

AVAILABILITY OF GROUNDWATER IN THE GOLDFIELDS -
ESPERANCE REGION 1995/21

A.D. ALLEN
GEOLOGICAL SURVEY

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SUMMARY

The Goldfields-Esperance region extends over an area of about 400 000 km² from Wiluna to Esperance. It is centred on Kalgoorlie and includes some of the most water deficient areas in Western Australia. This results from a combination of topographical, geological and climatic factors. Surface water resources are virtually absent except after major rainfall events and consequently groundwater provides the most readily available source of water. A regional water table extends through most of the region and the groundwater occurs in catchment controlled flow systems. The groundwater is recharged by episodic rainfall recharge, and moves slowly to discharge into the Eucla Basin and along the south coast. It is predominantly brackish to hypersaline with some local minor fresh groundwater resources in the north and along the south coast, and major saline groundwater resources occurring in the palaeodrainages associated with salt lake systems. Major aquifers occur in sands at the base of the palaeochannels; in calcretes (north of Menzies); in Tertiary sediments (south of Norseman); and occasionally within weathering profiles or fractured rock aquifers.

The availability and cost of groundwater for gold mining has been of concern since the early 1980s and has been the subject of a number of major studies. Fortunately the carbon-in-leach and carbon-in-pulp gold extraction technology can utilise groundwater up to about 150,000 milligrams per litre total dissolved solids. This is mainly obtained from the palaeodrainages (with a few exceptions) and underpins the gold mining industry.

Estimates of the groundwater resources in the region, based on assumed of recharge rates, and storage volumes have been made. These are useful for comparing resources between different areas (eg Bestow 1994) but are not particularly helpful for locating specific sources. The aquifers in the palaeochannels are concealed and require geophysical and exploratory drilling and testing programs to determine their location for establishing wellfields. This is generally undertaken by consultants working for the mining companies and has been supported by the Geological Survey which has undertaken systematic exploratory drilling on the Roe Palaeodrainage, hydrogeological mapping in the Kalgoorlie region and identification of calcrete aquifers, to provide regional overviews to guide exploration for the groundwater resources.

The frequency of the palaeodrainages and their distribution fortuitously results in most of the major gold mining operations being within about 25 km of a palaeodrainage. However, where several mines occur there may be competition for access to the palaeochannel and its groundwater resources. Fortunately, the groundwater resources in the palaeodrainages, as a result of leakage from overlying sediments and the underlying weathered bedrock are proving to be considerably larger than indicated by volumetric calculations of the aquifer. Furthermore the Water Authority under its licensing arrangements has permitted abstraction at rates greater than the estimated recharge rates (sustainable yield) of the groundwater resources. Consequently, for most mining operations with lives of less than 20 years, depletion of the groundwater resources should provide adequate supplies.

Fresh-brackish groundwater for small, town water supplies and pastoral activities is generally available north of Menzies and close to the coast at Esperance. It is generally obtained from fractured rock alluvial and eolian aquifers. These are not likely to be affected by pumping from the palaeochannels but because of their shallow depth and infrequent recharge may be affected by drought and variation in seasonal rainfall.

The region is fortunate to have access to relatively large though mainly saline groundwater resources. Currently the mining industry utilises about 90% of all groundwater used in the region and there should be adequate groundwater resources available for present and future development. It is considered that a hydrogeological mapping program would be an effective way to delineate resources and assist industry.

INTRODUCTION

LOCATION

For the purpose of this paper the Goldfields - Esperance region (GER) is taken to lie between latitudes 26° and 34° S and longitudes 120° E and 125° E (Figure 1), and has an area of about 400,000 km². Kalgoorlie lies in about the centre of the region with Wiluna and Esperance about 400 km to the north and south, respectively.

PURPOSE AND SCOPE

In 1994 the GER contributed about \$2 605 million (26%) of Western Australia's total mineral production. This comprised 100% of nickel production, 59% of gold, and a small percentage of other minerals. During the same period the value of pastoral production in the GER was about \$15 million. The viability of the mining and pastoral industries and some towns is underpinned by the availability of groundwater supplies.

