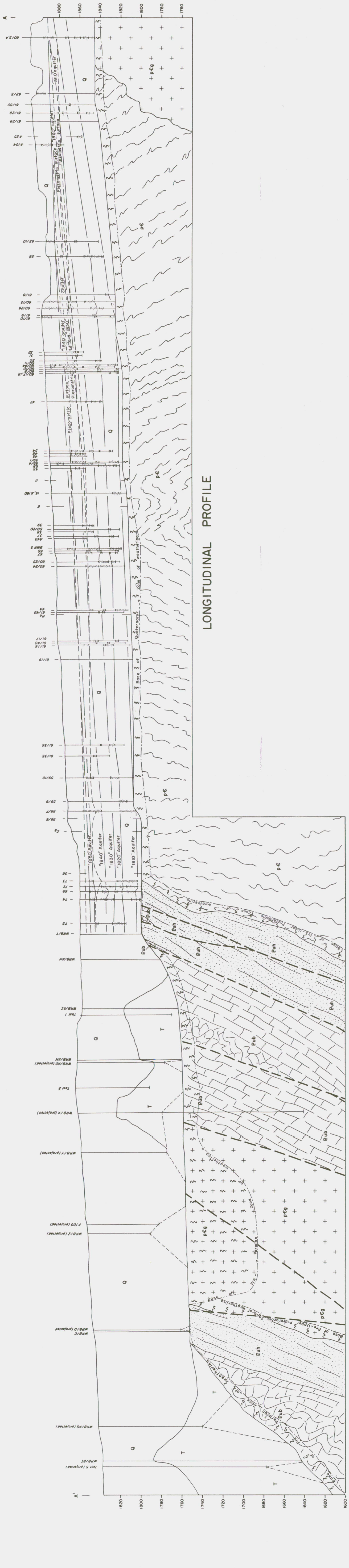
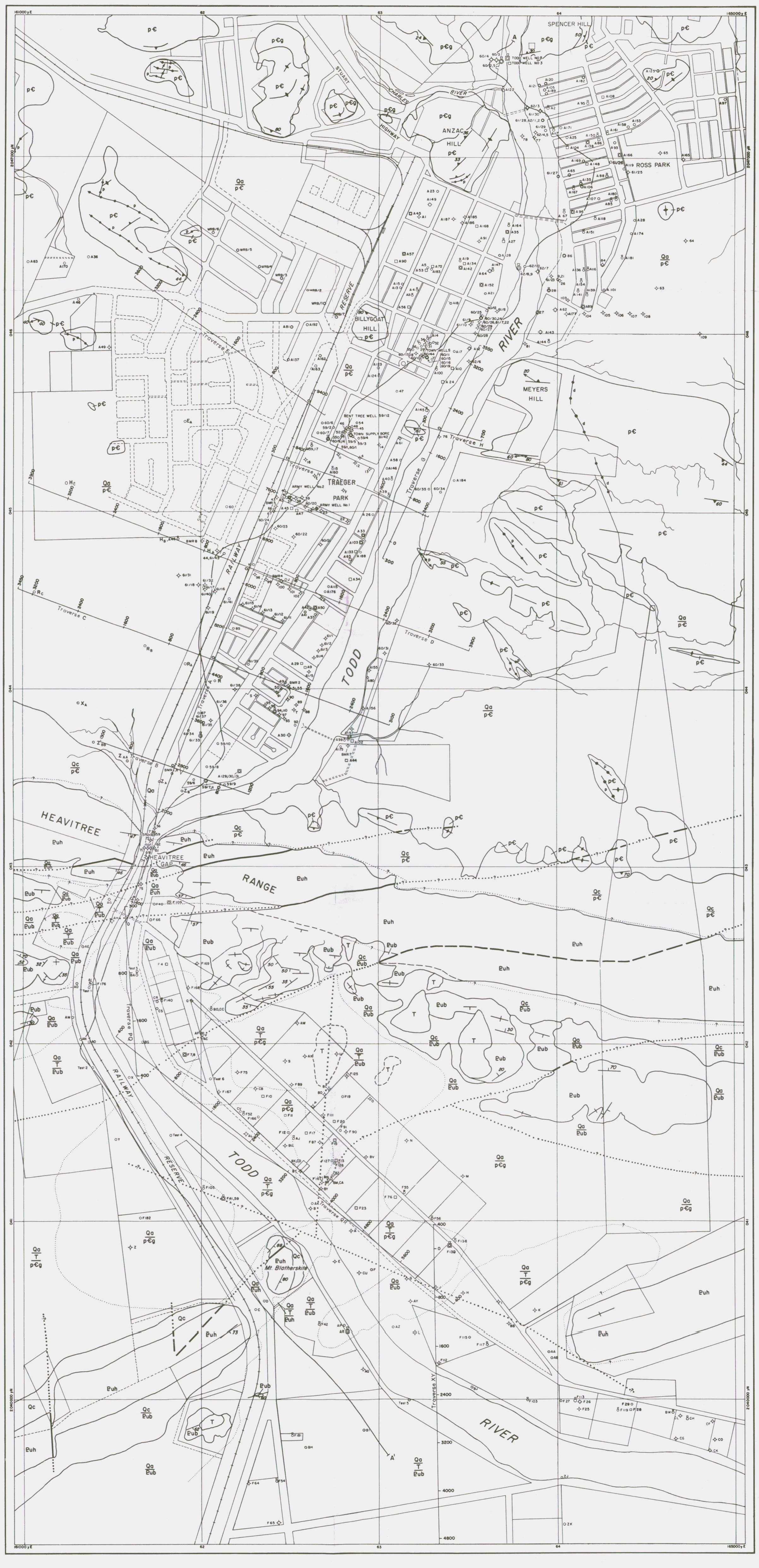


Fig. 1. Todd River, East Side Causeway, footbridge, and stage recorder installation (Photo: J. Zawartko)

Fig. 2. Bore 62/9, in bed of Todd River, showing concrete pier installation to raise pumping equipment above level of river flows (Photo: J. Zawartko)

GEOLOGICAL MAP OF THE TOWN AND INNER FARM BASINS, ALICE SPRINGS





	Q	Alluvium, colluvium (profile only)
QUATERNARY	Qc	Colluvium
	Qa	Alluvium
TERTIARY	T	Sandy clay, billy
UPPER PROTEROZOIC		
Bitter Springs Formation	Ꝑub	Dolomite, limestone, siltstone, gypsum
Heavitree Quartzite	Ꝑuh	Quartzite
PRECAMBRIAN		
Arunta Complex	p€	Schist, gneiss
	p€g	Granite
		Weathered zone
		Dolerite dyke
		Pegmatite

Horizontal Scale: 500 0 500 1000 2000 3000 FEET

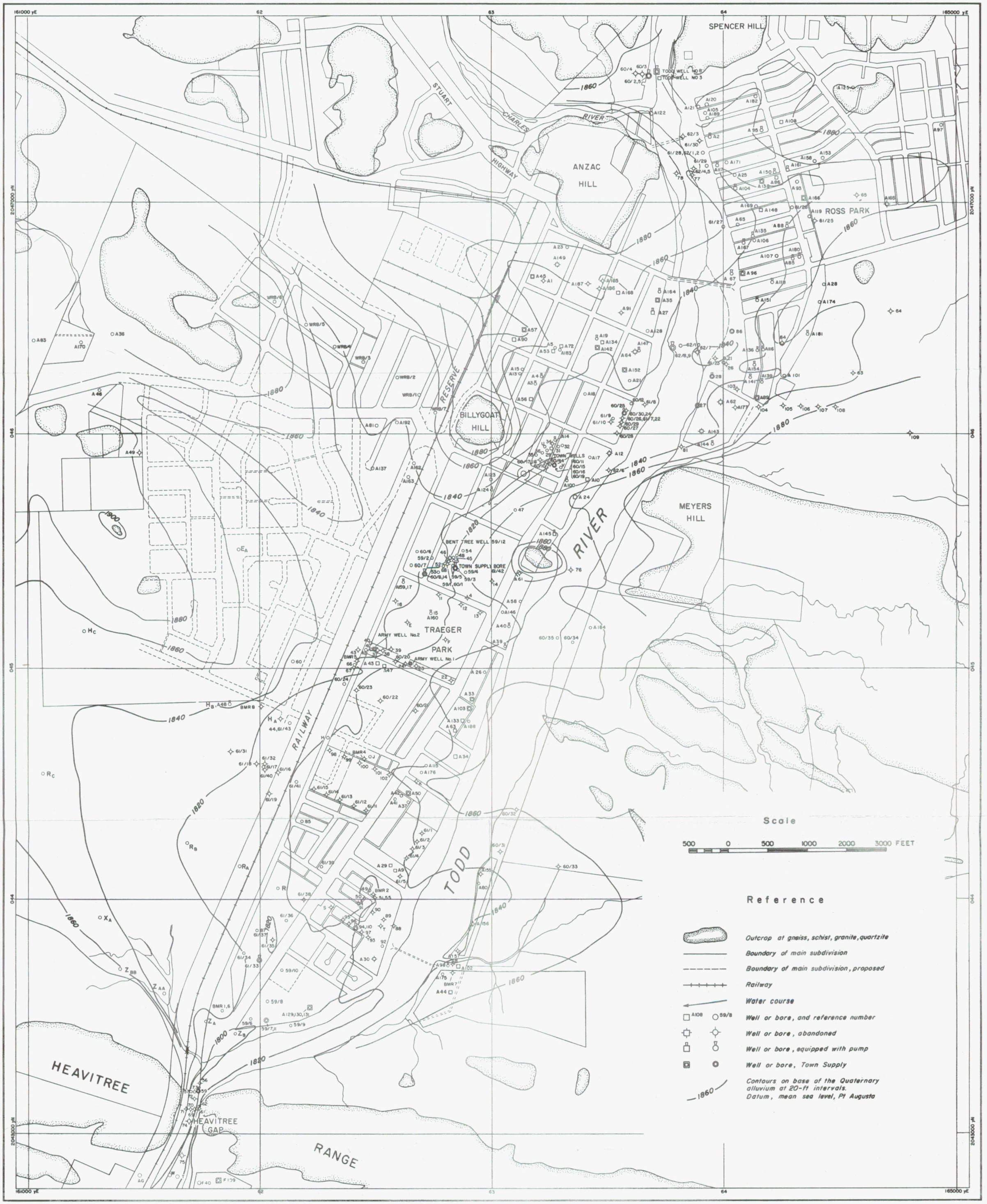
Vertical Scale (profile only): 20 10 0 20 40 60 80 FEET

