DEPARTMENT OF MINES
SOUTH AUSTRALIA

ANGAS-BREMER IRRIGATION AREA
GROUNDWATER RESOURCES
SUMMARY REPORT

by

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Rept.Bk.No. 77/153
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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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THE HYDROGEOLOGY OF THE ANGAS-BREMER IRRIGATION AREA SUMMARY REPORT

ABSTRACT

Underground water resources in the Angas-Bremer irrigation area have been used to irrigate lucerne pasture since the late 1950's. Falling water levels and rising salinities in the main aquifer, a Tertiary limestone, prompted local farmers to form an irrigation association, and they approached the Department of Mines for advice in 1961. Investigations of the hydrogeology of the area have been carried out since 1969.

The aquifer from which supplies are obtained is confined over most of the area, and is recharged by the ephemeral, and often brackish, Bremer and Angas Rivers. Water quality in the irrigation area is rarely better than 1 400 mg/l and rises to more than 1 000 mg/l a few kilometres away from the rivers.

Water balance studies have shown that an overlying unconfined aquifer contributes by downward leakage 52% of the estimated 25 000 megalitres/year extracted from the confined aquifer. This is made possible by the lack of effective confining beds between the two aquifers in the southern part of the area. The remaining withdrawals from the confined aquifer are balanced by natural recharge from the rivers on the north and north-west (22%), lateral flow of saline groundwater (14%), and induced recharge to the aquifer from Lake Alexandrina (12%). Changes in storage are not occurring from year to year in the confined aquifer except in response to changes in irrigation demand caused by variations in annual rainfall. Depletion of the groundwater resources is not considered to be a problem. There is no transport of salt out of the system, because of groundwater flow towards the permanent cones of depression in both aquifers.

The main problem facing water users is an inevitable salinity increase, caused by leakage of relatively saline water from the unconfined

aquifer, recirculation of salt from irrigation water and lateral inflow of saline groundwater from adjacent areas. Downward leakage is probably most significant in the short term near irrigation wells, because of drawdown effects and the almost universal uncemented well construction. The effects will be most noticeable in the south, where areas of high salinity occur in the unconfined aquifer.

Using a model which assumes perfect mixing, the confined aquifer salinity is estimated to be increasing at an approximate average annual rate of 65 mg/l. Much greater rates of salinity increase have been observed in practice, but problems of well construction make most sampling unreliable for quantitative assessment of aquifer salinity changes.

The groundwater system cannot support the present level of irrigation development without continued deterioration of water quality to a level which will make irrigation impossible.

Effective control of the salinity problem could most easily be achieved by a drastic reduction in the area irrigated, so that withdrawals would be smaller than river recharge. Alternatively the use of lake or Murray Bridge - Onkaparinga pipeline water for irrigation or a major artificial recharge scheme using lake or pipeline water could maintain present irrigation intensity. This could cause problems of a rising saline water table, prevented by the very overexploitation which is causing the current salinity problem.

INTRODUCTION

Investigations of the hydrogeology of the Angas-Bremer irrigation area (Fig. 1) began in 1967, in response to requests from local landholders who were concerned about falling water levels and rising water salinities. Continuing local interest and support have been a feature of the investigations.

Groundwater is the principle source of irrigation supplies, used mainly for locally grown lucerne (about 2 500 hectares), and it is also used in dry years to supplement river flood irrigation for the vineyards near

Langhorne Creek. There has been a marked increase in the area irrigated over the last 25 years (Figs. 2 and 3). This report summarises the results of work to date and presents the major conclusions. A further report giving the more detailed technical background for these conclusions is in preparation.

DESCRIPTION OF AREA

The irrigation area occupies about 200 km^2 of a southerly sloping plain, with a few northwesterly trending sand dunes, usually less than 5 metres high. It is bounded to the north by the Mount Lofty Ranges, and by Lake Alexandrina to the south (Fig. 1). To the east and west the groundwater is saline and agriculture is limited to dry farming, except where water from the lake is used for pasture irrigation.

Two rivers, the Angas and Bremer, traverse the area and discharge into Lake Alexandrina. Both flow in most winter months, and occasionally in the summer, in response to rainfall in their catc hments in the Mount Lofty Ranges. Prior to settlement the River Angas discharged into swampy floodplain areas, but later a channel was dug to allow it to flow directly into Lake Alexandrina. The Bremer River has a larger flow than the Angas and has a natural channel to the lake.

There are two small towns in the area, Langhorne Creek and Miland, each with a population of about 150.

The area has been cleared of most natural vegetation, except for some dune areas, occasional swamps, and fine stands of red gums especially near the Bremer River at Langhorne Creek.

GEOLOGY AND HYDROGEOLOGY

General

The Angas-Bremer irrigation area occupies part of the western extremity of the Murray Basin. Most of the basin is shallow (less than 300 metres) with Tertiary sediments resting on Cambrian or pre-Cambrian basement, and this is the case in the study area.

Several investigation holes have been drilled through the full sedimentary sequence to basement, which occurs at depths of 100-125 metres through most of the area, shallowing only near the northwest margin.

Stratigraphy is summarized in Table 1 with broad hydrogeological divisions and shown on Figure 4.

TABLE 1

STRATIGRAPHIC AND HYDROGEOLOGICAL SUMMARY

		Formation	Aquifer Characteristics
QUATERNARY SEQUENCE		Variable fluviatile and lacustrine clays, silts and sands with occasional gravels. Equivalent in part to Blanchetown Clay and Chowilla Sand. Modern aeolian sands and floodplain silts with dated wood fragments overlie the sequence. 10-35 m thick, typically red-brown and mottled.	Forms unconfined (sometimes slightly confined) aquifer in most of area. Low, but variable transmissivities and extremely variable salinities (1,000-30,000+ mg/l) characteristic. Good hydraulic separation from underlying aquifer system only in northern part of area. Little development has occurred because of high salinities and low well yields.
	PLIOCENE	Sands and clays of Parilla Sand, with occasional interfingering of shelly Norwest Bend Formation occur in most of area. 0-5 m thick, pale yellow brown.	Form aquifer which may be connected with either overlying unconfined or underlying confined aquifers, or both. Reputed to be more saline than underlying aquifer.
TERTIARY SEQUENCE	EOCENE-MIOCENE	Sequence dominated by richly fossiliferous Limestones with sandy and marly interbeds of variable thickness. Mannum and Ettrick Formations distinguishable on palaeontological grounds only. Carbonaceous clays and greensands towards base help identify Buccleuch beds.	Confined aquifer from which virtually all groundwater used locally is extracted. Salinities range from 1500 mg/l near recharge zone to more than 10,000 mg/l in the east and west, controlling the location of the irrigation area. Large well yields, up to 500 $m^3 day^{-1}$, are common.
CAMBRIAN BASEMENT		Schists, phyllites and greywackes of the Kanmantoo Group.	Poor aquifer with generally low permeabilities and high salinities in the adjacent Mount Lofty Ranges.

CLIMATE

The area has a mediterranean climate with hot, dry summers and cool, moist winters. Rainfall occurs mainly in the months April to October (Table 2), with erratic storms contributing most of the remainder. The total rainfall is low (about 400 mm) as the area lies in the rain shadow of the Mount Lofty Ranges. The catchments of the Angas and Bremer rivers have somewhat higher rainfall, particularly the Mount Barker Creek catchment which has annual average precipitation of 750 mm.

So that estimates of lake evaporation can be made over several years, an evaporimeter (Class 'A' pan) has been in operation at Milang, near the lake shore (Table 3). Average monthly rates of potential evaporation derived by Holmes and Watson, 1967 from work in an irrigated area near Murray Bridge are more appropriate. Figure 5 shows rainfall for Langhorne Creek P.O. and potential evapotranspiration based on this latter approach. There is a total precipitation surplus of 30 mm from May to July. This is most unlikely to be greater than the soil moisture deficit at the end of the summer, which has been estimated to be about 150 mm by Professor J.W. Holmes (Flinders University of South Australia).

Recharge by rainfall is only likely in unusually wet winters of where localized runoff concentrates water for infiltration. High groundwater salinities suggest that these processes are unlikely to contribute significantly to the groundwater resources.

SURFACE WATER RESOURCES

1. Lake Alexandrina

The Lake forms the southern boundary to the area. It

TABLE 2

AVERAGE MONTHLY AND ANNUAL RAINFALL

Station	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
Langhorne Creek	73	17	20	19	29	41	42	40	40	37	32	27	24	368
Milang	96	18	19	18	33	43	48	47	43	38	34	24	19	384
Strath-albyn	113	21	22	24	40	56	59	64	60	58	44	29	24	496

(Data from Commonwealth Bureau of Meteorology)

TABLE 3

AVERAGE MONTHLY AND ANNUAL PAN EVAPORATION AT MILANG

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
174	137	114	57	33	27	29	57	97	118	140	160	1143

is a permanent body of water, fed by the River Murray, with a large surface area, small depth (less than 5 metres) and an average salinity of 300-400 mg/l and a salinity range of 100 to 500 mg/l T.D.S. from July 1974 to December 1977.

Since the construction of the Goolwa barrages in the 1930's Lake Alexandrina has been a freshwater impoundment, with pond level maintained approximately 0.75 metres above sea level at Goolwa. Prior to the construction of River Murray locks the lake was usually fresh to brackish, and its water level only fell in unusually dry periods (information from local farmers).

2. Bremer and Angas Rivers

Two ephemeral rivers cross the area, flowing from their catchments in the Mount Lofty Ranges to discharge into Lake Alexandrina.

Both have very small baseflows, which pass underground near the edge of the Murray Basin. They flow irregularly for most of the winter months reaching the lake only occasionally. Short duration floods (a few days at most) occur at any time of the year, but their intensity and frequency of flooding is reported by local residents to have decreased markedly over the last 40 years.

The Bremer has the larger and wetter catchment with correspondingly larger flows, longer flood peaks and lower water salinities. Neither river has water salinities below 1 000 mg/l except during short periods of high flow, and salinities in excess of 3 000 mg/l can occur at times of low flow.

Several towns and industries contribute to pollution in the Bremer River (Deland, 1976). The Angas is certainly much less polluted, although data is scarce.

Both rivers are sources of groundwater recharge. They commonly flow only as far as the approximate edge of the Murray Basin, all water diappearing in short distances downstream except during floods.

The salinities of the rivers have been measured at gauging sites, to correlate water quality with flow. This will be reported in detail with future work by the Water REsources Branch of the Engineering and Water Supply Department.

Mosquito Creek is a distributary of the Bremer River, flowing only when the river floods.

GROUNDWATER RESOURCES

General

There are two main aquifer systems in the area, an unconfined aquifer in the Quaternary sediments and a confined aquifer in the underlying Tertiary limetsones (Table 1 and Figure 4).

The confined aquifer is the main source of groundwater in the area, because it combines generally better quality water with high well yields when compared with the unconfined aquifer.