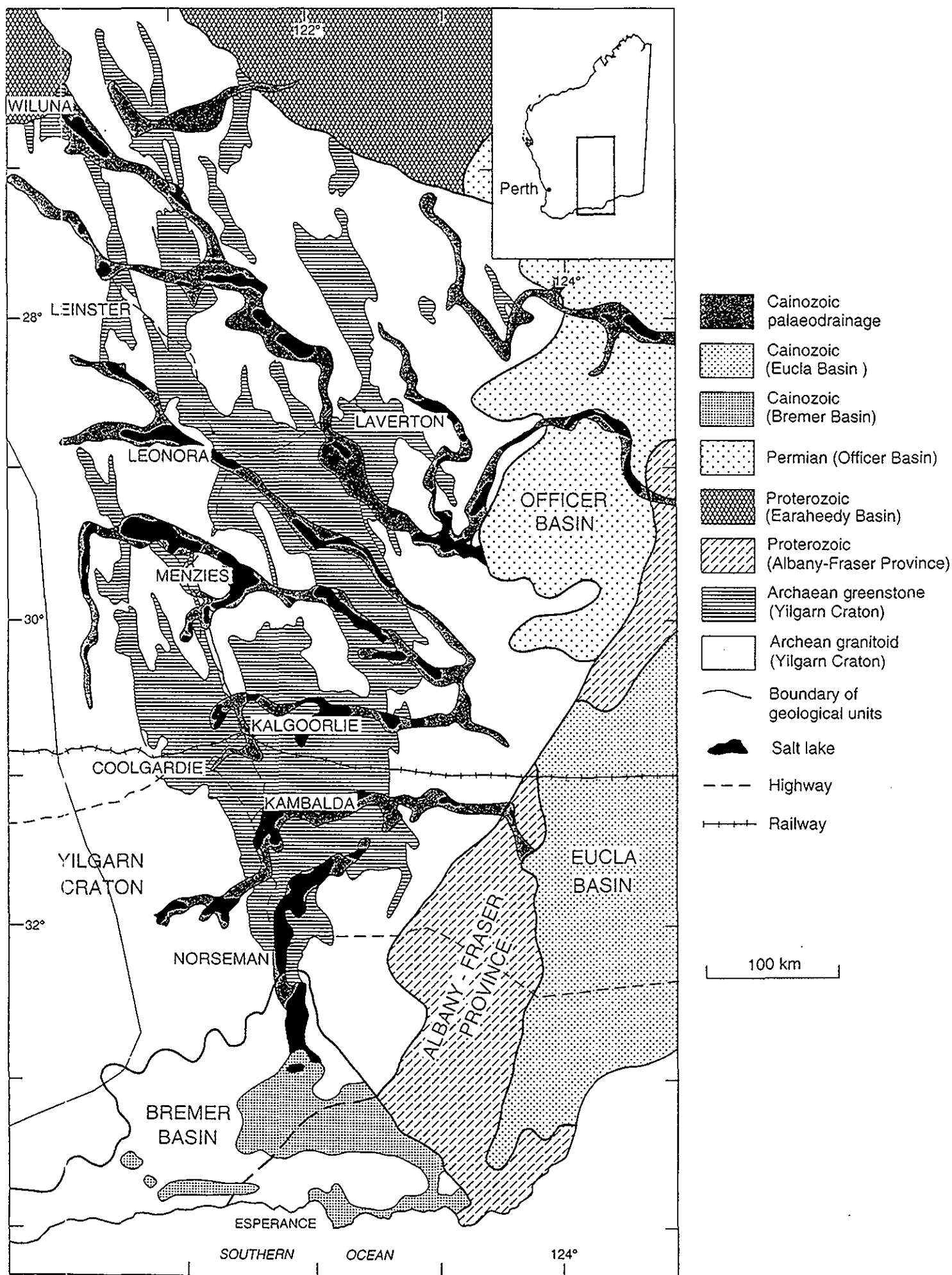
The Goldfields - Esperance Development Commission has identified that the continued availability of water in the region is a major perceived issue. It is concerned that current water supplies from the Goldfields and Agricultural Water Supply Scheme (G & AWS), and groundwater resources may be inadequate for domestic expansion, the mining industry and for security of the pastoral industry.

This paper is intended to provide a review of the groundwater resources in the region. It is based on data held by the Geological Survey (GSWA), in particular various GSWA maps and publications, and some consultants' reports, which may not be widely known or readily accessible.