Reference

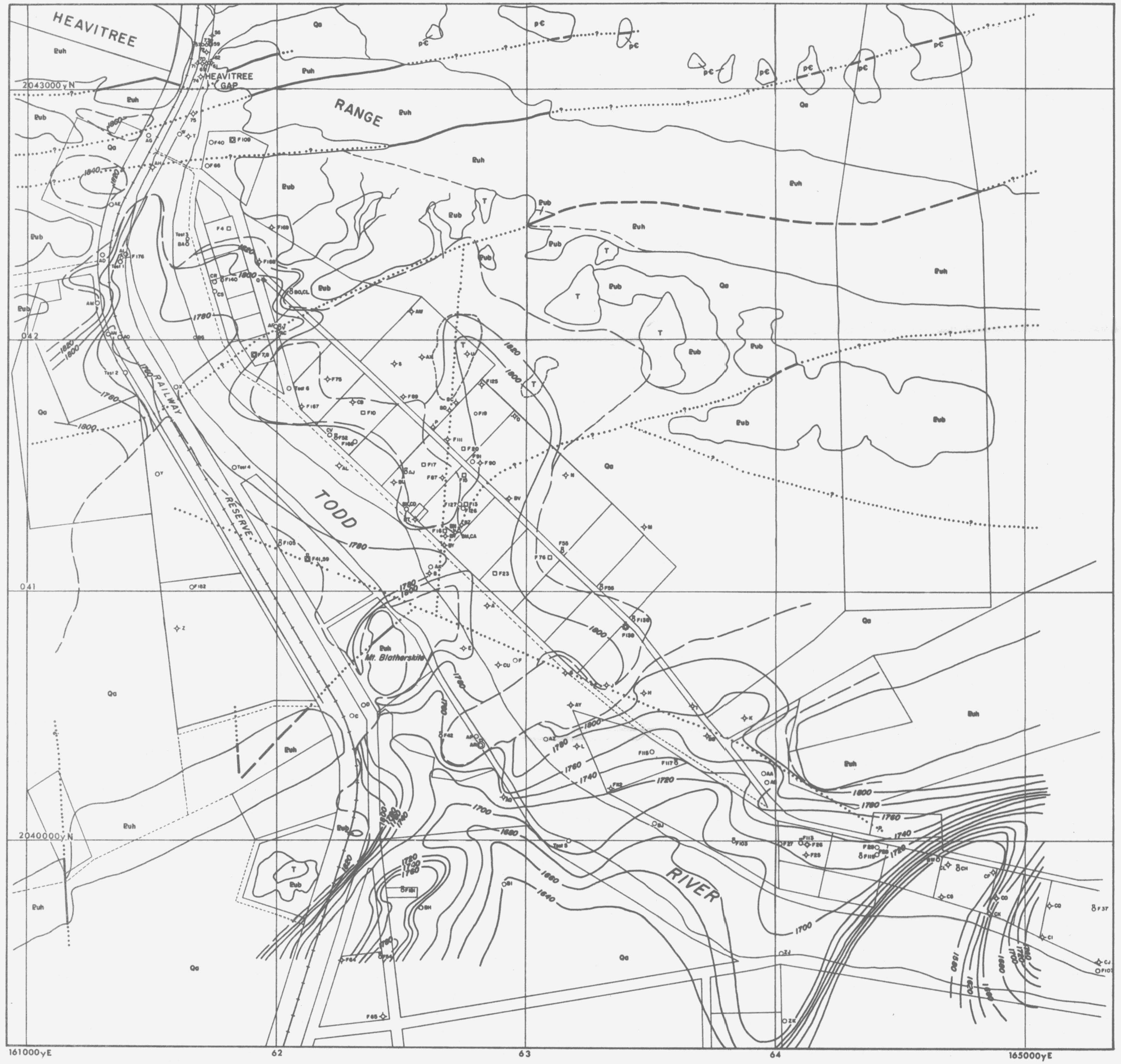
- Geological boundary
- Geological boundary, position approximate
- Geological boundary, concealed
- Geological boundary, inferred and concealed
- Fault, position accurate
- Fault, position approximate
- Fault, concealed
- Fault, inferred and concealed
- Foliation and lineation
- Dip and strike
- Dip and strike, horizontal
- Dip and strike, vertical
- Dip and strike, less than 15°
- Dip and strike, less than 15°
- Anticlinal axis showing direction of plunge
- Line of longitudinal profile
- Boundary of main subdivision
- Boundary of main subdivision, proposed
- Railway
- Water course
- Well or bore, and reference number
- Well or bore, abandoned
- Well or bore, equipped with pump
- Well or bore, Town Supply
- Geophysical traverse line