The unconfined aquifer

A sequence of clays, silts and sands ranging in thickness from 10 to 35 metres occurs throughout the area, and forms an unconfined aquifer in which groundwater salinities vary from 1 000 to at least 30 000 mg/l. Salinity distributions have been generalised on Figure 6. Most salinities are greater than those in the confined aquifer beneath.

Well yields are low, and withdrawals from the aquifer are small and in terms of water balance studies, negligible. Water table contours (Figs. 7 and 8) show flow towards a cone of depression, which is caused by aertical leakage into the underlying confined aquifer.

The confined aquifer

A sequence of ,ossiliferous limestones 75 to 100 metres thick, with minor sands and clays, forms the confined aquifer in the area.

Salinity in the aquifer ranges from 1 500 to 3 500 mg/l near the rivers, but increases to the west and east, and limits the extent of the irrigation area (Fig. 9).

Well yields are commonly 2 000 to 3 000 kl/day. Potentiometric contours (Figs. 10 and 11) show flow towards a cone of depression caused by the withdrawal of water for irrigation. This cone is now a permanent feature and never fully recovers.

Fig. 12 shows hydrographs of water levels in selected observation wells in the irrigation area.

Groundwater recharge and discharge

There is an intimate relationship between the rivers, Lake Alexandrina and the two aquifer systems. This relationship has been changed by the irrigation practices from one where the confined aquifer discharged into the unconfined aquifer and into the lake, to one where the unconfined aquifer and the lake feed into the confined aquifer.

Figure 13 shows diagrammatically the pre-irrigation and modern groundwater systems.

Flow net analysis using parameters determined for the confined aquifer was used to apportion the lateral flow into the irrigation area (Table 4). The amount of water being extracted for irrigation of lucerne has been estimated at 25 000 Ml per year from considerations of the area under irrigation and the transpiration rate of 1 042 mm per year for lucerne with no water stress (Holmes and Watson, 1969).

TABLE 4

COMPONENTS OF LATERAL FLOW IN CONFINED AQUIFER

Area from which flow is derived	Annual flow (Ml)	Percentage of total
Northern Margin Recharge Zone	5 600	45
Aquifer Beneath Lake Alexandra	3 000	25
Eastern and Western Saline Zones	3 400	30
TOTAL	12 000	100

The water balance for the confined aquifer can thus be written in the form:

INFLOW = OUTFLOW

12 000 + 13 000 = 25 000 (megalitres)

Lateral Vertical Irrigation

Flow Leakage Withdrawals

It is stressed that all the components of the water budget have been estimated from limited data, and are not particularly reliable. They suggest that vertical leakage from the unconfined aquifer is of comparable size to the lateral inflow to the irrigation area, that recharge to the unconfined aquifer deserves more study and that withdrawals should be measured if the water balance data are to be improved.

CONFINED AQUIFER SALINITY CHANGES

There is an inflow of groundwater into the aquifer in the irrigation area, partly by lateral flow within the confined aquifer and partly by vertical leakage from the unconfined aquifer. The potentiometric surfaces for both aquifers show that the cones of depression rarely, if ever, recover to allow southerly flow towards the lake in the south of the area. The excess irrigation water is not intercepted by any form of man-made drainage system and must then infiltrate to the unconfined aquifer, returning eventually to the confined aquifer.

Figure 14 shows diagrammatically the salt flow in the system. The only salt removal from the area is achieved by the removal of agricultural produce. This is a very small component, and can be ignored.

Therefore there must be a net inflow of salt to the confined aquifer in the irrigation area, and this can be estimated from present data. Recirculated salt from irrigation does not represent a net gain or loss in the long term and need not be considered in this discussion if it is assumed that salinities measured recently in the unconfined aquifer have not yet been affected significantly by recirculating irrigation water.

Lateral salt flow within confined aquifer

Potentiometric contours are available for March-April and September for the past several years. A conservative approximation of salt inflow can be obtained by assuming that each plan is representative of six months of the year.

By application of Darcy's Law the volume of groundwater flow into the irrigation area can be calculated on the basis of known transmissivities and hydraulic gradients.

The annual salt inflow on this basis is 30 000 tonnes per year (to 1 significant figure). The groundwater beneath the lake is probably derived from the Angas and Bremer rivers, and probably still has salinities in the range 1 500 - 3 000 mg/l, which are likely to decrease with time because of the input of better quality lake water.

Leakage from the unconfined aquifer

From the water balance, vertical leakage has been estimated at 13 000 Ml per year and using a value of 7 500 mg/l to represent the "average" salinity of the unconfined aquifer in the leakage zone, about 100 000 tonnes/year is estimated to be leaking into the confined aquifer in the irrigation area.

This estimate assumes that the salinities measured in the unconfined aquifer are at present largely independent of the salt inflow from recirculating irrigation water. This is considered to be a reasonable basis for calcaultion, as it is almost certainly a much smaller error that that incurred estimating bulk salinity of suach a heterogeneous aquifer.

Well construction leakage

The salt influx from the upper aquifer via poorly constructed wells (Fig. 15) is difficult to estimate. Most leakage will occur when pumps are being operated, under the influence of drawdown in the well. It is considered to be a minor problem when considering the salt balance of the confined aquifer, because

(a) The low hydraulic conductivity of the upper aquifer must limit horizontal flow towards a well, and

(b) salt leaked down under the influence of pumping is likely to be removed immediately from the confined aquifer by the pumping process.

This is not the same as stating that leakage past poorly constructed wells is not serious, because salinity of the water produced at the well head may be increased substantially. This affects crops, and gives an exaggerated impression to the landowner of the rate at which regional groundwater salinities are increasing.

Discussion

In the long term the water in the unconfined aquifer will be displaced to varying extents by recirculating irrigation water which will itself ultimately reach the confined system again.

The long-term salt inflow is then the sum of 100 000 tonnes/year (leakage) and 30 000 tonnes/year (lateral flow) i.e. 130 000 tonnes/year, an increase of 65 mg/l per year in a perfectly mixed aquifer*. This estimate is probably of the correct order of magnitude, but should not be used for quantitative work on rates of salinity increase.

The salinity increase estimates made on the assumption of perfect mixing in the aquifer are known to be much smaller than the apparent increases that are measured by samples taken from some production wells in the area. Most wells take their water from the upper 10-20 metres of the aquifer, and will thus show a salinity increase biased by the salt influx from vertical leakage and that caused by faulty well construction. Wells near the margins of the zone of good quality water may show the effects of lateral migration of saline water. Wells penetrating limited zones of poor quality water, such as the one between the rivers, may improve their water quality in the short term as the poor quality water is displaced by better.

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* Volume of water in the confined aquifer in irrigation area
= 80 km^2 (area) x 75 m (thickness) x 0.3 (porosity)
= $2 \times 10^{12} m^3$

The variation in water salinity and lithology in the unconfined aquifer will result in wide variations in individual well salinity increases and some wells will show short to medium term decreases which will eventually reserve.

The predicted overall rate of increase of salinity with time gives the area a limited life under present extraction conditions.

POLLUTION POTENTIAL

The obvious sources of groundwater pollution in the area are dairy effluent, domestic effluent, winery wastes and pollutants carried into the area by the Bremer and Angas Rivers.

No systematic study has been made, however it is believed that underground waste disposal is rarely practised. A school at Milang has a drainage well tapping the confined aquifer, but this is the only example known.

One of the main local sources of pollution, the Bleasdale winery at Langhorne Creek, discharges its wastes into a usually dry branch of the Bremer River, and later the solids are spread amongst the vines. This is not a major problem as the unconfined aquifer will receive the liquid wastes, and the area is one where downward leakage and withdrawals are both negligible.

Dairy wastes may affect the unconfined aquifer slightly in places, however its water quality is naturally low and rates of water movement slow, and the water resources of the confined aquifer are unlikely to be significantly affected.

The main problem in the area is the increasing pollution load of the Bremer River (Deland, 1976). The river is a major source of natural recharge to both aquifers, and its quality has been seriously degraded by acidic mine waters from an abandoned pyrite quarry. The pollution is unlikely to have much effect on the groundwater in either aquifer in the short term (less than 10 years) but may well affect water supply wells in future years if the problem is not checked. Other industries in the Bremer catchment also have a considerable local effect on river water quality.

Very little data is available for the River Angas. Data available indicates that the pollution load is much lighter than that of the Bremer.

MANAGEMENT OF THE GROUNDWATER RESOURCES

1. General

There is at present no plan for long-term management of the area's water resources. Some control is being exercised upon drilling methods and Bremer River water quality through the Water Resources Act.

2. Well Permit Application

All permit applications for new wells are approved, and endorsed for a Class 2 licensed well driller if the confined aquifer is to be developed, to ensure that drillers working in the area are competent to pressure cement casing (Fig. 15). New wells are therefore properly constructed and from May, 1977 all permits have been endorsed with a condition requiring the backfilling of any existing well for which a replacement is required.

3. Problems

The immediate problem is that advice given to farmers who depend upon the groundwater for a livelihood about the long term viability of the water resource can only be pessimistic. Furthermore it has not been possible to control irrigation of greater areas of lucerne.

Another management problem is the condition of the 500-

800 wells tapping the confined aquifer. Few have cemented casing, and the remainder will fail, or perhaps have already failed unnoticed. Their rehabilitation or proper abandonment is a pressing problem particularly as indications of salinity changes from these wells may be quite misleading, as discussed earlier. Until a well survey has been carried out, little planning or action can be undertaken.

To be effective, management must overcome the salt problem, by removing salt from the groundwater system, or by preventing its inflow, or by a combination of the two.

(i) Artifical drainage could intercept saline water below the root zone, but would be extremely costly to install and maintain, and would create a disposal problem. It would not solve the main salt inflow problem caused by saline groundwater.

(ii) The use of lake or Murray Bridge - Onkaparinga pipeline water for irrigation (in planned, more concentrated areas to minimize pipelines) would overcome the serious salinity problem. However this change in regime would reduce the vertical leakage from the unconfined aquifer, and would be likely to cause a rise in the water table. This has been avoided in the past by the very over-exploitation which is causing the salinity problem.

(iii) Artificial recharge to the confined aquifer from the lake or the Murray Bridge - Onkaparinga pipeline could restore the groundwater flow through the area to discharge areas beneath the lake. This would prevent some or all salt inflow by lateral groundwater flow in the confined aquifer, reduce vertical leakage, and transport salt from the confined aquifer. To be effective in the long term the artifical recharge would need at least to balance the discrepancy between river recharge and irrigation withdrawals (i.e. about 20 000 Ml/year for the present intensity of irrigation). This could generate a rising water table problem beneath irrigated land.

(iv) Reducing the area irrigated until withdrawals were less than river recharge would redress the balance and groundwater flow through the area to the lake would again take place. To be effective this would involve a five-fold reduction in irrigation, and again water tables could rise beneath irrigated land.

CONCLUSIONS

The broad investigations by the Department of Mines into the groundwater resources of the area are now complete and it is considered that the next stage will involve co-ordinated studies by several departments to formulate a management policy, and give local landowners a clear indication of their futures as irrigators.