PREVIOUS WORK

There are a large number of reports relating to the occurrence of groundwater in the GER. Many of these are only of historic interest, relate to local areas, or to specific geotechnical or research problems. Consequently only the known, main publications relating to groundwater resources, are reviewed here.

Sanders (1969) mapped the location of calcrete deposits and the salinity of existing bores and wells in a study of the Murchison and north Eastern Goldfields for prospective town and mine water supplies. He showed that calcretes occurred mainly to the north of the latitude of Menzies within the palaeodrainages and recognised twenty five potential aquifers.



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Figure 1. Location and regional geology of Goldfields - Esperance region

Forbes (1978) in a paper presented in a seminar on water resources and use, in semi arid areas of Western Australia reviewed the probable groundwater potential of the Eastern Goldfields. He made estimates of the groundwater resources and concluded that they were very large in relation to the projected requirements at that time, and their availability should not limit development.

BHP Engineering in association with Australian Groundwater Consultants (BHPE 1984) undertook a water demand study in the Goldfields for the Department of Resource Development. The report was commissioned in response to increased demand for water to meet expected expansion of the goldmining industry. They examined the supply capacity and cost of water provided by the G & AWS (and other sources) and noted that all new mining developments were planning to use saline groundwater. They projected a tenfold increase of groundwater usage to $15 \times 10^6 \text{ m}^3/\text{year}$ and recommended consideration be given to establishing a Government scheme to provide saline groundwater to the major mining operations. Later (BHPE 1988) undertook a further survey for the Department of Resource Development by means of a questionnaire. They estimated demand for groundwater would reach $32.6 \times 10^6 \text{ m}^3/\text{year}$ by 1990. They recognised the major importance of the palaeochannel sand and estimated that "economically commandable" groundwater resources (ie in storage) were about $1230 \times 10^6 \text{ m}^3$, and concluded they should meet projected industry demands.

To assist the mining industry, in 1988 the GSWA undertook a systematic investigation of the palaeodrainage sands in the Roe Palaeodrainage encompassing Coolgardie and Kalgoorlie (Commander et al. 1991). They confirmed the role and importance of the palaeochannel sands and reliably estimated groundwater in storage to be $600 \times 10^6 \text{ m}^3$, sufficient to sustain current and projected requirements at that time.

Bestow (1992) estimated both the renewable and stored groundwater resources for each 1:250 000 map sheet in the GER (except for the area south of Norseman). He warned his estimates were very approximate but concluded that substantial groundwater resources existed in the region and that they were likely to satisfy most foreseeable non-potable water supply requirements.

Kern (1994, 1995a, 1995b, in press) has produced 1:250 000 scale hydrogeological Widgiemooltha maps for Kalgoorlie, Kurnalpi, Boorabin and Widgiemooltha as part of a State-wide hydrogeological mapping program of the GSWA. The maps are intended to assist groundwater exploration and show the regional location and potential of the major rock-types, and in particular the location of palaeodrainage lines (where known) and the location of existing wellfields.

Allen (in press) has described the hydrogeology of the Sir Samuel, Duketon, Leonora, Laverton, Menzies and Edjudina 1:250 000 sheets as a contribution to a rangeland survey being conducted jointly by the Departments of Agriculture and Land Administration. He noted the general availability of groundwater in the area, the location of some fresh groundwater resources and importance of the palaeodrainage sands and calcretes as major aquifers.

SETTING

TOPOGRAPHY AND DRAINAGE

The elevation of the GER ranges from about 200 m near the south coast and increases north and to about 550 m in the Wiluna area. The region is generally of very low relief with occasional erosional escarpments (breakaways) bordering some areas of duricrust and local ranges and isolated hills formed by resistant rock types.

Superimposed on the northern and central part of the region are a number of broad dominantly southeast trending palaeodrainage systems containing occasional large playa lakes. However in the south a number of small modern drainage systems flow southward to the Southern Ocean from a regional drainage divide (Figure 2).