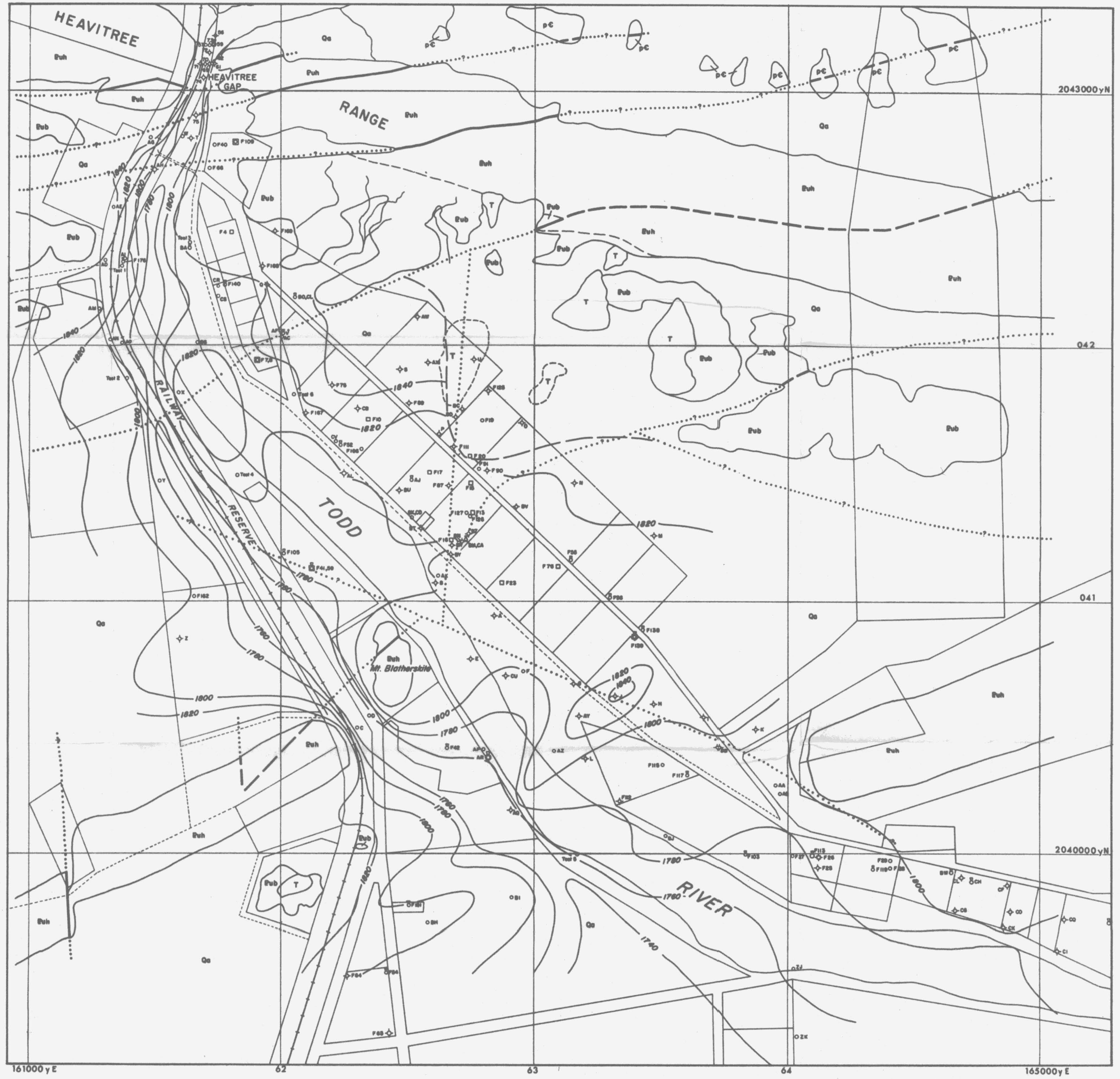
CONTOURS ON THE BASE OF THE QUATERNARY ALLUVIUM TOWN BASIN, ALICE SPRINGS

PLATE 7



CONTOUR MAPS ON THE BASE OF THE TERTIARY SEDIMENT AND QUATERNARY ALLUVIUM, INNER FARM BASIN ALICE SPRINGS





Scale

500 0 500 1000 2000 3000 FEET

R e f e r e n c e

QUATERNARY	Qa	*Alluvium, colluvium*
TERTIARY	T	*Sandy clay, billy*
UPPER PROTEROZOIC		
Bitter Springs Formation	Ꝑub	*Dolomite, limestone, siltstone, gypsum*
Heavitree Quartzite	Ꝑuh	*Quartzite*
PRECAMBRIAN		
Arunta Complex	p€	*Schist, gneiss*
	p€g	*Granite*

Geological boundary

Geological boundary, position approximate

Fault, position accurate

Fault, position approximate

Fault, concealed

Fault, inferred and concealed

1820 *Contours at 20-ft intervals. Datum, mean sea level, Pt Augusta*

Boundary of main subdivision

Boundary of main subdivision, proposed

Railway

Water course

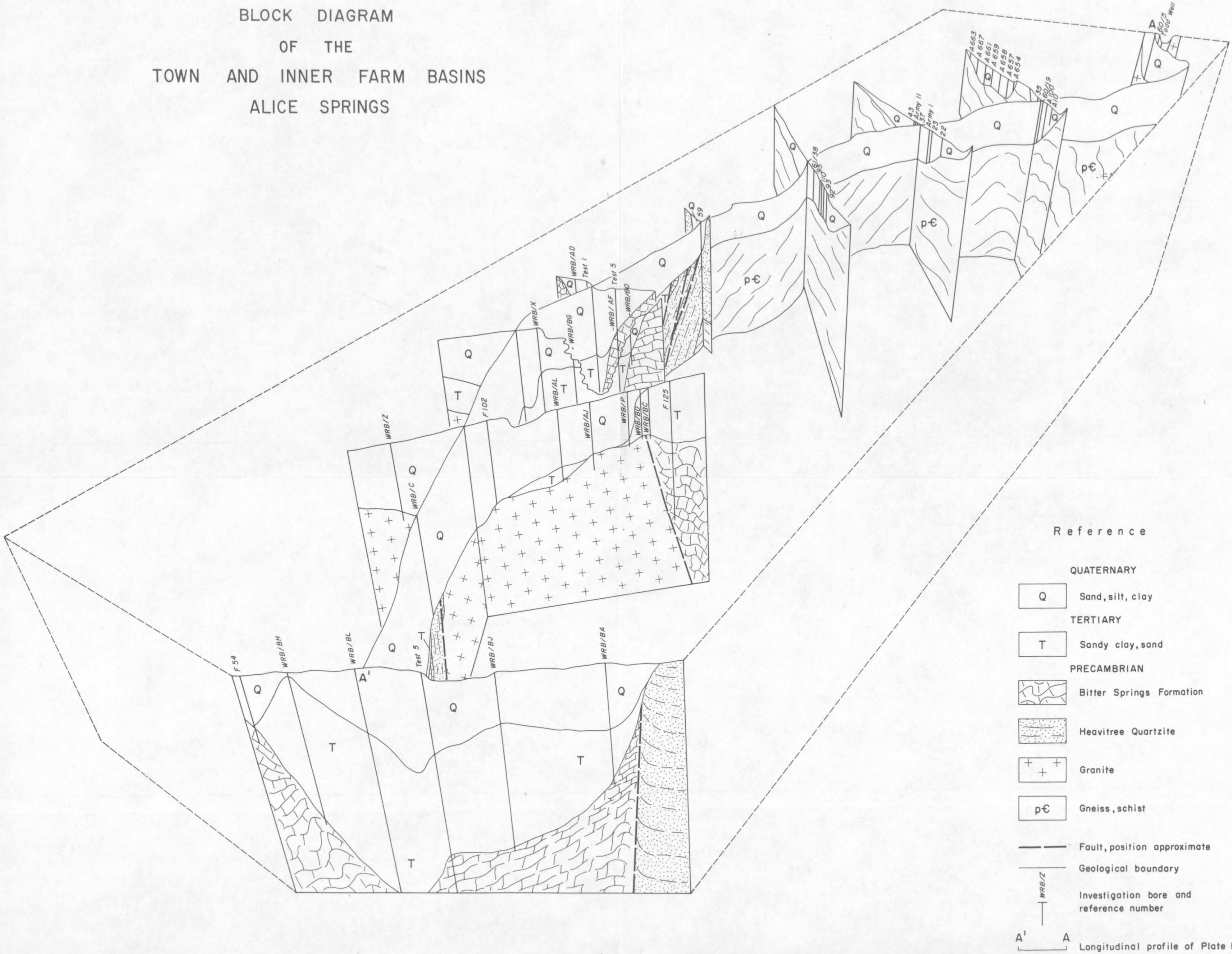
F28 59/10 *Well or bore and reference number*