The present level of irrigation cannot be sustained without further deterioration in water quality which will force many farmers to give up irrigation, unless a major programme of artificial recharge to the confined aquifer is undertaken or an alternative water supply provided. Each of these might in turn create a rising water table problem beneath irrigated lands necessitating further capital investment in drainage and saline water disposal schemes.

The problems facing the irrigators are imminent, and the longer the time taken to make and implement management decisions, the fewer the options that will be available as water salinities continue to increase.

ACKNOWLEDGEMENTS

The local farmers, especially Ken Turvey, Jack MacLean, Len Potts, the late David potts and other members of the Angas-Bremer Irrigators Association deserve thanks for their help and support.

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GEOLOGIST

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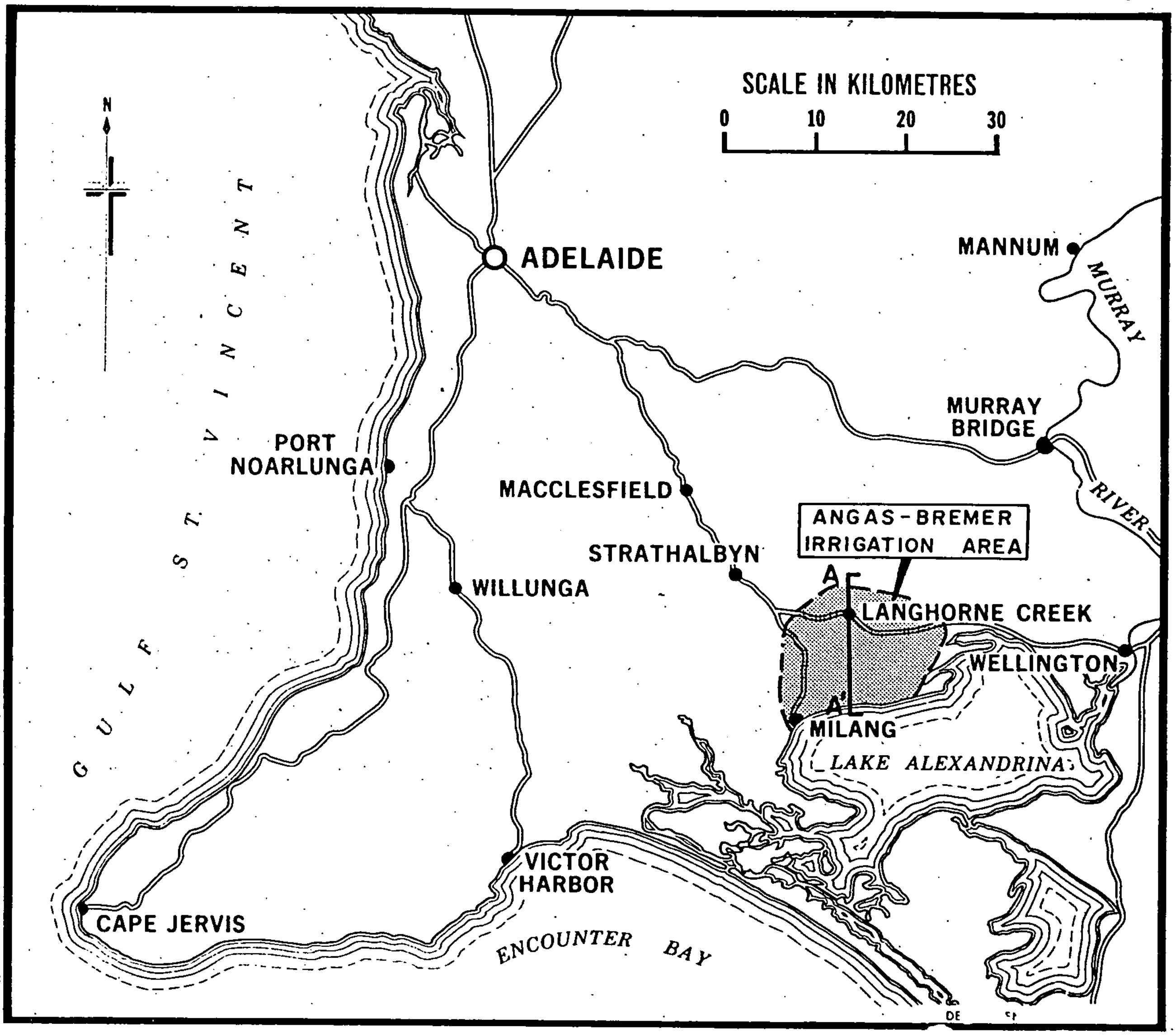

FIG. 1

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Drn. / Ckd.	LOCALITY PLAN	Drg. No. S12542

500—6.76 G6584 O

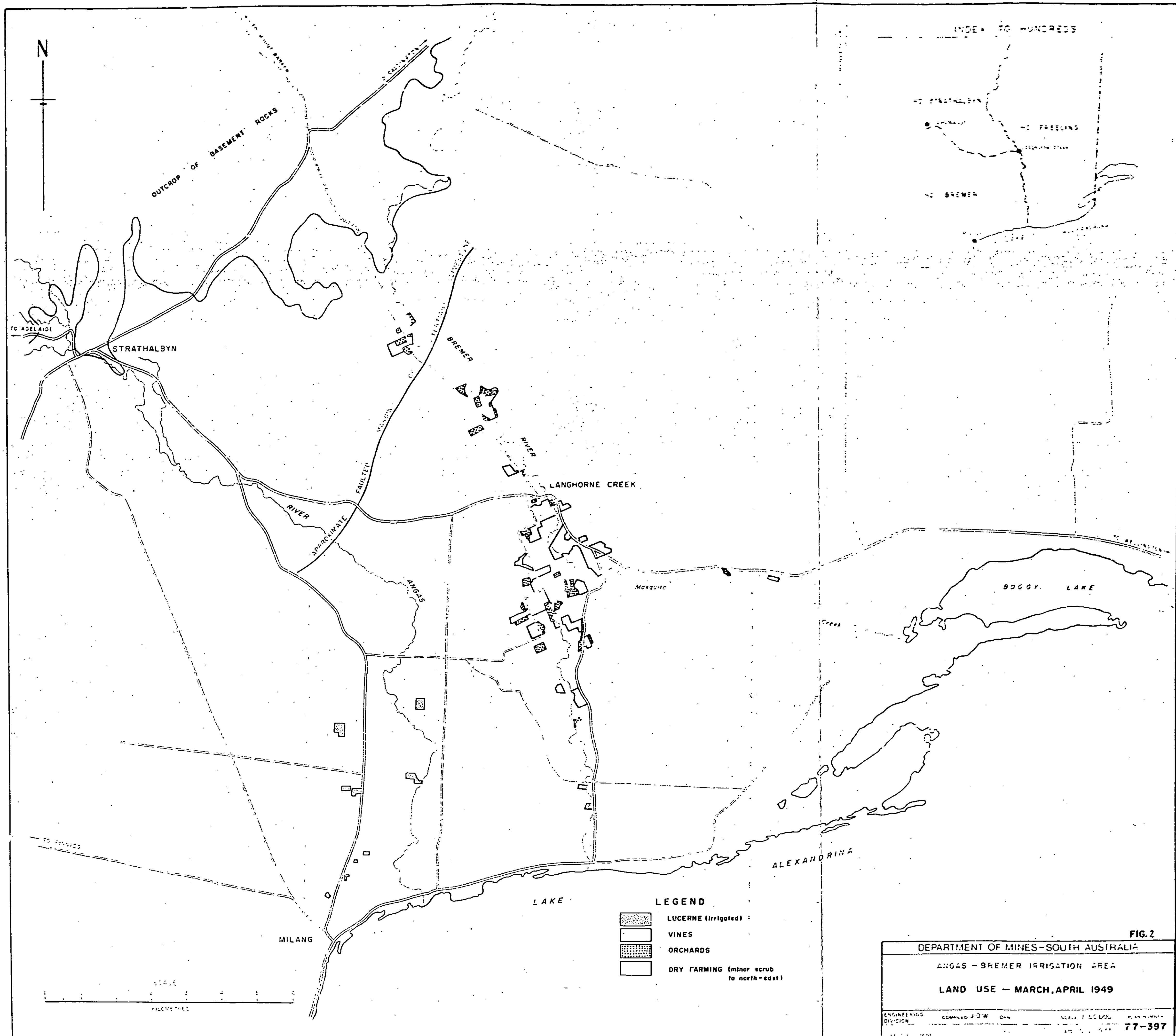

FIG. 2

DEPARTMENT OF MINES-SOUTH AUSTRALIA

ANGAS - BREMER IRRIGATION AREA

LAND USE — MARCH, APRIL 1949

77-397

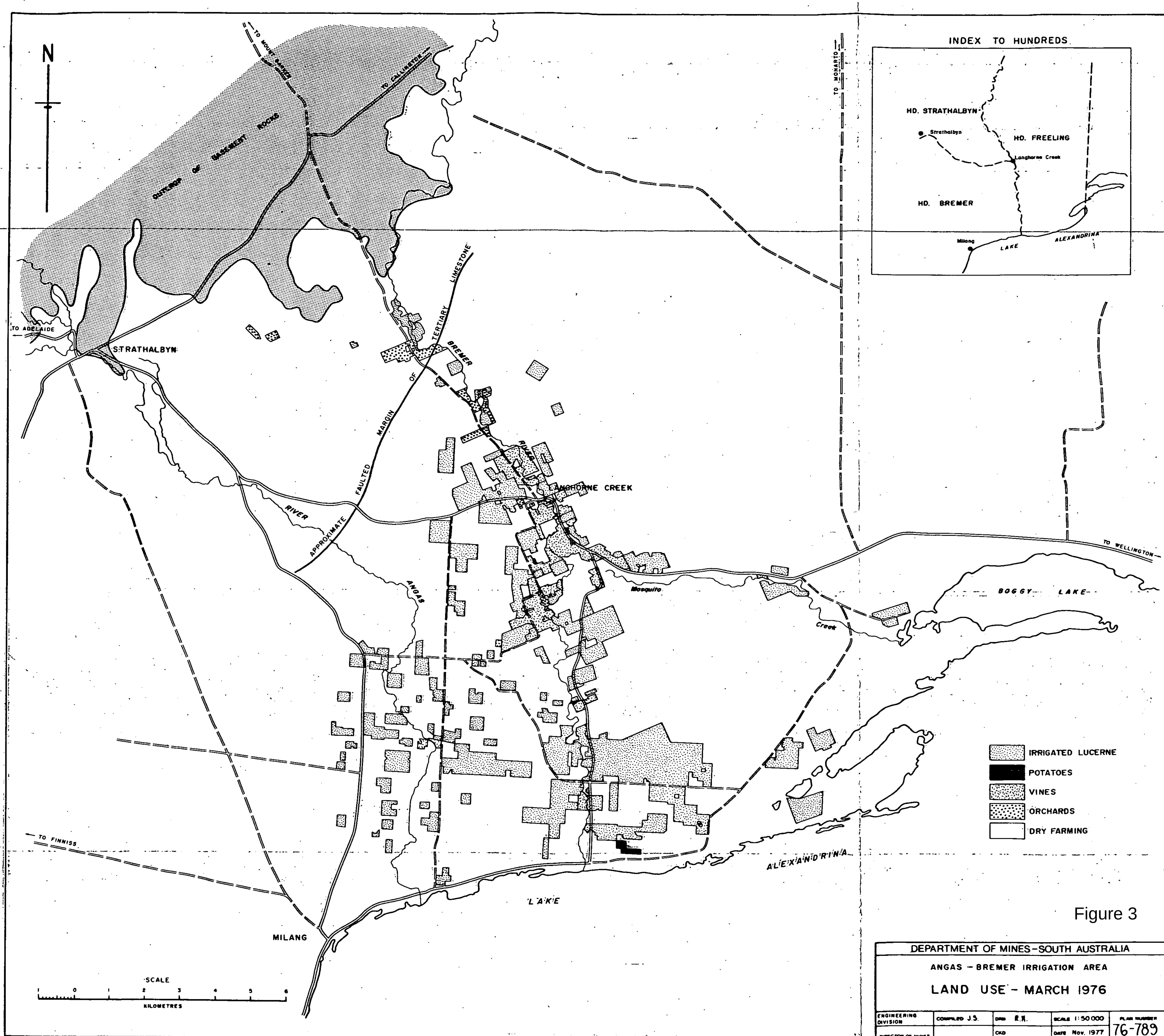

Figure 3

DEPARTMENT OF MINES–SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA

LAND USE – MARCH 1976

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DIRECTOR OF MINES		CKD	DATE Nov. 1977	76-789