CLIMATE

The region extends between about eight degrees of latitude and borders the Southern Ocean to the south, consequently there is a climatic variation from south to north. Average annual rainfall decreases from about 600 mm at Esperance to 200 mm at Wiluna and average annual evaporation increases from 1600 mm to about 3600 mm between the same centres (Figure 3). From about Esperance to Menzies the region receives mainly winter rainfall whereas to the north rainfall is fairly evenly distributed between winter and summer. The rainfall intensity increases northward and annual rainfall may vary widely between different years. Droughts and floods are a feature of the region's climate.

GEOLOGY

GENERAL

The GER includes parts of a number of major geological basins and provinces. In order of age these are the Yilgarn Craton, Albany-Fraser Orogen, and Eeraheedy, Officer, Eucla and Bremer Basins (Figure 1). The main aquifers in each basin or potential, together with comments on their groundwater province are given in Table 1. Structurally, the Yilgarn Craton, and Albany-Fraser Orogen comprise highly deformed and deeply weathered metamorphic, and igneous rocks whereas, the sedimentary basins are mainly underformed and comprise flat lying sedimentary rocks. The palaeodrainages are superimposed on the basins and provinces.

114°

122°

BONAPARTE
BASINORD
BASIN

- Regional drainage divide
- "Meckering Line" marking boundary of river rejuvenation
- ~ River
- - - Palaeoriver
- Playa lake (salt)

CANNING
BASINCARNARVON
BASINOFFICER
BASINPERTH
BASINEUCLA
BASIN

PERTH

COLLIE BASIN

BREMER
BASIN

400 km

36°

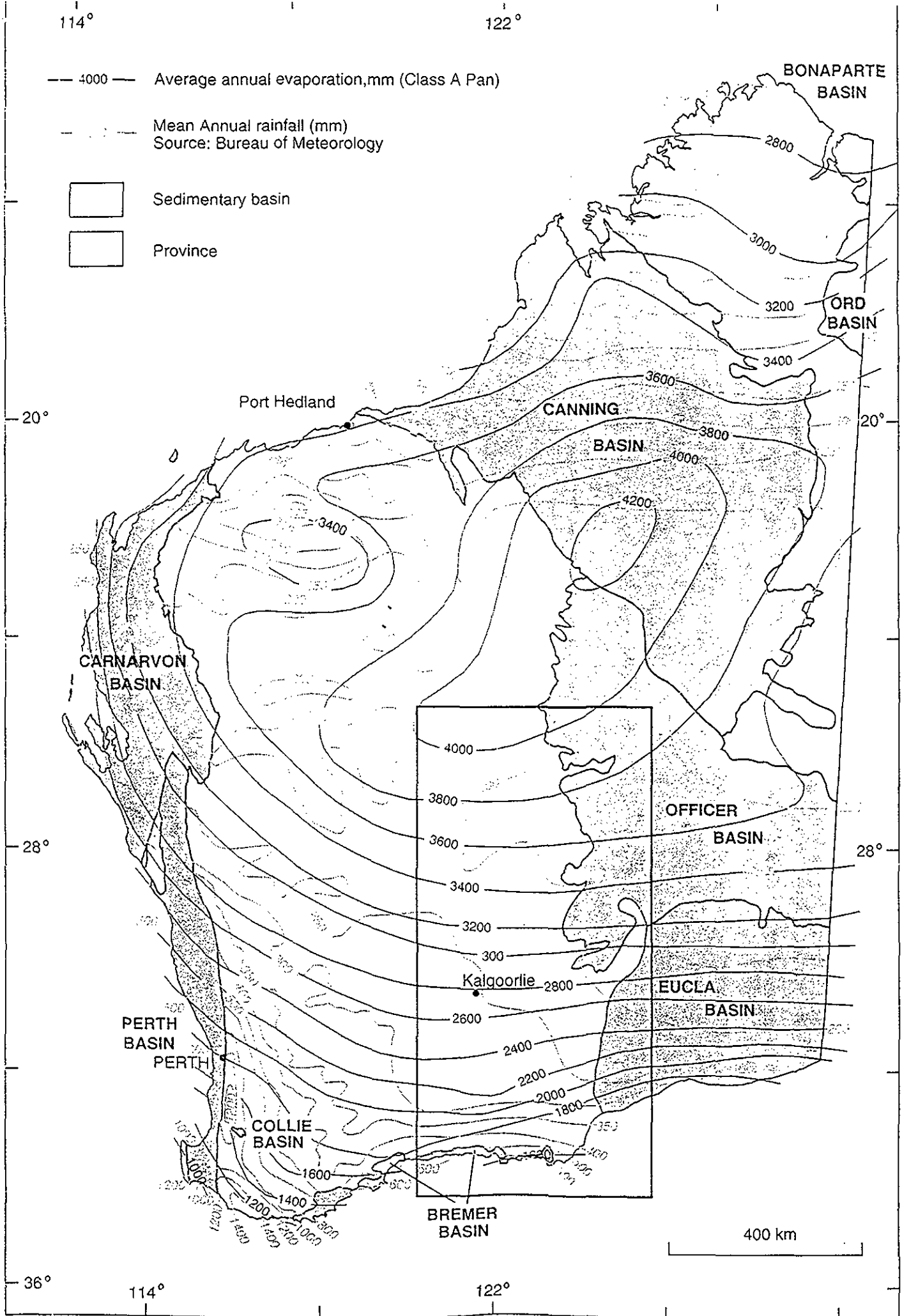
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Figure 2. Palaeodrainage system