Well or bore, abandoned

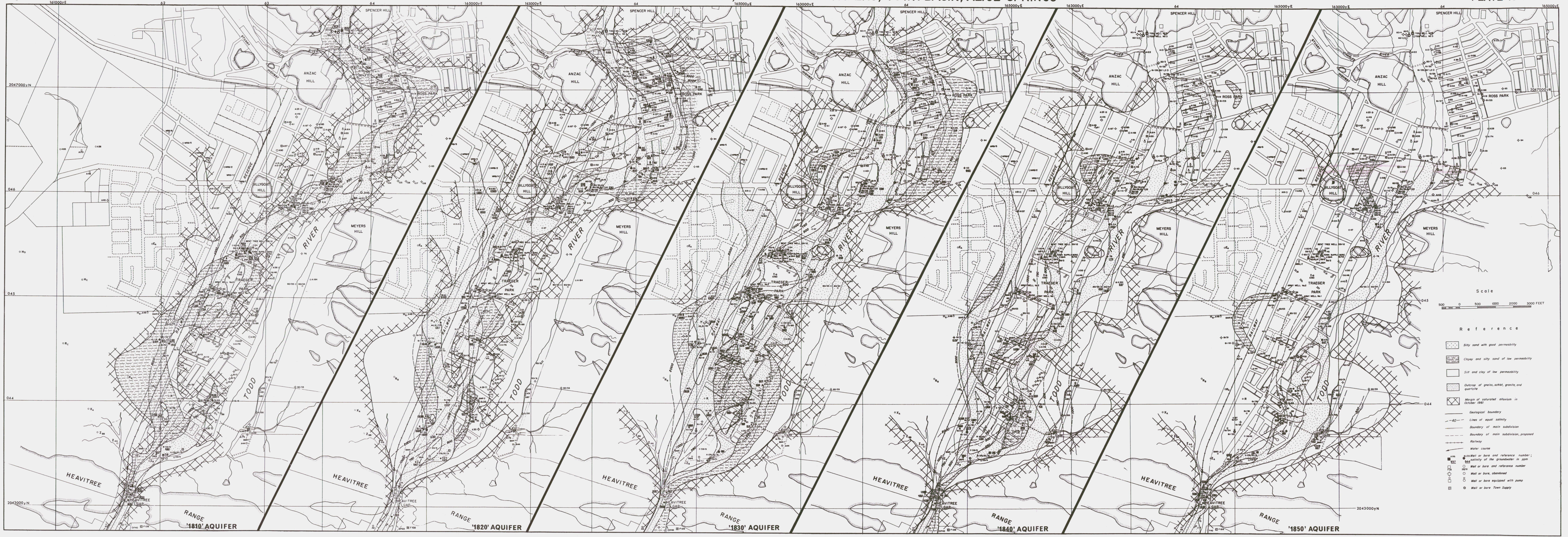
Well or bore equipped with pump

Well or bore Town Supply

BLOCK DIAGRAM OF THE TOWN AND INNER FARM BASINS ALICE SPRINGS

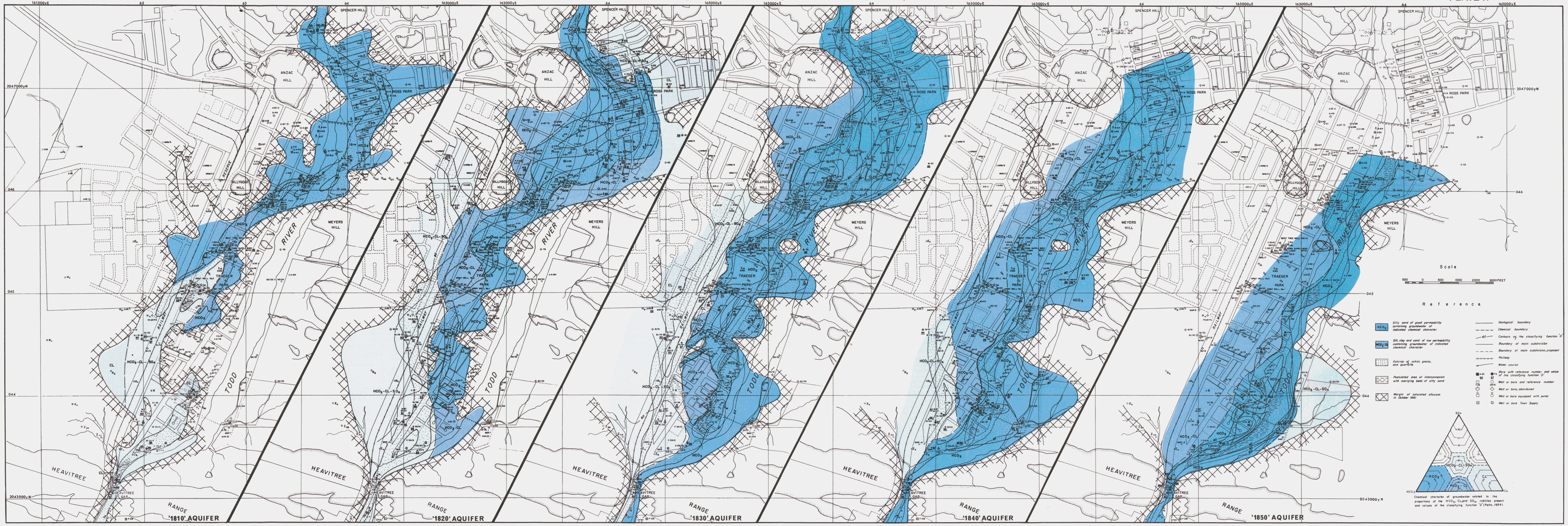


GEOLOGY AND SALINITY OF GROUNDWATER, QUATERNARY AQUIFERS, TOWN BASIN, ALICE SPRINGS



CHEMICAL CHARACTER (ANIONS) OF GROUNDWATER, QUATERNARY AQUIFERS, TOWN BASIN, ALICE SPRINGS

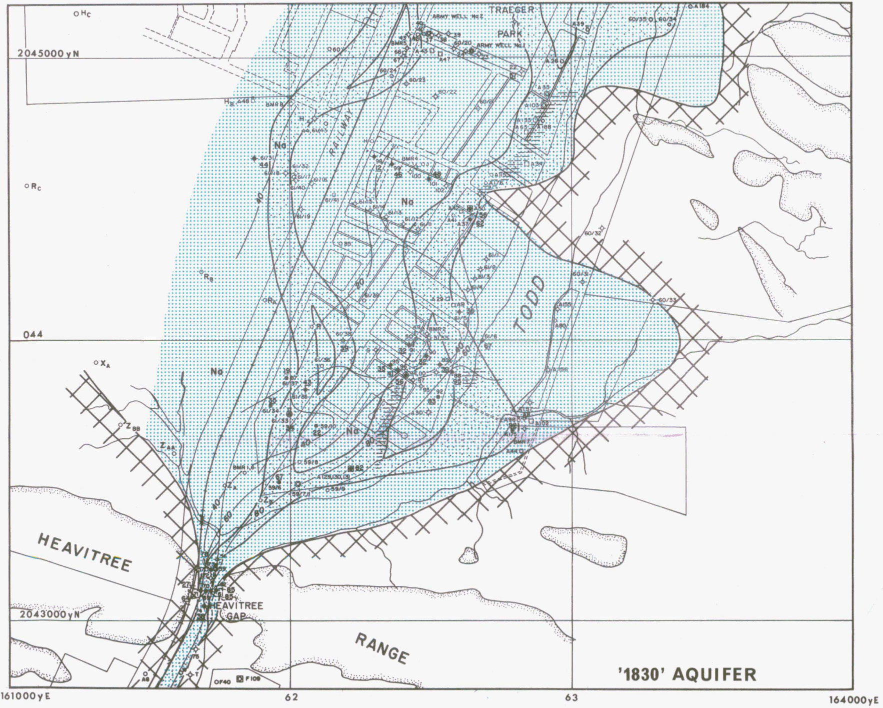
PLATE II

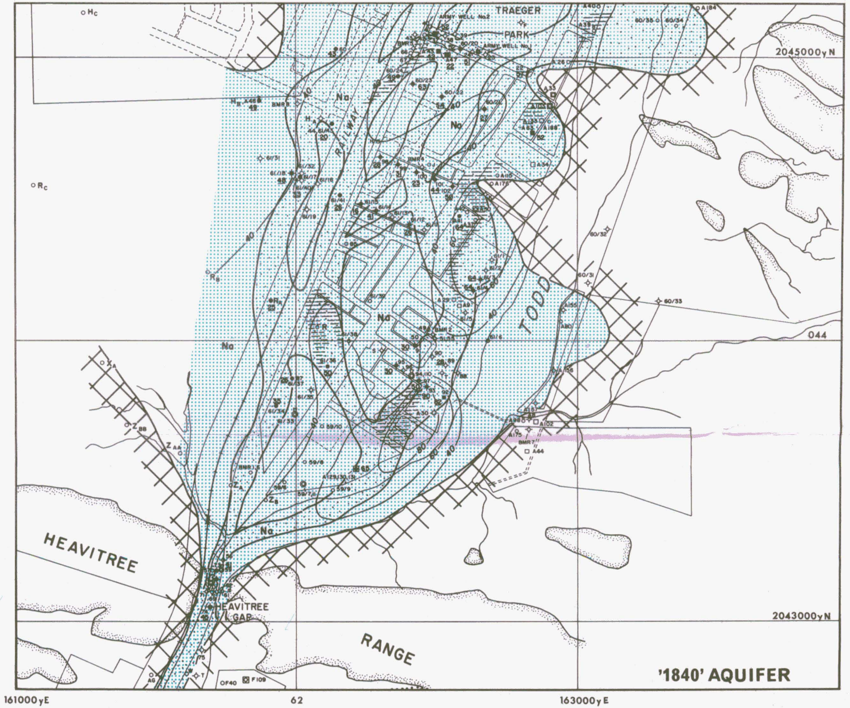


Chemical character of groundwater related to the proportions of the HCO_3, CL, and SO_4, radicles present and values of the classifying function 'D' (Pelto, 1954)