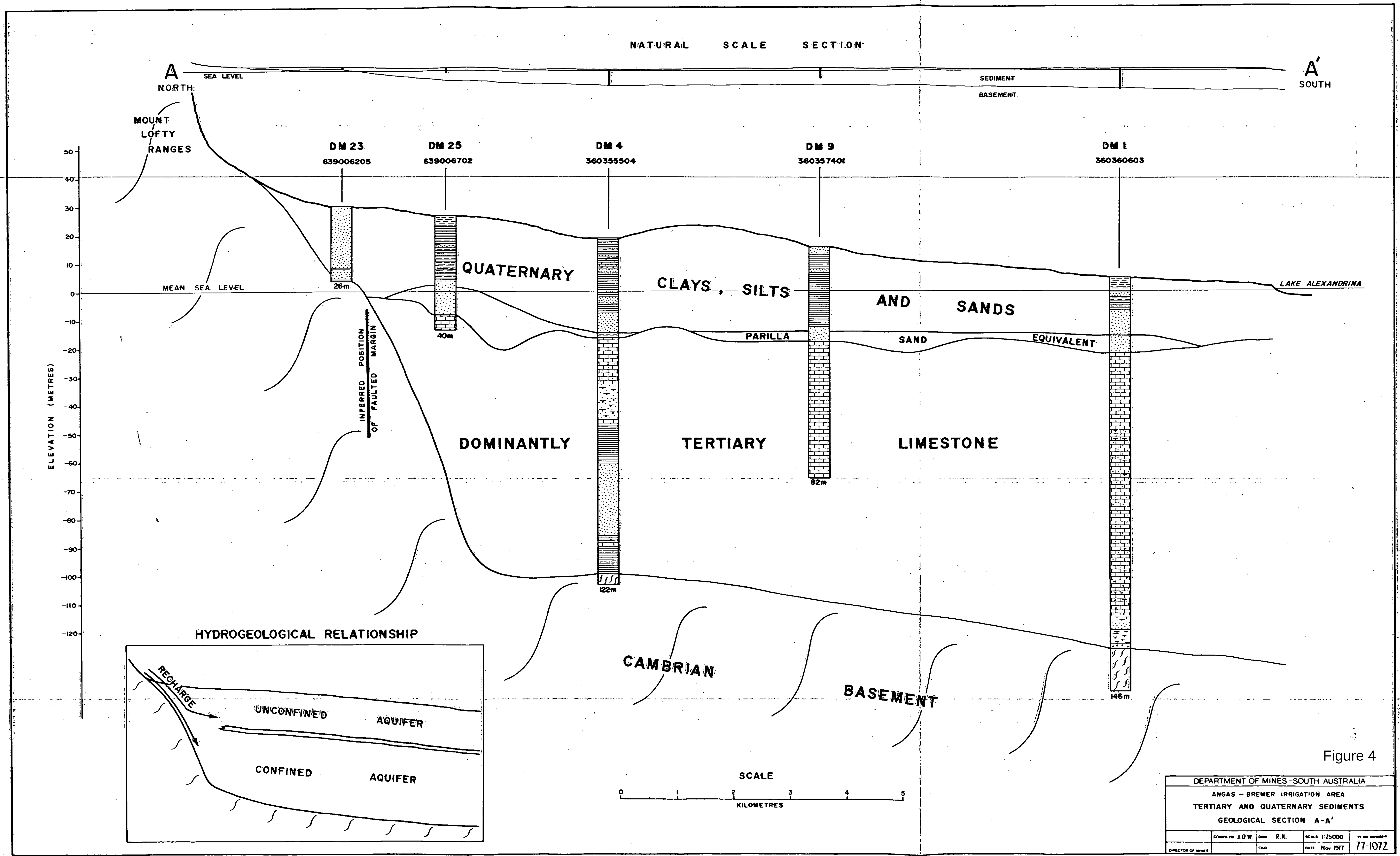

Figure 4

77-1072

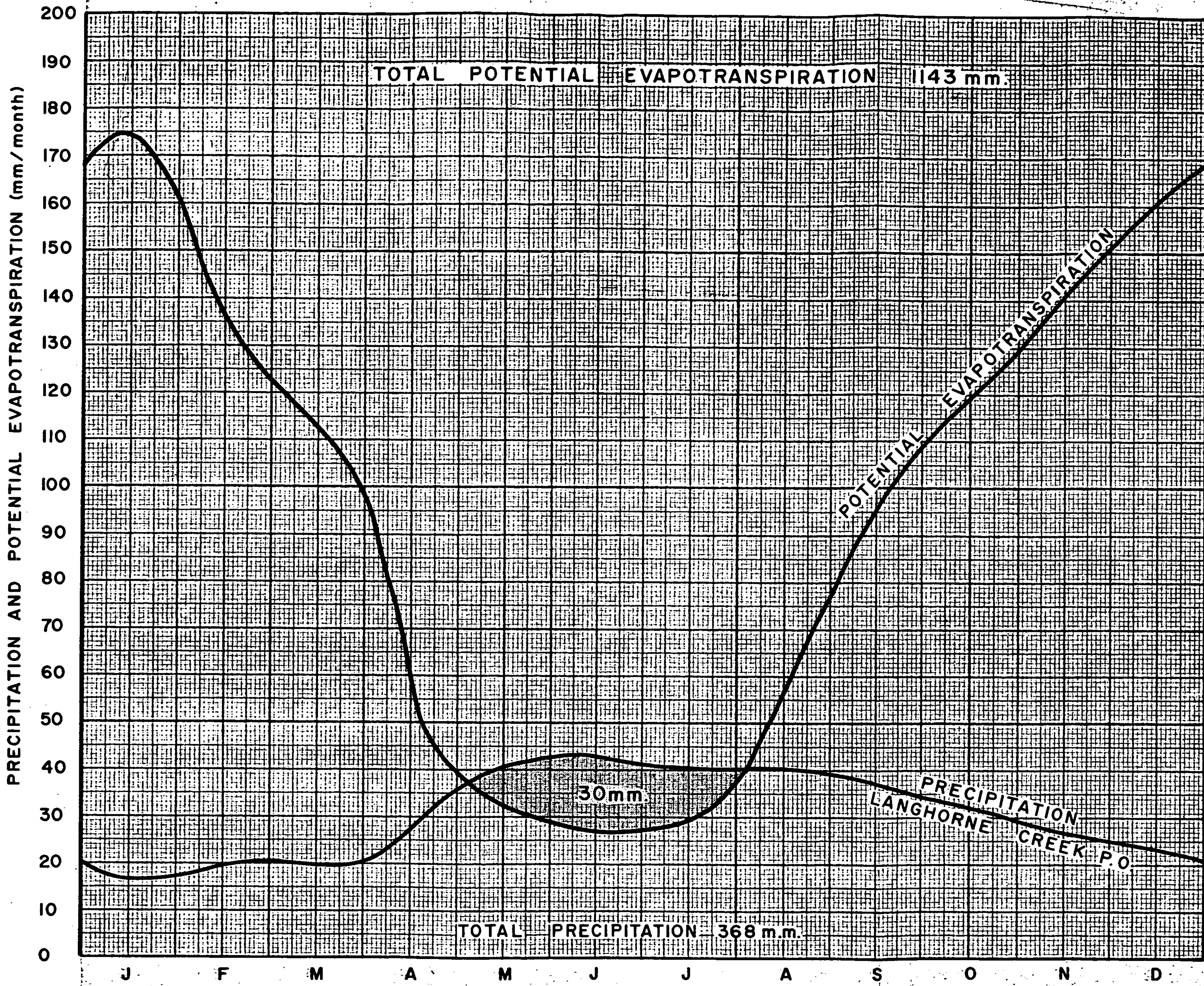

Figure 5

	DEPARTMENT OF MINES — SOUTH AUSTRALIA	Scale
Compiled J.D.W.	ANGAS - BREMER IRRIGATION AREA	Date: Nov. 1977
Drn. R.H. Ckd.	ANNUAL PRECIPITATION AND POTENTIAL EVAPOTRANSPIRATION	Drg. No. 77-1067