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Figure 3. Average annual rainfall and evaporation

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Table 1 Main aquifers in the basins and provinces of the Goldfields-Esperance region

BASIN/PROVINCE	MAIN AQUIFERS	YIELD (m ³ /d)	SALINITY (mg/l TDS)	REMARKS
Bremer Basin	Coastal sand dunes	300 - 500	500 - 1 000	Local aquifer, important fresh groundwater resources
	Werrilup Formation	200 - 1 000	10 000 - 50 000	Local aquifer, largely untested
	Weathered/Fractured bedrock	5 - 100	1 000 - 30 000	Minor aquifer
Eucla Basin	Welson Bluff Limestone	? 1 000 - 2 000	1 000 - 16 000	Widespread aquifer, untested
	Loongana Sandstone	? 200 - 1 500	20 000 - 40 000	Widespread aquifer, very large resources
Officer Basin	Patterson Formation	? 1 000	? 2 000 - 50 000	Discontinuous aquifer; no data
Eeraheedy Basin	Sandstone (undifferentiated)	? 5 - 100	? 1 500 - 5 000	No data, not likely to be important
Albany - Fraser Orogen	Coastal dune sands	300 - 500	500 - 1 000	Local aquifer; important fresh groundwater resources
	Palaeochannel sands	200 - 1 500	30 000 - 300 000	Restricted to palaeodrainages; local aquifer, untested
	Weathered/Fractured bedrock	<5 - 100	? 10 000 - 30 000	Local aquifer
Yilgam Craton	Calcrete	<100 - 1 500	2 000 - 6 000	Local high yielding aquifer; in palaeodrainages north of Menzies
	Palaeodrainage sand	<200 - 1 500	30 000 - 300 000	Restricted to palaeodrainages; large supplies generally available; large resources
	Weathered/fractured greenstones	<5 - 1 500	1 000 - 5 000	Local aquifer; large supplies rare
	Weathered/fractured granitoids	<5 - 1 200	1 000 - 5 000	Local aquifer; large supplies rare

GROUNDWATER

OCCURRENCE

Groundwater occurs throughout the GER. There is a regional water table, except in some areas of massive bedrock. The water table forms a subdued surface sub-parallel to the topography. The groundwater occurs within sparse fractures in the metamorphic and igneous rocks, within secondary porosity (produced by chemical leaching) in weathering profiles, and in intergranular porosity in the sedimentary and alluvial rocks.

The groundwater originates from rainfall recharge mainly during intense rainfall events such as the recently experienced Cyclone Bobby. It initially flows slowly under gravity in regional catchment controlled flow systems to discharge into the salt lakes and then via groundwater flow in the palaeodrainages, into the Eucla Basin. In the southern part of the region the groundwater discharges along the coast into the sea.

The high evaporation (Figure 3) and poor flushing of the groundwater systems has resulted in large concentrations of salt, mainly derived from rainfall, being retained in the region. The general pattern of groundwater salinity is shown in Figure 4. It shows that the lowest salinity groundwater is mainly in the north as a result of more intense and effective rainfall recharge events and higher relief, and is generally found along drainage divides. Other low salinity groundwater is also found along the south coast on drainage divides and also in modern coastal dune sands. The figure also shows that brackish and saline groundwater occurs along the palaeodrainages and throughout most of the region south of Menzies.