CHEMICAL CHARACTER (CATIONS) OF GROUNDWATER, PART OF THE '1830' AND '1840' AQUIFERS, TOWN BASIN, ALICE SPRINGS

PLATE 12



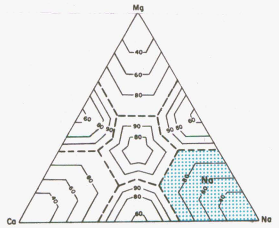


Scale

500 0 500 1000 2000 3000 FEET

Reference

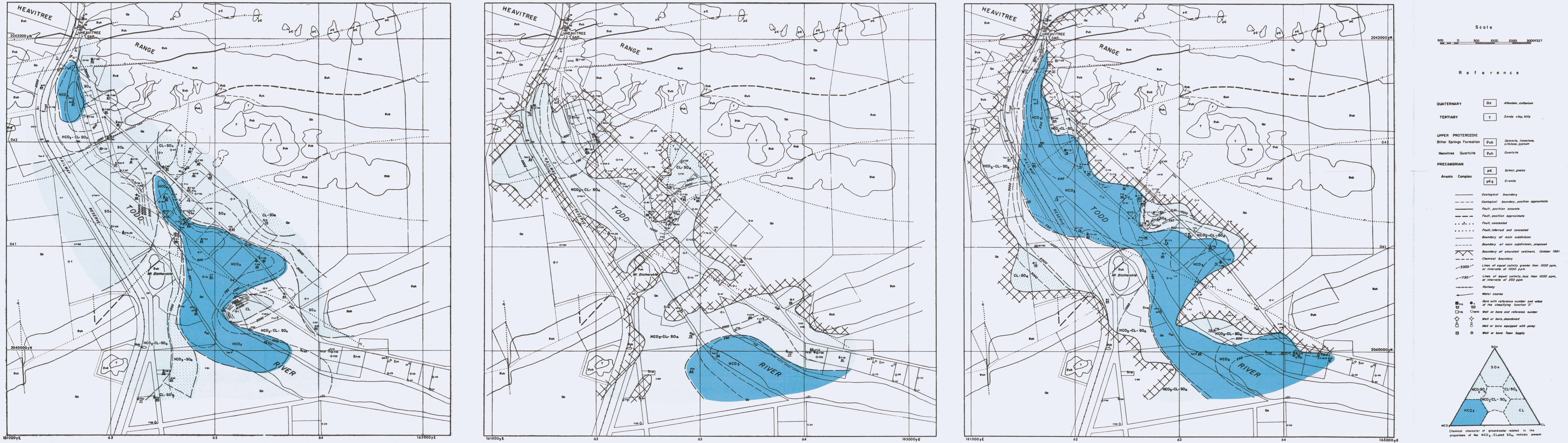
- HCO_3 — Silty sand of good permeability containing groundwater of indicated chemical character
- HCO_3-Cl — Silt, clay, and sand of low permeability containing groundwater of indicated chemical character
- Outcrop of schist, gneiss, granite, and quartzite
- Postulated area of interconnexion with overlying beds of silty sand
- Margin of saturated alluvium in October 1961
- Geological boundary
- Chemical boundary
- 40 — Contours on the classifying function 'D'
- Boundary of main subdivision
- Boundary of main subdivision, proposed
- Railway
- Water course
- A63 52 / 61/6 67 — Bore with reference number and value of the classifying function 'D'
- F28 / 59/10 — Well or bore and reference number
- Well or bore, abandoned
- Well or bore equipped with pump
- Well or bore Town Supply



Chemical character of groundwater related to the proportions of the Mg, Ca, and Na radicles present and values of the classifying function 'D' (Pelto, 1954)

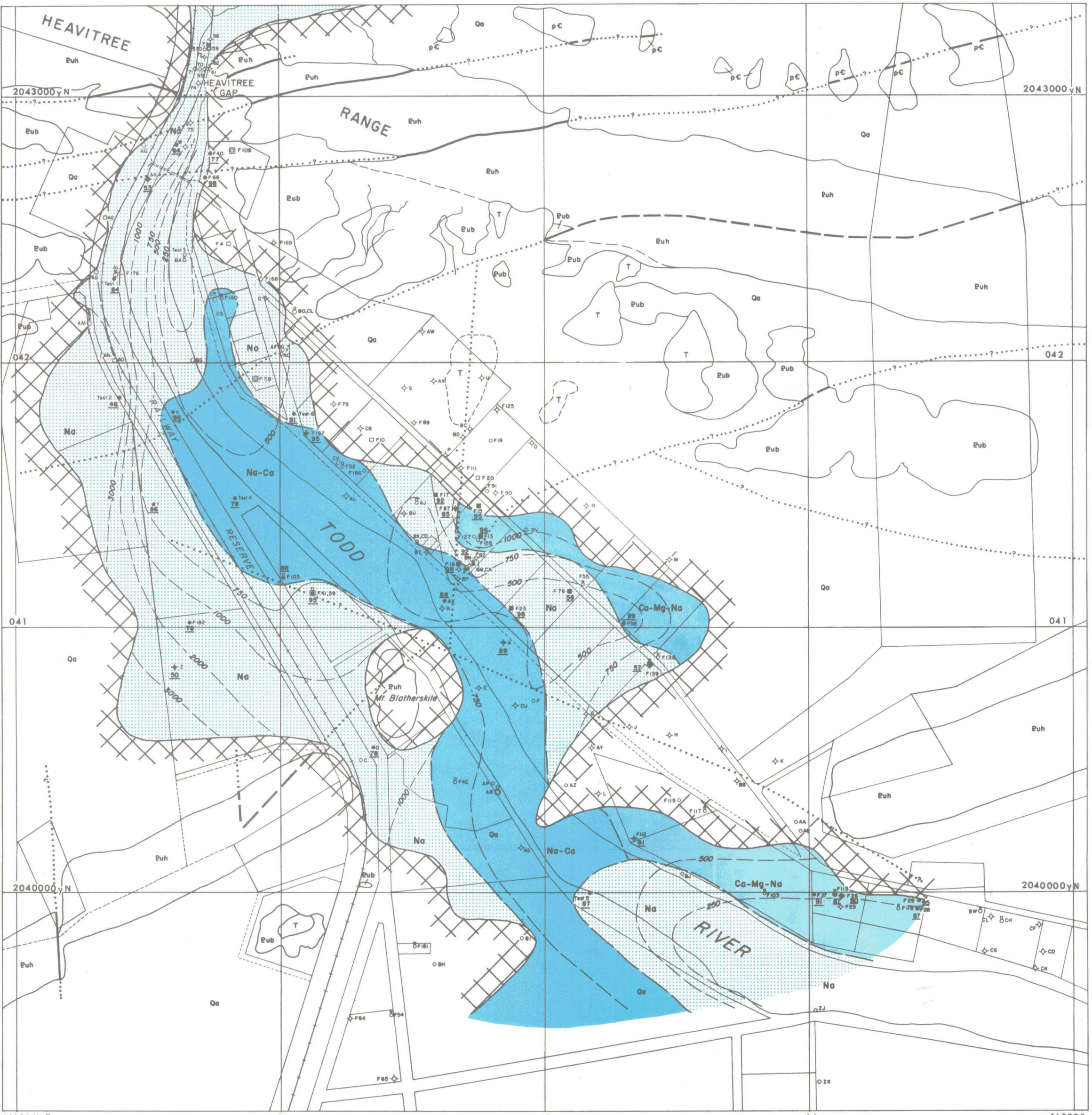
CHEMICAL CHARACTER (ANIONS) AND SALINITY OF GROUNDWATER, QUATERNARY, TERTIARY, AND PRECAMBRIAN ROCKS, INNER FARM BASIN, ALICE SPRINGS

PLATE 13



CHEMICAL CHARACTER (CATIONS) AND SALINITY OF GROUNDWATER QUATERNARY ALLUVIUM, INNER FARM BASIN, ALICE SPRINGS

PLATE 14



Scale

500 0 500 1000 2000 3000 FEET

Reference

QUATERNARY	Qa	*Alluvium, colluvium*
TERTIARY	T	*Sandy clay, billy*
UPPER PROTEROZOIC Bitter Springs Formation	Ꝑub	*Dolomite, limestone, siltstone, gypsum*
Heavitree Quartzite	Ꝑuh	*Quartzite*
PRECAMBRIAN Arunta Complex	p€	*Schist, gneiss*
	p€g	*Granite*

Geological boundary

Geological boundary, position approximate

Fault, position accurate

Fault, position approximate

Fault, concealed

Fault, inferred and concealed

Boundary of main subdivision

Boundary of main subdivision, proposed

Boundary of saturated alluvium, October 1961

Chemical boundary

Lines of equal salinity greater than 1000 ppm, at intervals of 1000 ppm

Lines of equal salinity, less than 1000 ppm, at intervals of 250 ppm

Railway

Water course

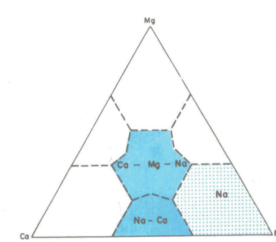
Bore with reference number and value of the classifying function 'D'

Well or bore and reference number

Well or bore, abandoned

Well or bore equipped with pump

Well or bore Town Supply



Chemical character of groundwater related to the proportions of the Mg, Ca, and Na radicles present

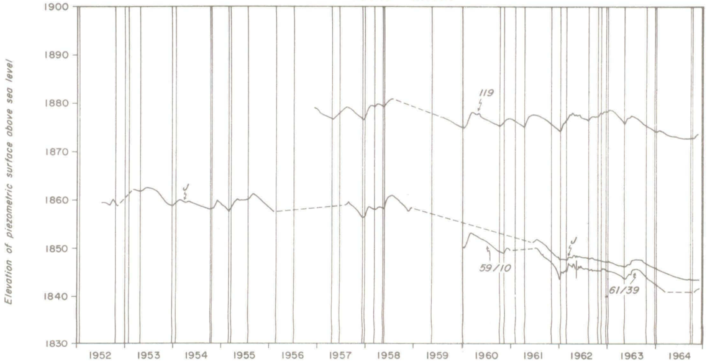
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE

TOWN AND INNER FARM BASINS

ALICE SPRINGS

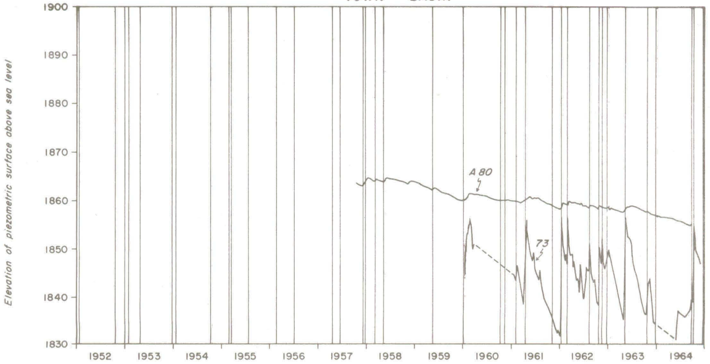
PLATE 15

TOWN BASIN



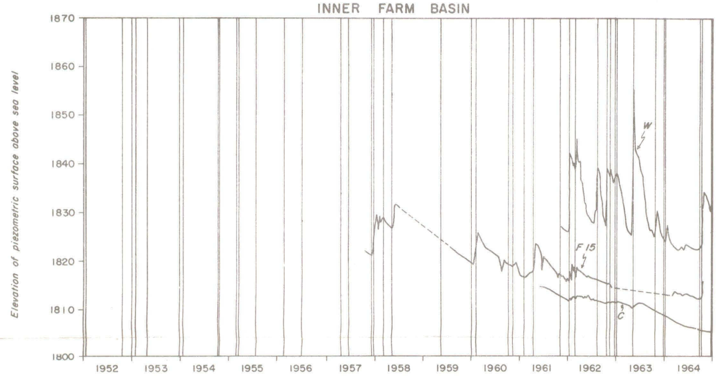
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE '1820' AQUIFER

TOWN BASIN

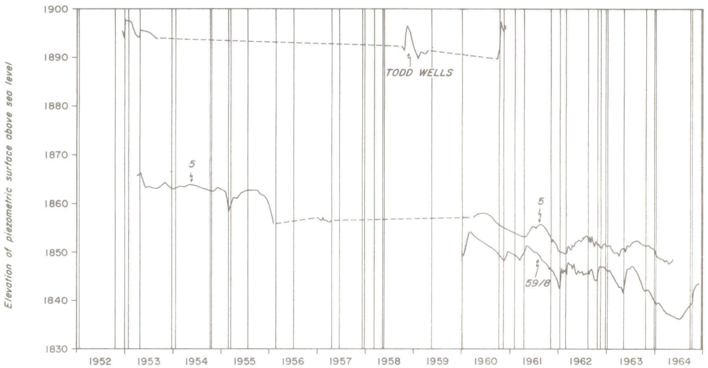


FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE '1850' AQUIFER

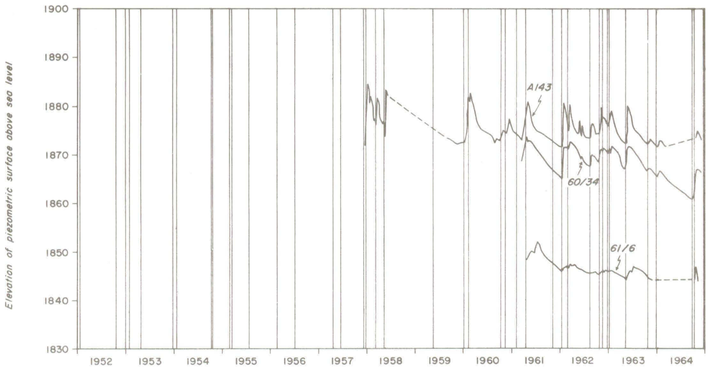
INNER FARM BASIN



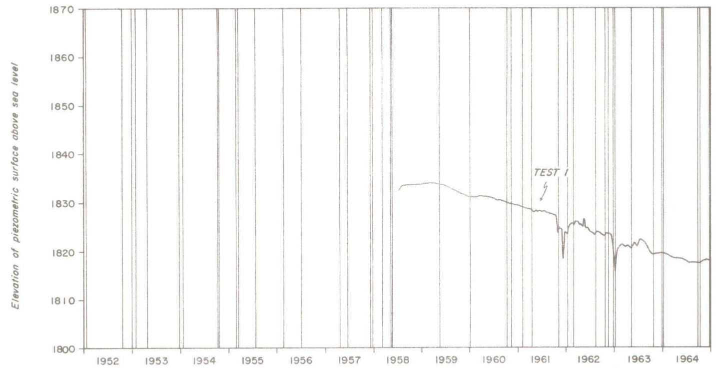
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE QUATERNARY ALLUVIUM



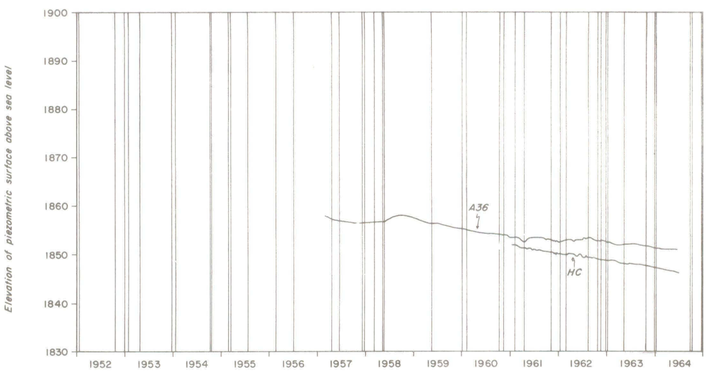
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE '1810' AQUIFER



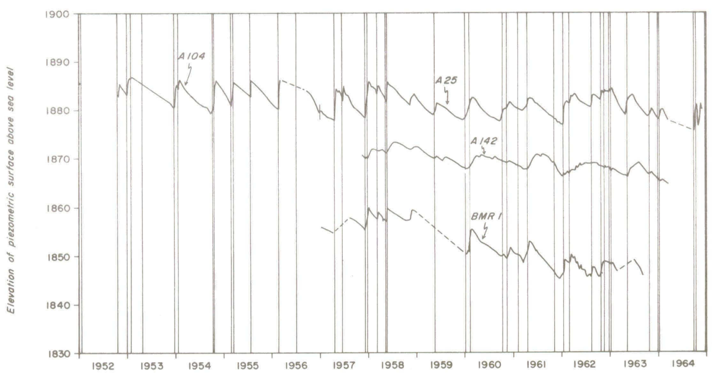
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE '1840' AQUIFER



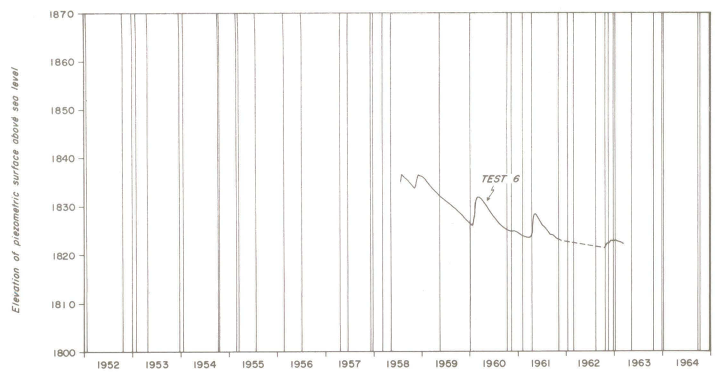
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE TERTIARY SEDIMENT