77-1067

DUPLICATE
77-1069

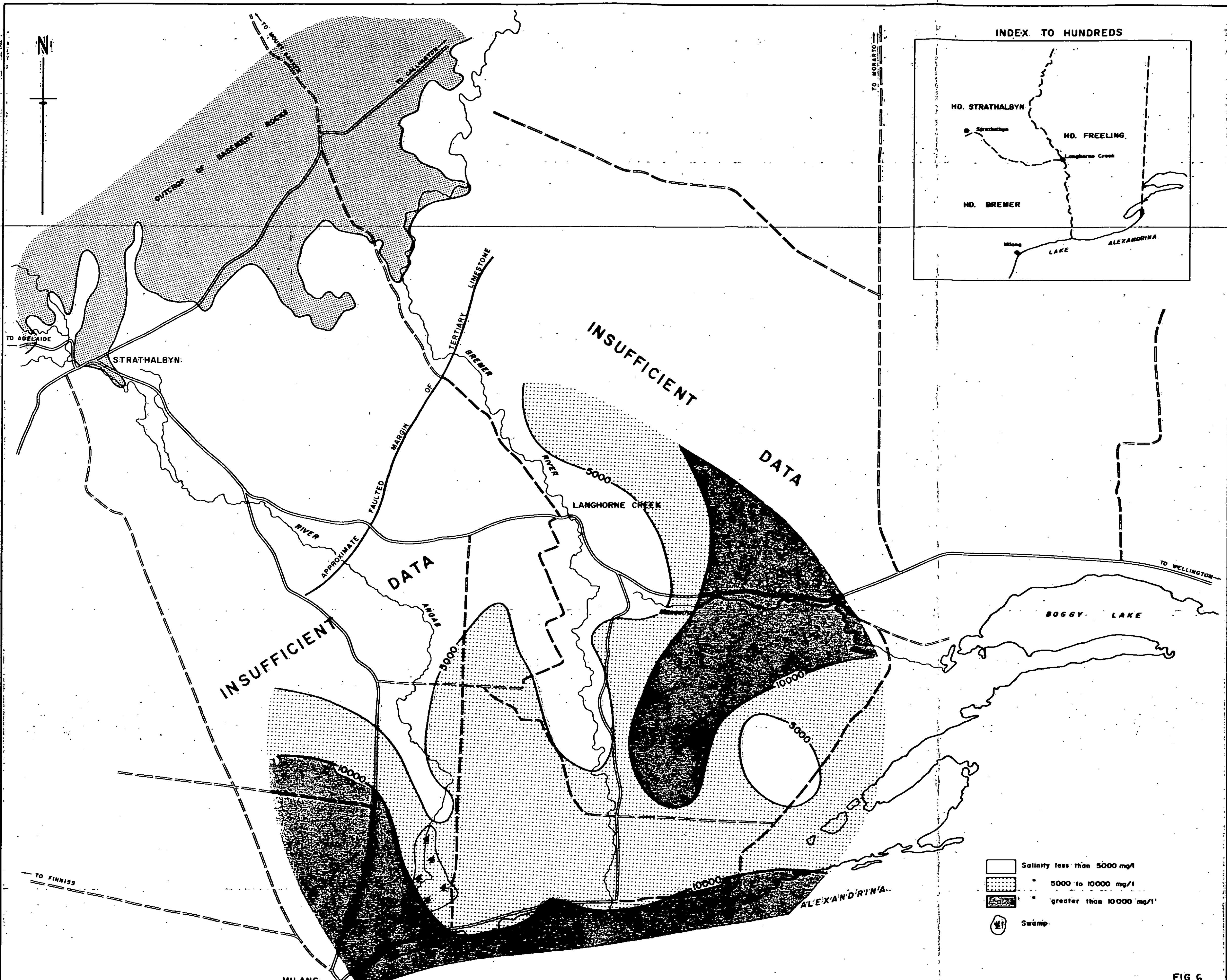

FIG. 6

DEPARTMENT OF MINES–SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA

UNCONFINED AQUIFER

APPROXIMATE SALINITY ZONES

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DIRECTOR OF MINES	CKD.	DATE Nov. 1977	

76-924

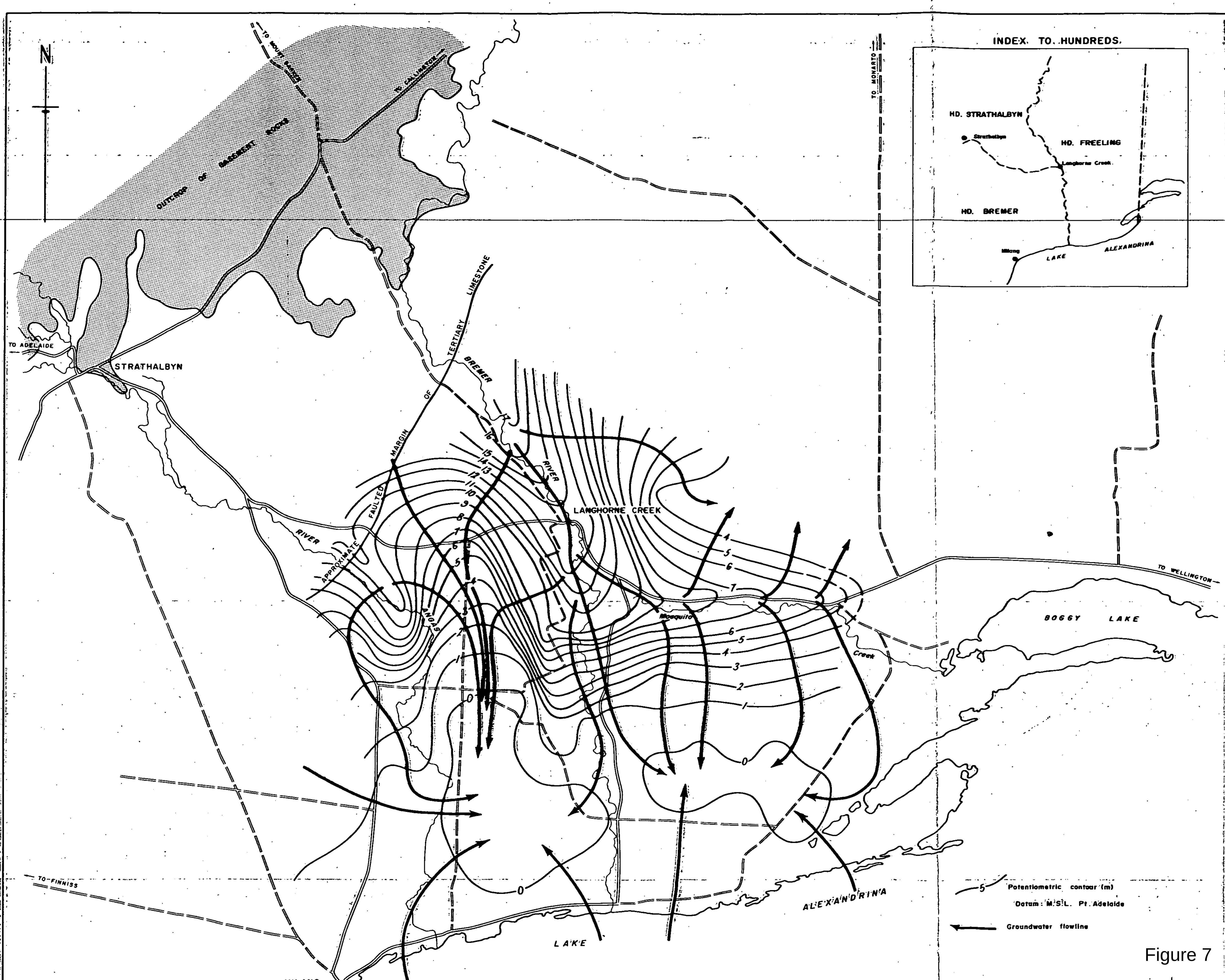

Figure 7

DEPARTMENT OF MINES - SOUTH AUSTRALIA

ANGAS - BREMER IRRIGATION AREA

UNCONFINED AQUIFER

POTENTIOMETRIC CONTOURS - AUGUST 1976

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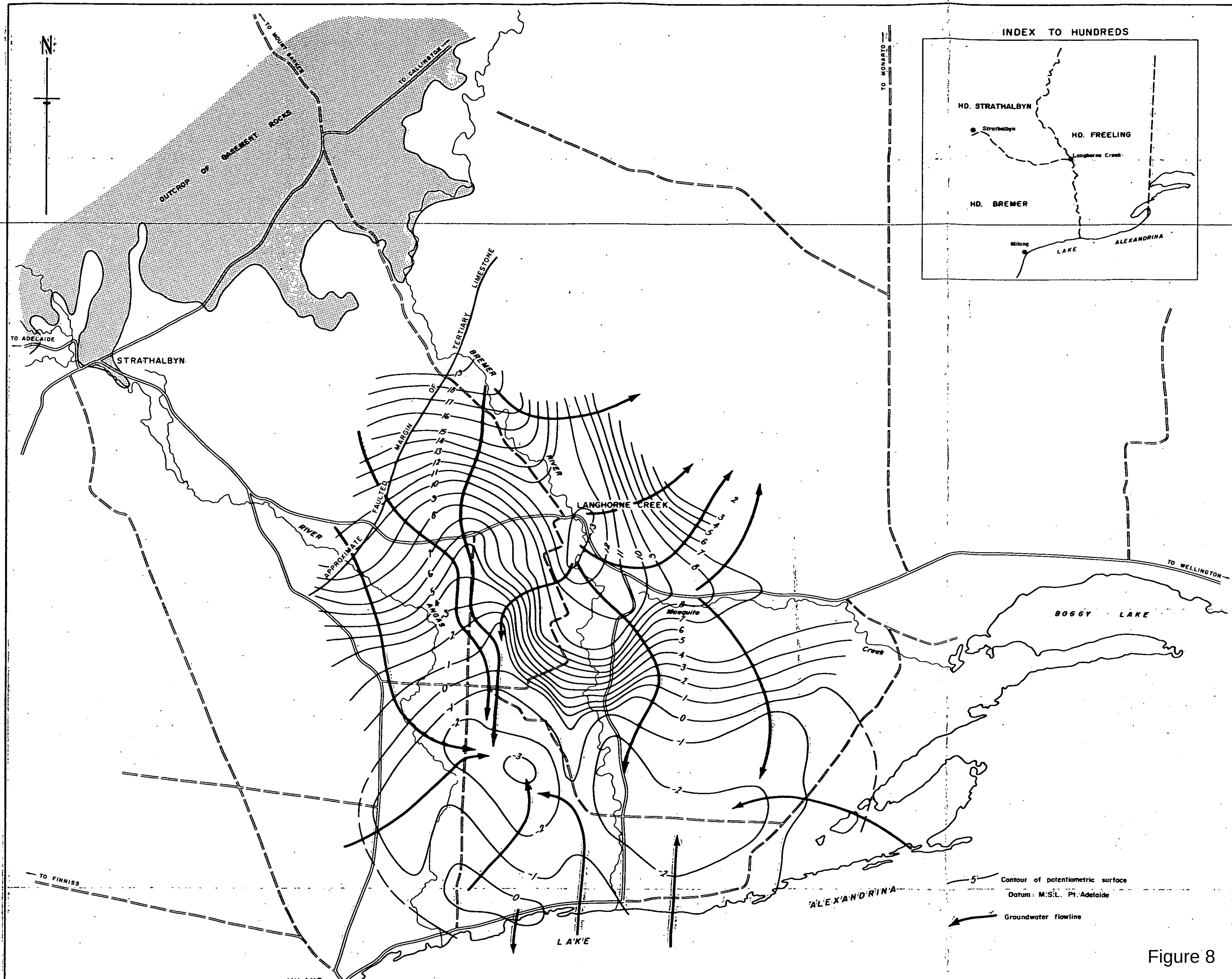

Figure 8

DEPARTMENT OF MINES–SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA
UNCONFINED AQUIFER
POTENTIOMETRIC CONTOURS
MARCH 1977