MAIN AQUIFERS

Groundwater supplies are available in most of the rock types found in the region. However, major aquifers are generally only found in rock types with primary porosity such as the sands at the base of the palaeochannels, sand dunes along the south coast, calcrete and sandstone and limestone in the sedimentary basins (Figure 5). Occasionally large supplies are obtained from site specific locations in the fractured rocks or from their weathering profiles.

The major aquifers in the different geological basins and provinces are summarised in Table 1.

GROUNDWATER RESOURCES

ESTIMATED RESOURCES

Groundwater resources are generally expressed as renewable, and stored resources. Renewal resources are those replenished each year from rainfall, whereas stored resources are those accumulated in all voids beneath the water table within aquifers, and may have accumulated over millenia.

Because groundwater recharge from rainfall in the GER is episodic and very difficult to quantify, the stored groundwater resources are usually used for estimating the groundwater resources in the region (eg BHPE 1984).

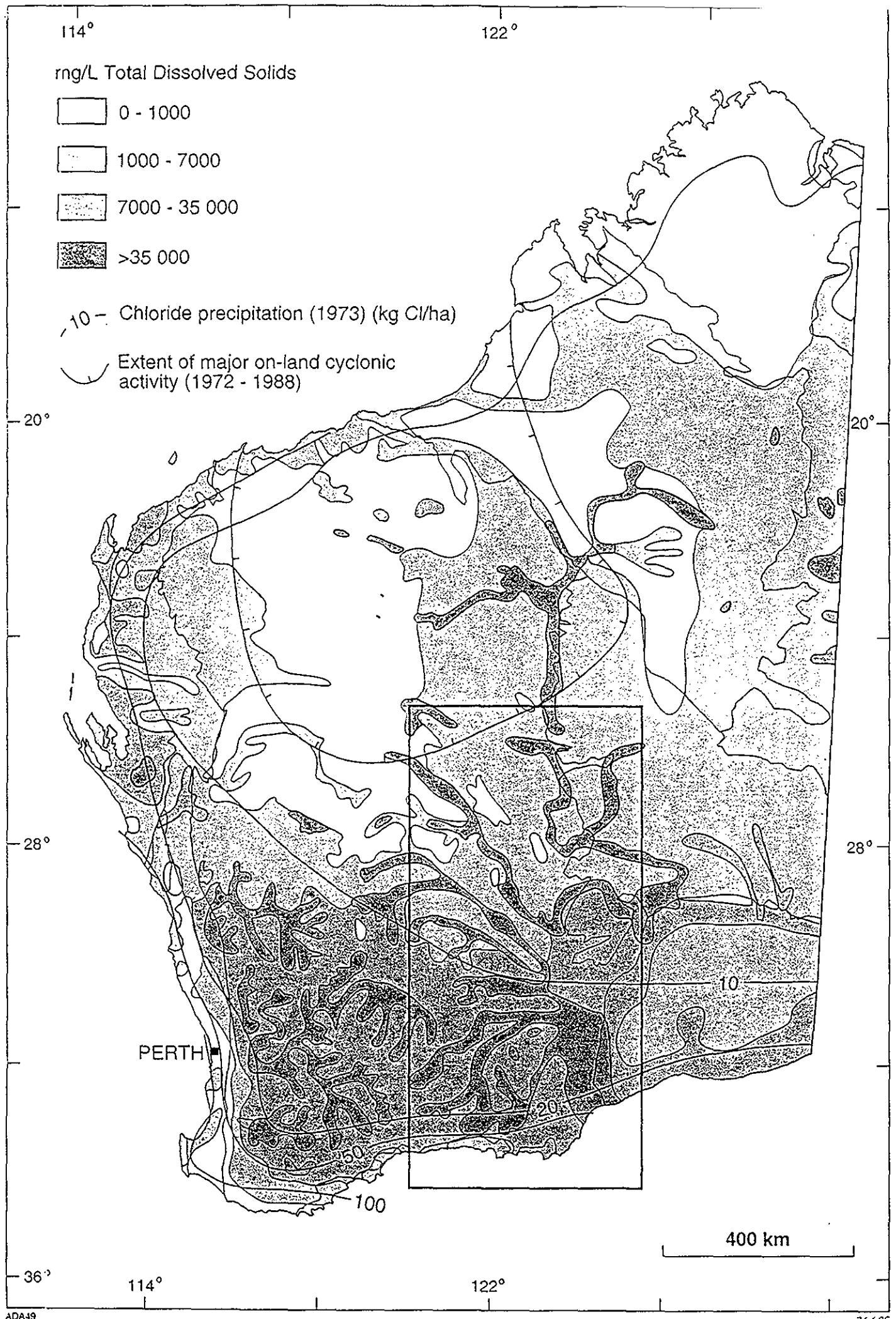


Figure 4. Variation of groundwater salinity

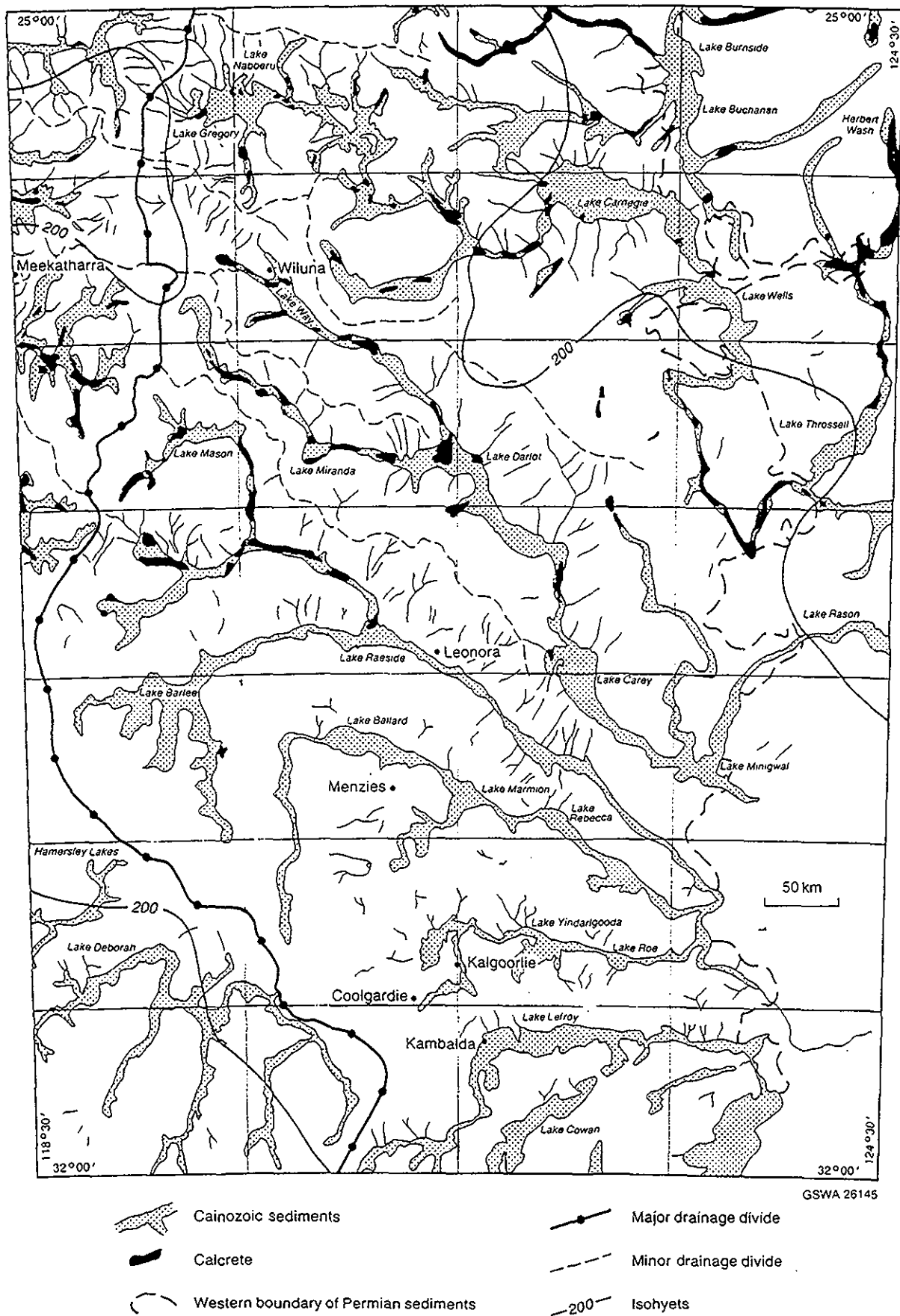


Figure 5. Distribution of calcrete aquifers (after Bestow 1992)