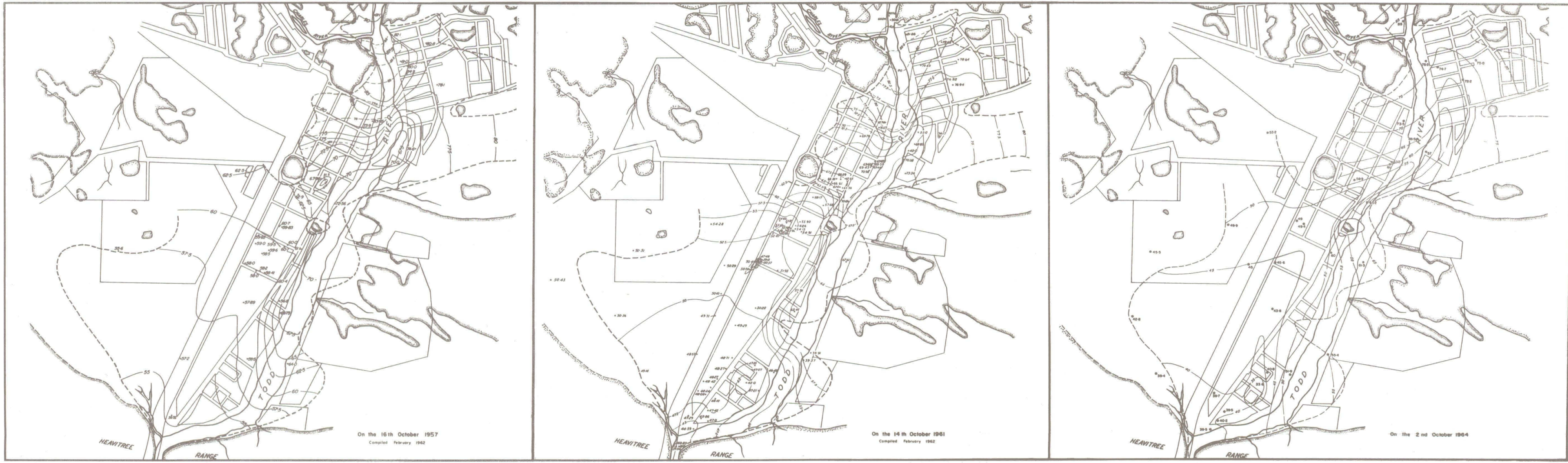
FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE PRECAMBRIAN ROCKS



FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE '1830' AQUIFER



FLUCTUATIONS IN THE PIEZOMETRIC SURFACE OF THE PRECAMBRIAN ROCKS



Reference

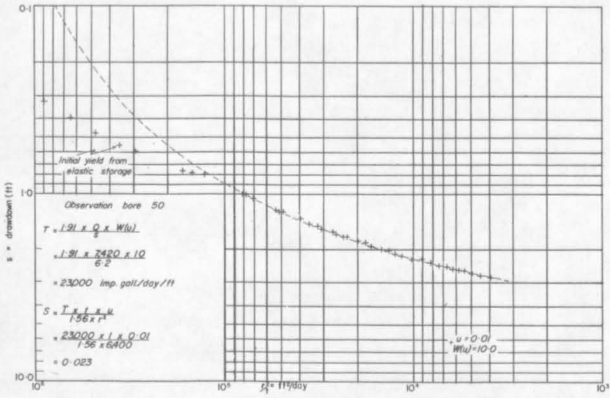
- • 48·10 — Measuring point and height of piezometric surface. Datum 1800 feet above mean sea level, Pt Augusta
- Outcrop of schist, gneiss, granite, and quartzite
- Boundary of main town subdivision
- —67— Contour on piezometric surface at 2·5-ft intervals Datum 1800 feet above mean sea level, Pt. Augusta
- --72·5-- Contour on main piezometric surface, in area with a perched water table. Datum 1800 feet above mean sea level, Pt Augusta
- ----- Edge of saturated alluvium

CONTOUR MAPS OF THE PIEZOMETRIC SURFACE

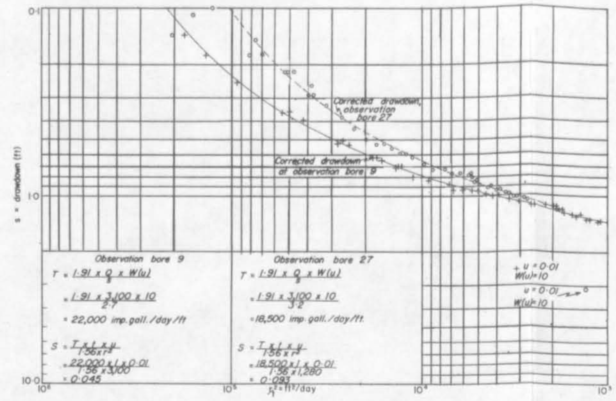
ALICE SPRINGS TOWN BASIN

Scale

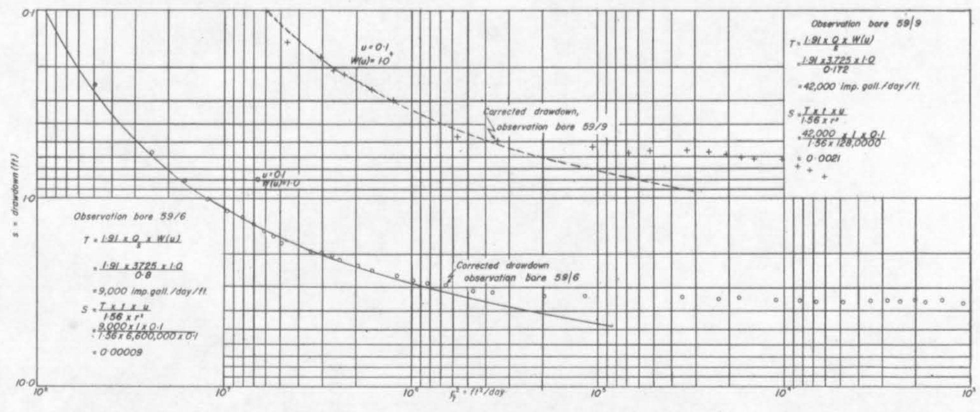
1200 0 1200 2400 3600 4800 FEET



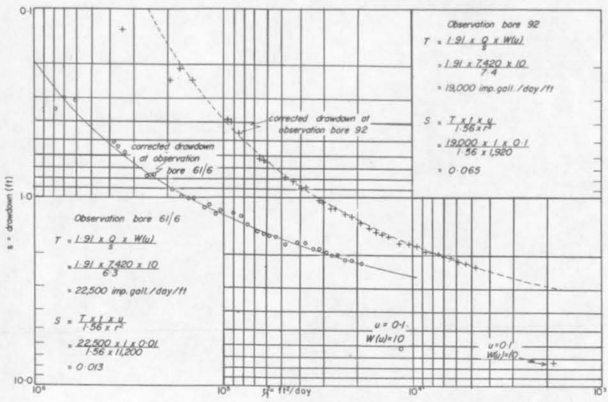
Drawdown curve at bore 50 for aquifer test of bore 110



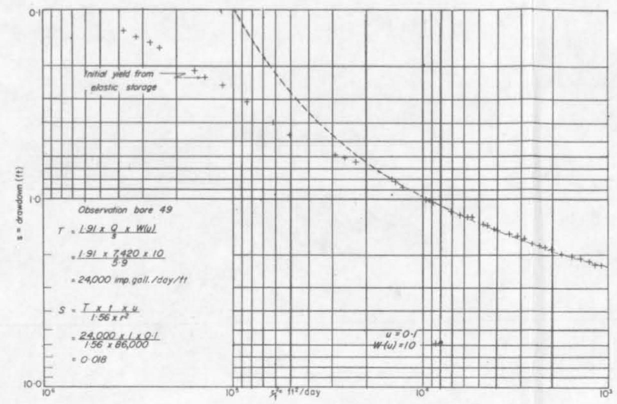
Drawdown curves at bores 9 and 27 for aquifer test of bore 28



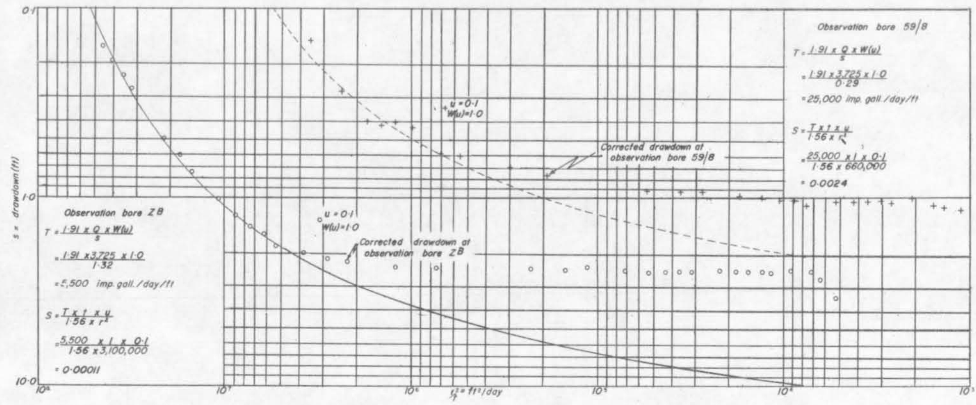
Drawdown curves at bores 59/6 and 59/9 for aquifer test of bore 59/11