ENGINEERING DIVISION	COMPILED J.D.W.	DRN E.H.	SCALE 1:50000	PLAN NUMBER
DIRECTOR OF MINES		CKD	DATE Nov. 1977	77-1070

77-1071

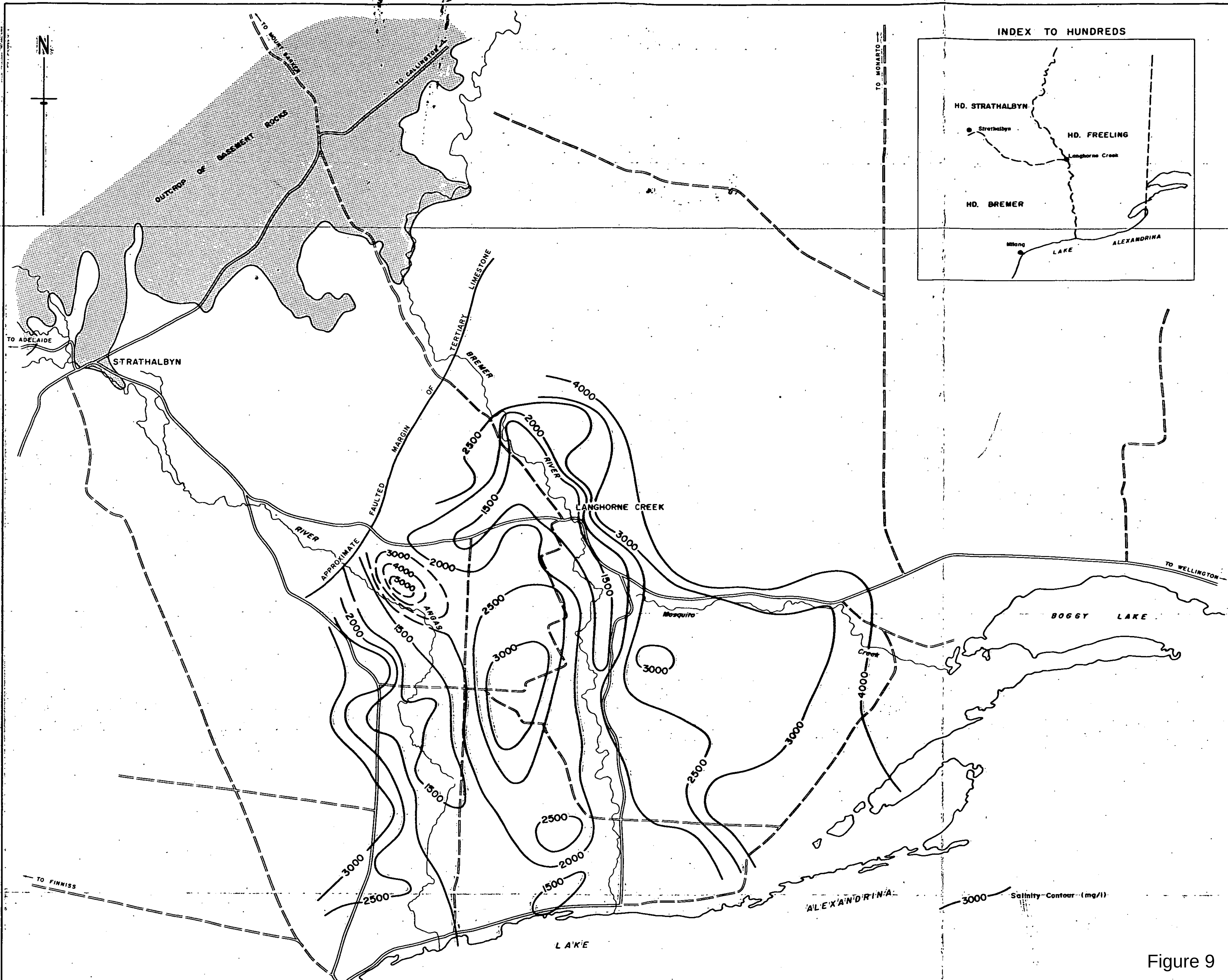

Figure 9

DEPARTMENT OF MINES–SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA
CONFINED AQUIFER
ISOHALSINES – MARCH 1974

ENGINEERING DIVISION	COMPILED A.F.W.	DRN R.N.	SCALE 1:50 000	PLAN NUMBER 77-1071
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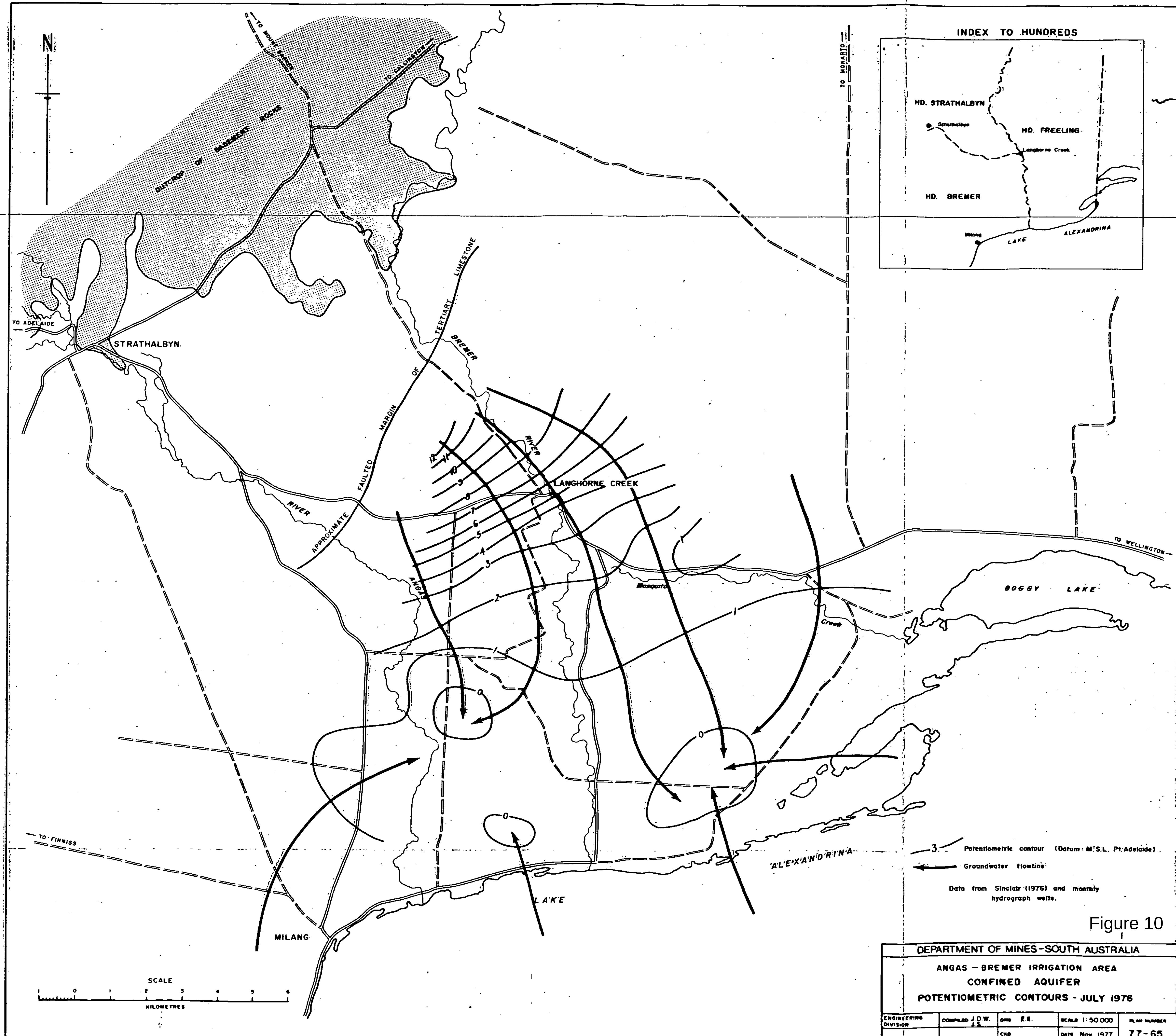


Figure 10

DEPARTMENT OF MINES-SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA
CONFINED AQUIFER
POTENTIOMETRIC CONTOURS - JULY 1976

ENGINEERING DIVISION	COMPILED J.D.W.	DRN	SCALE 1:50 000	PLAN NUMBER
DIRECTOR OF MINES		CKD	DATE Nov. 1977	77-65

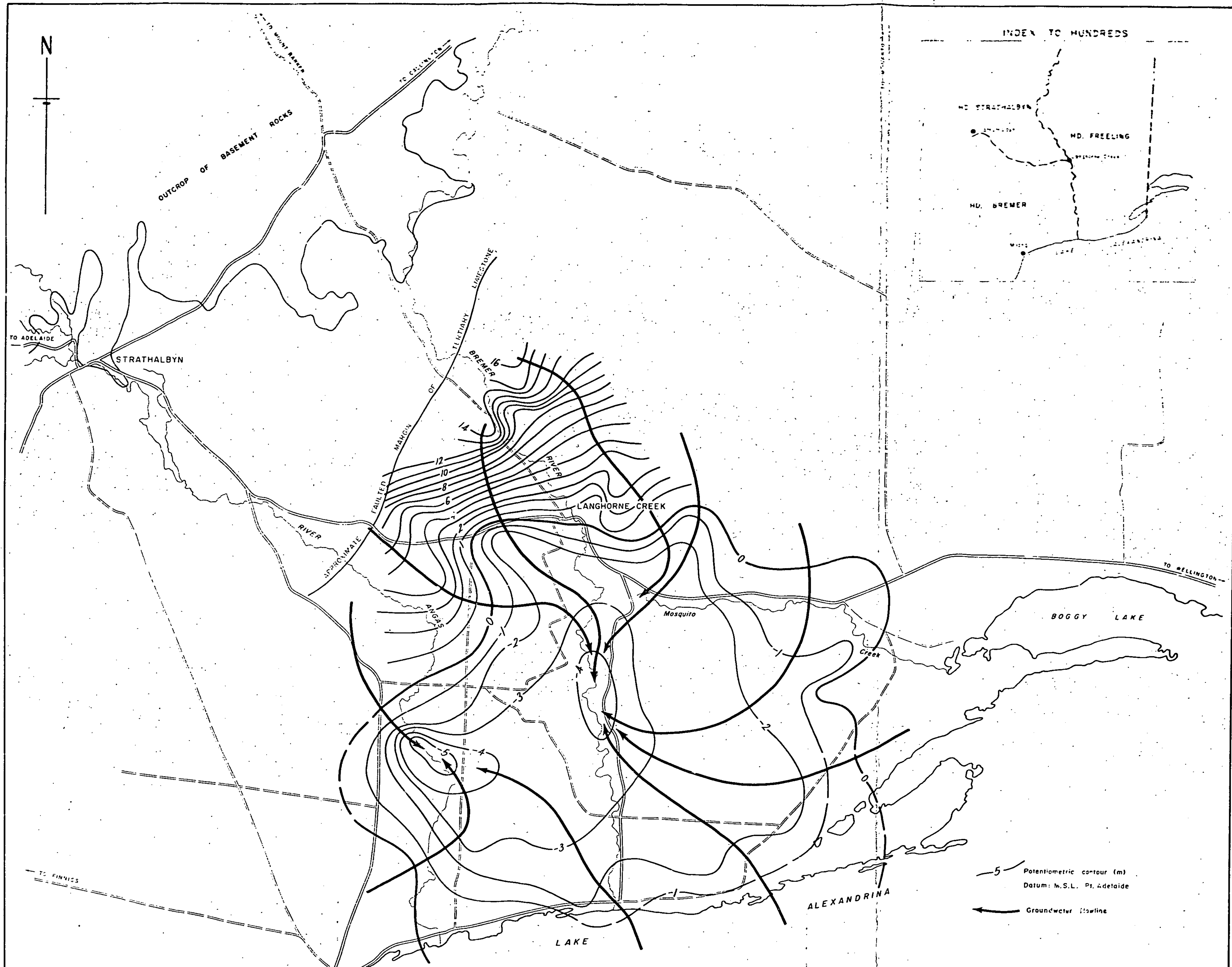


FIG.11

DEPARTMENT OF MINES-SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA
CONFINED AQUIFER
POTENTIOMETRIC CONTOURS - MARCH 1977