The estimates of stored groundwater resources as mentioned, have generally been based on various geological assumptions and are indicative only. It is considered that the approach adopted by Commander et al. (1991), defining the thickness and extent of sand in each palaeodrainage, provides the most systematic and reliable results. They estimated that the groundwater resources in the palaeodrainage sand in the Roe Palaeodrainage were about $600 \times 10^6 \text{ m}^3$. Extrapolating their data it is likely that palaeodrainages in the region may contain at least ten times this quantity.

The actual available groundwater resources are likely to be more than the estimated stored resources. According to Commander et al. (1991), leakage from overlying sediments and the underlying weathered bedrock are likely to contribute significant additional resources. The amount of groundwater available is further improved by the policy of the Water Authority which allows abstraction at rates exceeding recharge and results in gradual depletion (mining) of the resources. The policy is applied because of the high salinity of the groundwater and because there is no other perceived beneficial use for the resources. As a result gradual "mining" of the groundwater resources is occurring in some areas, but as far as is known the resources should be available for the projected life of most mines.

The groundwater resources in the calcretes vary from marginal to saline and have only been estimated at sites near Wiluna (Sanders 1973). The calcretes are reasonably widespread, but only form local aquifers which may vary considerably in thickness and extent. Over-exploitation of these aquifers may result in an increase in groundwater salinity resulting from ingress of saline groundwater from adjacent aquifers, consequently licensed abstraction is limited to available renewable resources.

Large un-utilised brackish-saline groundwater resources occur in the Eucla Basin, while small or untested resources occur in the Bremer and Officer Basins.

GROUNDWATER USAGE

Mining Industry

Reliable data on groundwater usage by the mining industry is not available. The demand forecast for 1990 was $32.6 \times 10^6 \text{ m}^3/\text{y}$ (BHPE 1988). Currently, according to the Water Authority, 298 groundwater licences to abstract $142 \times 10^6 \text{ m}^3/\text{year}$ have been issued for the Eastern Goldfields. However the actual abstraction is uncertain and is likely to be 50-75% of the licensed figure, possibly about $100 \times 10^6 \text{ m}^3/\text{year}$.

Pastoral Industry

There are about 4 000 pastoral bores in the region. Many of these are now not operating. However assuming they are operational and produce about $5 \text{ m}^3/\text{day}$, total annual abstraction for the pastoral industry is about $7.5 \times 10^6 \text{ m}^3/\text{year}$.

Town Water Supplies

Wiluna, Leinster, Laverton, Leonora, Menzies, Cosmo Newbery, and Esperance depend on groundwater supplies. Total abstraction for these supplies in 1993 was about 1.5×10^6 m³/year.

CONCLUSIONS

1. The Goldfields - Esperance region includes some of the most water deficient areas in Western Australia.
2. Current annual groundwater usage in the region is estimated to be about 115×10^6 m³/year of which the mining industry utilises about 90%.
3. Reliable estimates of groundwater resources are not available. However, the largest readily accessible resources are known to occur in sands and calcretes located in palaeodrainages. Large mainly utilised resources occur in the Eucla Basin 350 km to the east of Kalgoorlie.
4. Based on consideration of estimated stored resources there are adequate fresh-brackish groundwater resources for the pastoral industry and for town water supplies from fractured rock and alluvial aquifers; and adequate brackish-hypersaline groundwater from palaeodrainages for most current and proposed mining operations located with access to of the palaeodrainage system.
5. It is considered that the most effective way to delineate the location of the groundwater resources is by hydrogeological mapping supported by some drilling as carried out by the Geological Survey on the Roe Palaeodrainage.

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MGR80996