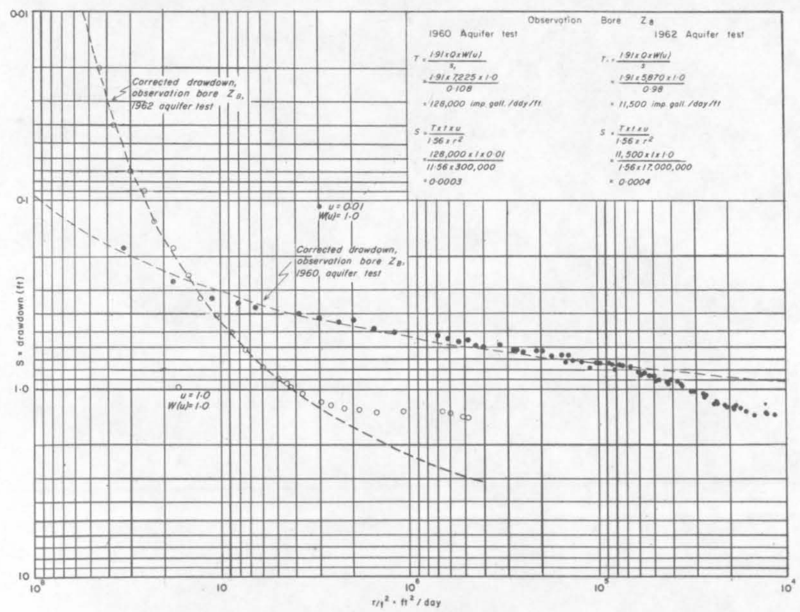
Drawdown curves at bores 61/6 and 92 for aquifer test of bore 110



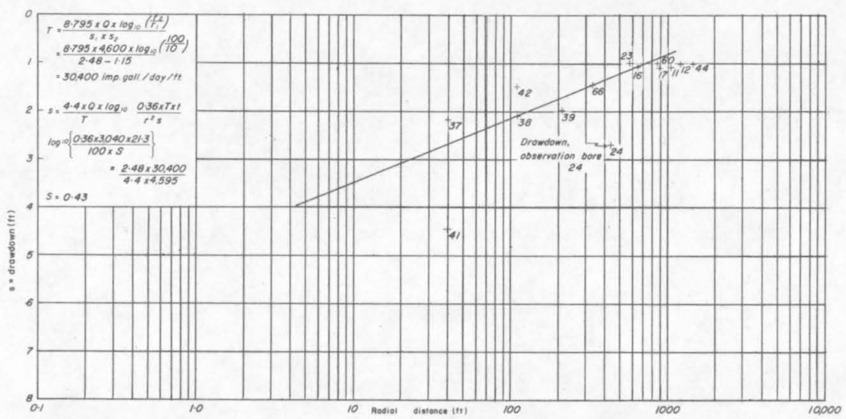
Drawdown curve at bore 49 for aquifer test of bore 110



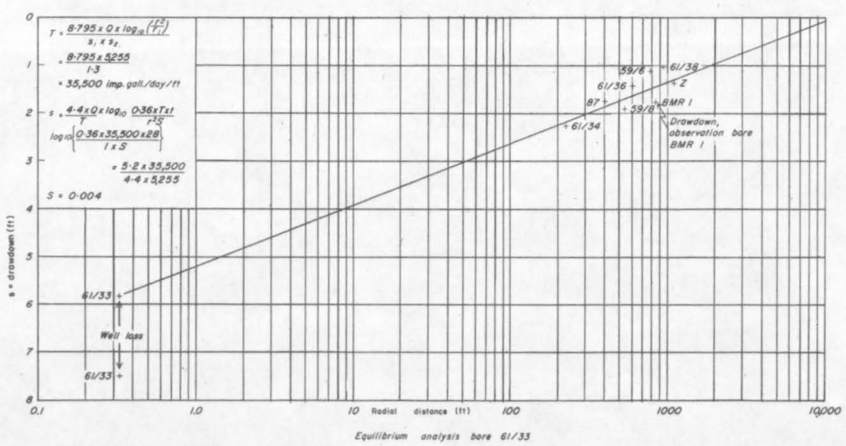
Drawdown curves at bores Z8 and 59/8 for aquifer test of bore 59/11



Drawdown curves at bore Z8 for aquifer tests of bore 59 in 1960 and 1962



Equilibrium analysis army well No. 2



Equilibrium analysis bore 61/33

DRAWDOWN CURVES FOR AQUIFER PERFORMANCE TESTS

TOWN BASIN — ALICE SPRINGS

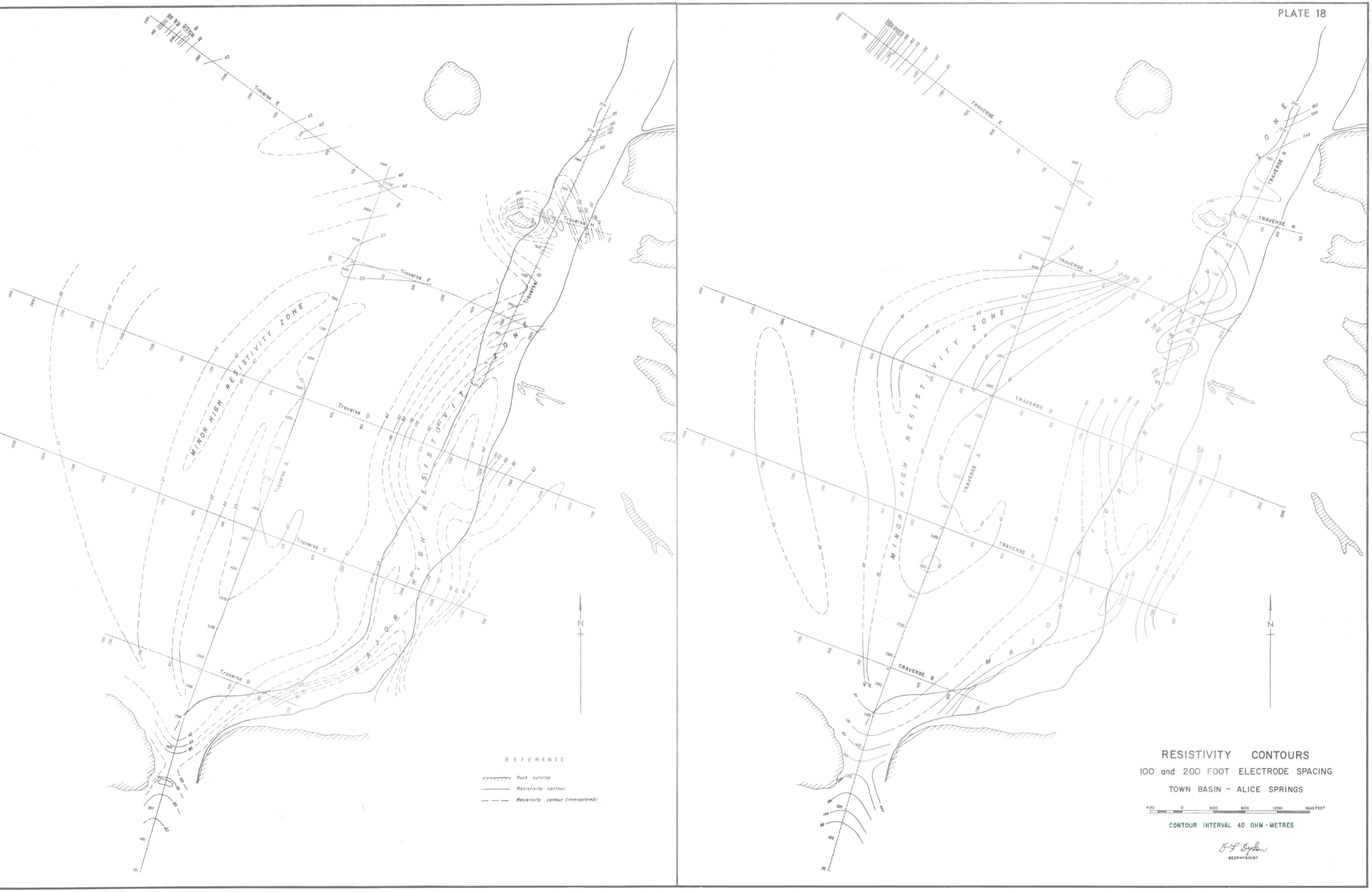


PLATE 18
Traverse E
Traverse F
Traverse G
Traverse H
Traverse D
Traverse C
Traverse B
Traverse A
MINOR HIGH RESISTIVITY ZONE
MAJOR HIGH RESISTIVITY ZONE
N
REFERENCE
Rock outcrop
Resistivity contour
Resistivity contour (interpolated)
RESISTIVITY CONTOURS
100 and 200 FOOT ELECTRODE SPACING
TOWN BASIN - ALICE SPRINGS
400 0 400 800 1200 1600 FEET
CONTOUR INTERVAL 40 OHM-METRES
GEOPHYSICIST