ENGINEERING DIVISION	COMPILED J.G.W. N.Z.G.	DRN R.H.	SCALE 1:50 000	PLAN NUMBER 77-396
DIRECTOR OF MINES		CKD	DATE Nov. 1977	

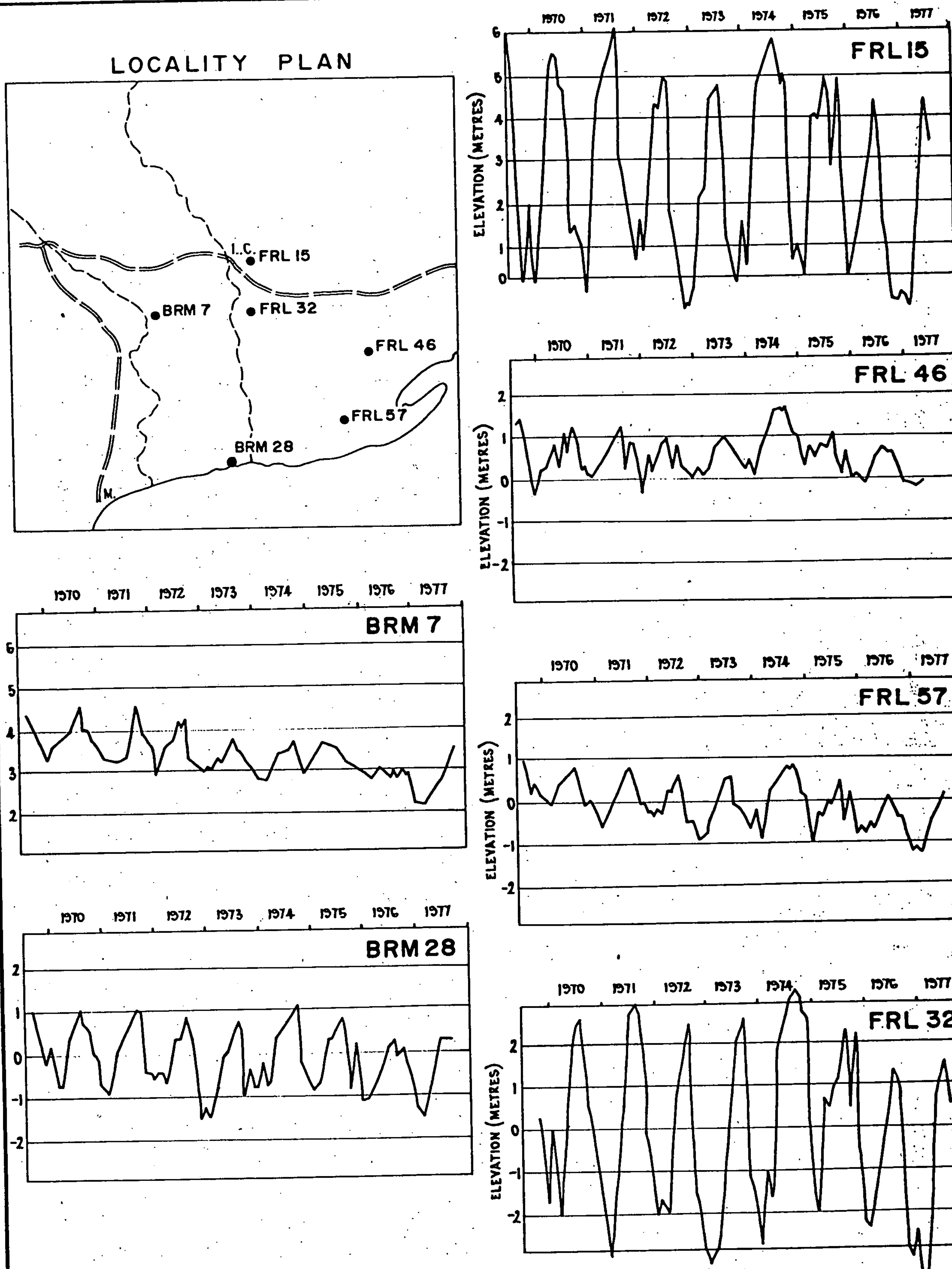
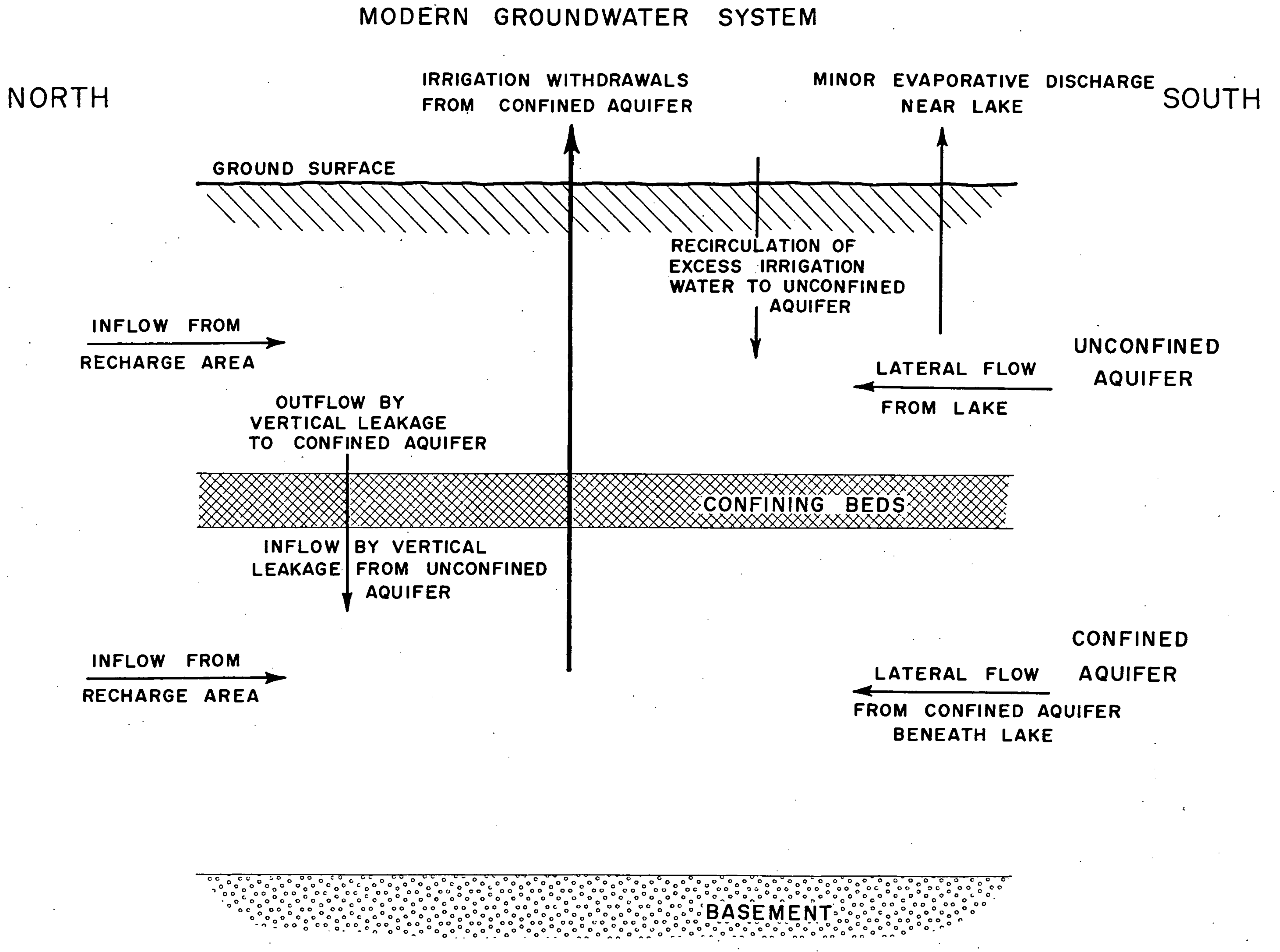


Figure 12

ENGINEERING DIVISION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	SCALE: –
COMPILED: J.D.W.	ANGAS - BREMER IRRIGATION AREA	DATE: NOV, 1977
DRN. R.H. / CKD	CONFINED AQUIFER HYDROGRAPHS	PLAN NUMBER: S13144



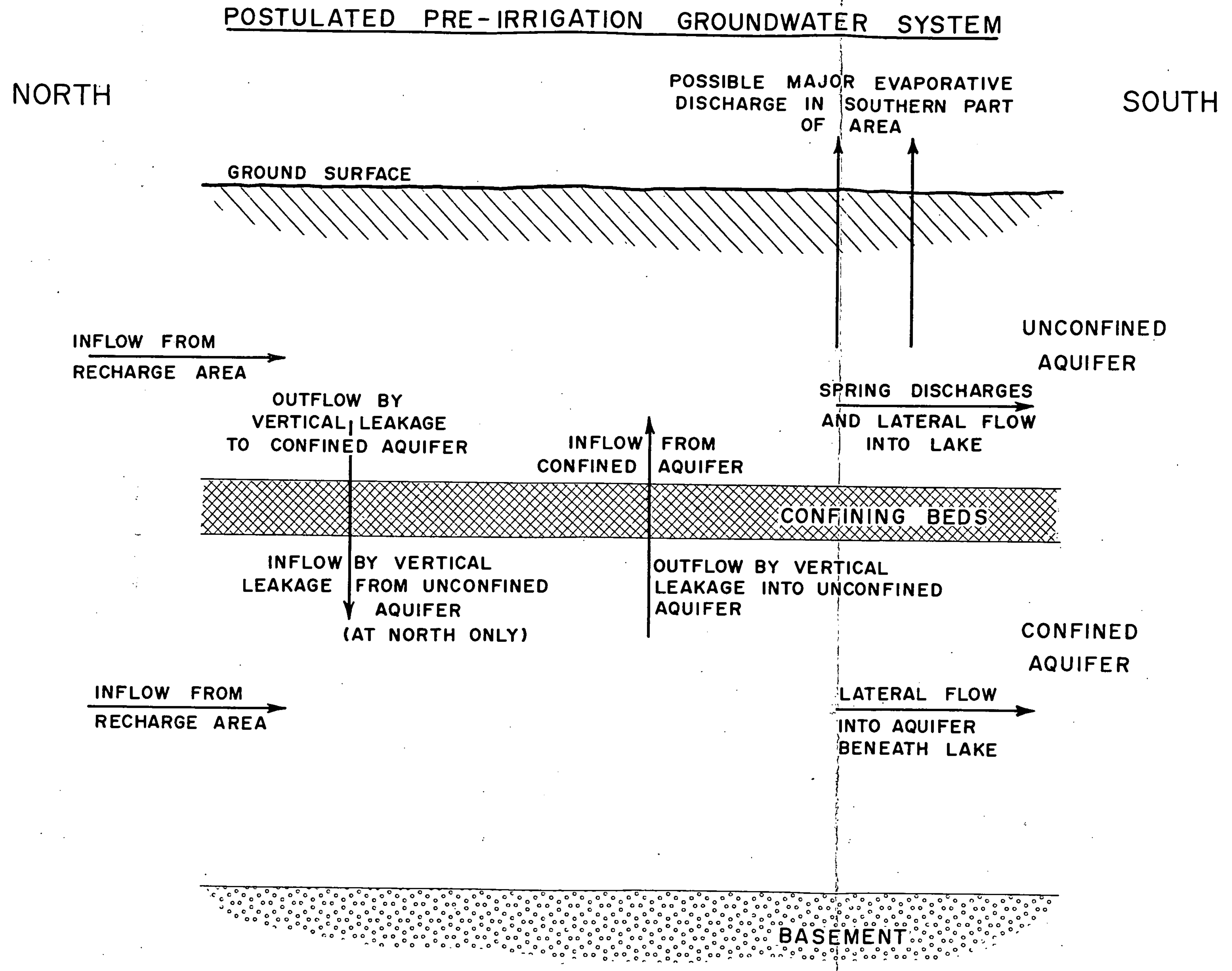


Figure 13

ENGINEERING DIVISION	DEPARTMENT OF MINES - SOUTH AUSTRALIA	SCALE: DIAGRAMMATIC
COMPILED: J.D.W.	ANGAS - BREMER IRRIGATION AREA	DATE: NOV. 1977
DRN R.H. CKD.	DIAGRAMMATIC GROUNDWATER SYSTEMS BEFORE AND AFTER THE COMMENCEMENT OF IRRIGATION	PLAN NUMBER: 77-1068

DEPARTMENT OF MINES–SOUTH AUSTRALIA

ANGAS – BREMER IRRIGATION AREA

SALT FLOW IN THE MODERN GROUNDWATER SYSTEM

COMPILED J.D.W.
DRN R.H.
CKD

SCALE DIAGRAMMATIC
DATE NOV. 1977
PLAN NUMBER: S13145

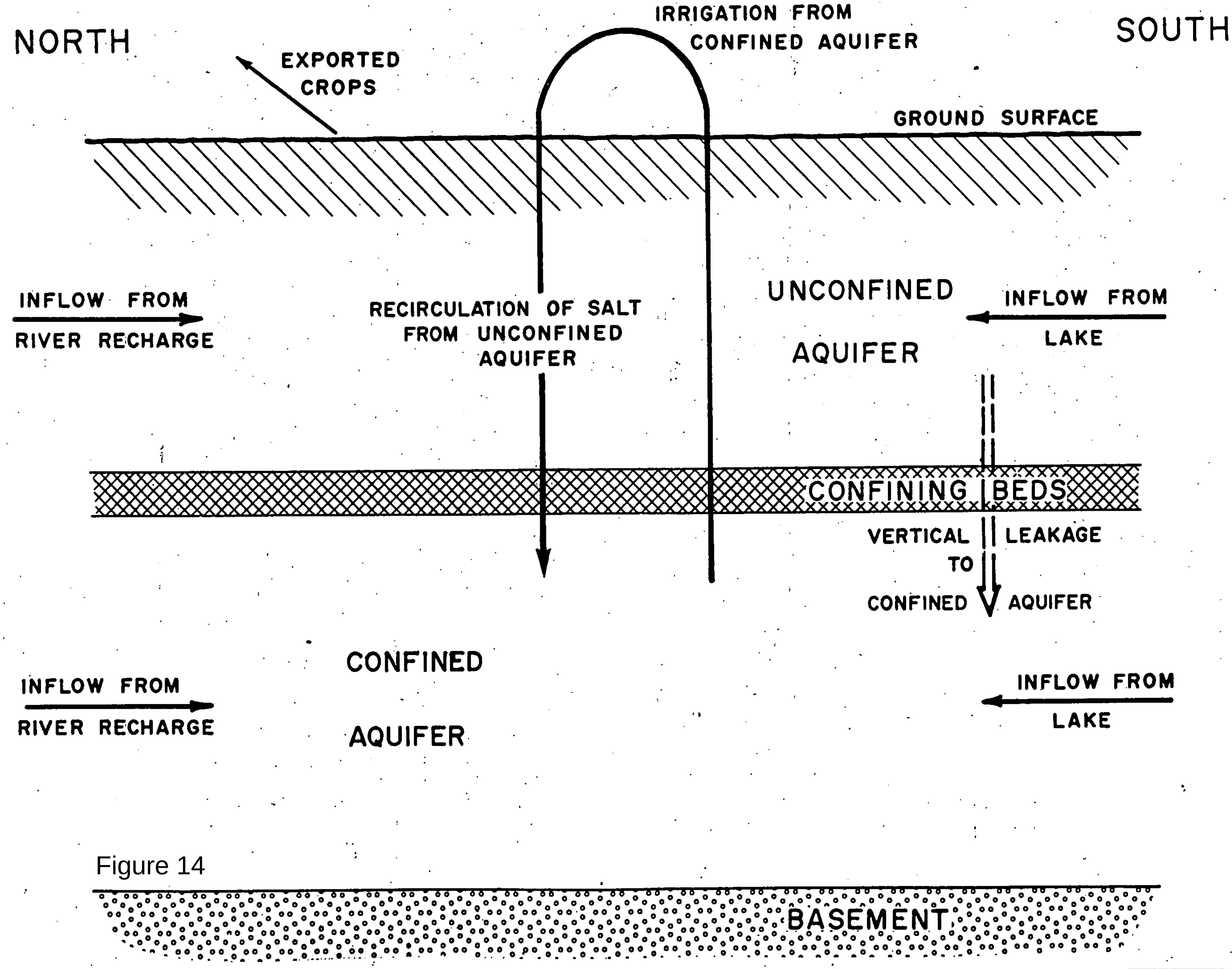
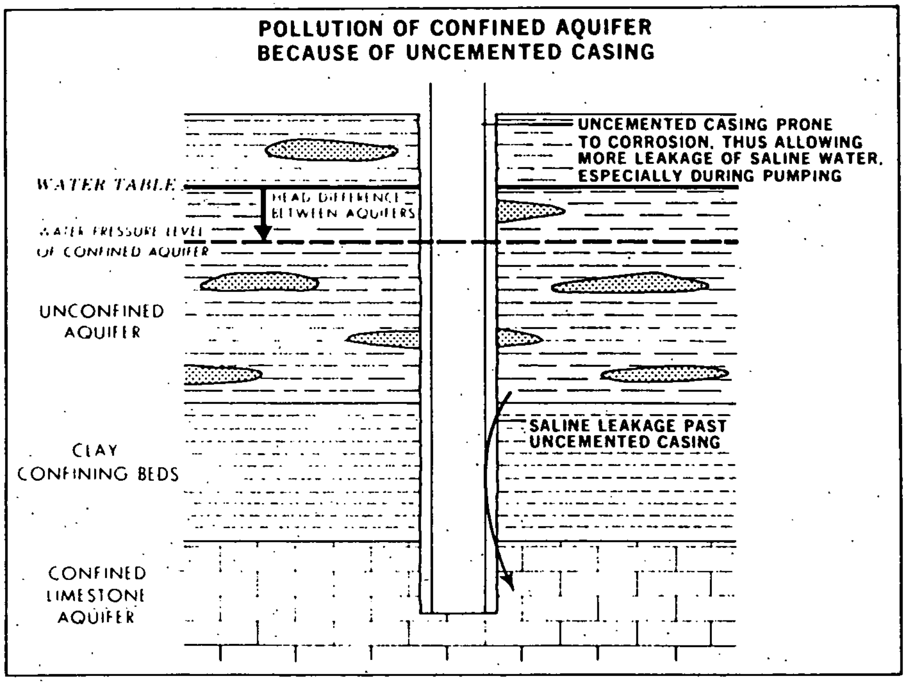


Figure 14



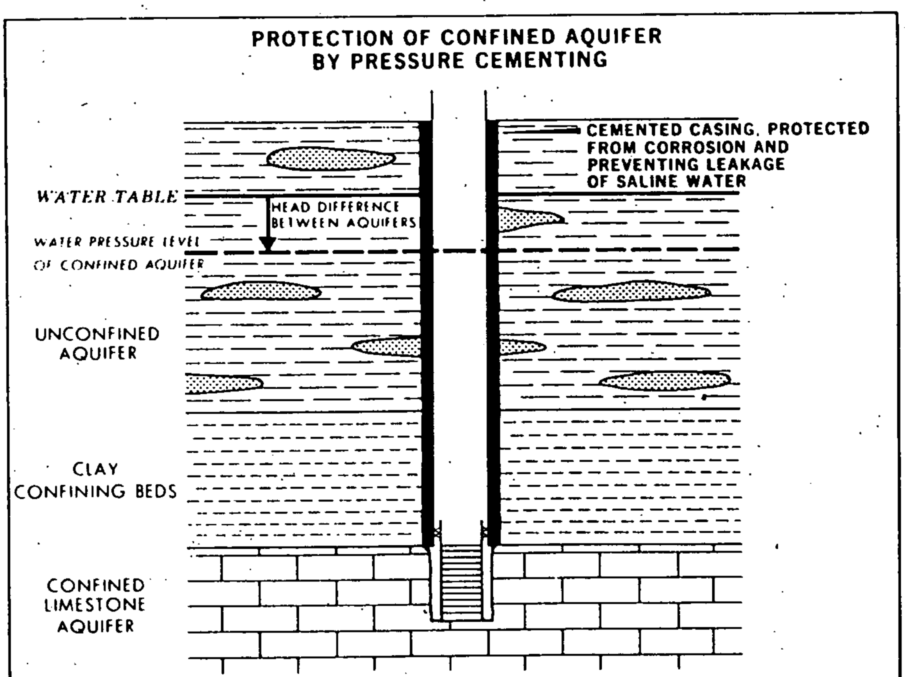


Figure 15

ENGINEERING DIVISION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	DIAGRAMMATIC
J.D.W.	ANGAS – BREMER IRRIGATION AREA	NOV. 1977
R.H.	**WELL CONSTRUCTION REQUIREMENTS AND PROBLEMS**	S13146