CASE STUDY

GROUNDWATER IN THE EASTERN GOLDFIELDS OF WESTERN AUSTRALIA

Palaeorivers:
Rivers which existed in the geological past under a different climate

Palaeochannels:
Former riverbed infilled with sand or gravel and forming an aquifer

Giga Litres (GL):
1000,000,000 Litres

The eastern goldfields of Western Australia are semi-desert, with only 300 mm annual rainfall and 2500 mm annual evaporation. The rocks consist mainly of granite with linear greenstone belts of metamorphosed basaltic and sedimentary rocks of Archaean age ranging from 2.8-2.5 billion years old.

The area is relatively flat and the wide valleys are mostly blocked by sand dunes and occupied by internally draining salt lakes, which are dry for most of the year. Water only flows between some of the lakes after cyclonic rains, and this only happens at intervals of several decades. Given the low rainfall, poorly permeable rocks, and salt lakes, it is not surprising that there is very little groundwater, and most of this is highly saline. In spite of the low rainfall, the clay flats around Kalgoorlie are covered with eucalypt woodland, but vegetation becomes sparser to the north.

FIGURE 1 A GEOLOGICAL CROSS-SECTION OF THE MINERALIZED OREBODY BELOW THE WATERTABLE.

Water Supply

Water supply to the goldfields in the 1890s was difficult and expensive. In desperation, bores were drilled to 3000 feet in solid granite in the hope of finding 'artesian water', but of course without success! In the early years, saline groundwater was desalinated in plants that required huge amounts of wood, denuding the countryside for miles around. Engineer in Chief C.Y. O'Connor solved the water supply problem by construction of a 600 km pipeline from the Mundaring Weir in the Perth hills. Since 1903 this has been the supply of drinking water to Kalgoorlie, however, supply is limited by the size of the pipeline to around 13 Gigalitres/annum, and it would require a completely new pipeline to increase the flow.

In the 1980s, the resurgence of gold mining created demand for large amounts of water, and new technology (carbon in pulp) for treatment of low grade ore enabled local saline water to be used in the processing, hence there was a renewed need to explore for saline groundwater.

Palaeochannels and salt lakes

In the Eocene Epoch (around 45 million years ago) the continent of Australia was farther south, the rainfall was higher, and the area around Kalgoorlie was drained by rivers flowing south eastwards. Continental drift northwards, and tilting of the continent, combined with a drying climate, caused the rivers to cease flowing, and the valleys gradually filled with sediments.

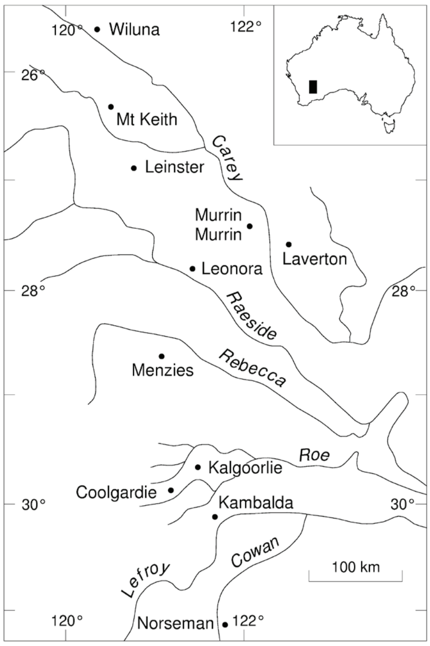

FIGURE 2 PALAEORIVERS IN THE EASTERN GOLDFIELDS

The basal sediments are sands, typically between half a kilometre to a kilometre wide and up to 30 metres thick. These were then covered by clay marking a change to an environment of lakes with low sediment input. The clays filled the valleys, spreading up to ten kilometres wide at the surface. The basal sands are known locally as palaeochannels – old river channels, and these form the most important aquifers, as the granite, greenstones and clay generally do not yield useful supplies of groundwater.

Australian Government
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Water table
Water table is the upper surface of groundwater in the aquifers.

Dewatering
Dewatering is the active removal of groundwater to lower the water table.

Sustainable yield:
The groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects the higher value uses that have a dependency on the water.

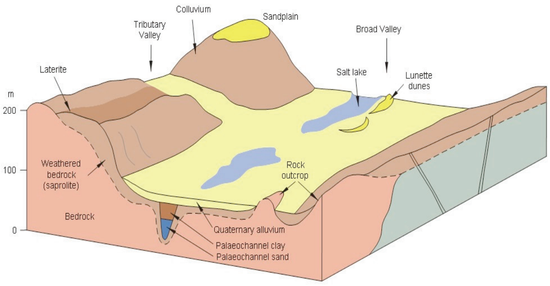

FIGURE 3 SCHEMATIC DIAGRAM OF A PALAEOCHANNEL AQUIFER.

Because the valleys are so flat and do not have enough slope to drain water at the surface, the salt lakes act as a discharge from the groundwater systems, evaporating water, and leaving the salt behind. The salt also gets flushed back into the palaeochannel aquifers below, thus the groundwater salinity increases progressively down the valleys. In some areas, the salinity reaches six times the salinity of seawater. Groundwater flow is inferred to be very slow, with the salt accumulating over periods of at least hundreds of thousands of years.

FIGURE 4 SATELLITE IMAGE OF LAKE BALLARD NEAR MENZIES.

Some groundwater flow from the Kalgoorlie region flows out into the limestone aquifers of the Nullarbor Plain, resulting in very high groundwater salinity along the western margin of the plain.

Exploration for palaeochannel aquifers

Exploration for these hidden valley bottom sediments has been carried out by using geophysical techniques such as gravity, which can distinguish deep sediments from the surrounding bedrock, and electromagnetic or resistivity methods, which can distinguish electrically conductive saline groundwater from the relatively dry and electrically resistive surrounding bedrock. Geophysical traverses are usually carried out to provide a target before drilling bores. Exploratory drilling can then home in on the deepest most productive part of the palaeochannel aquifers, and enable production bores to be constructed along the axes of the channels.

Borefield production

Because recharge to the groundwater in the palaeochannels is very small, water pumped out is considered to be non-renewable. However, pumping has induced leakage from unexplored parts of the palaeochannel system, from the weathered bedrock and overlying sediments, so that initial estimates of the groundwater resource have been found to be conservative, and the resources are likely to last for decades to come.

The presence of saline groundwater has given a new lease of life to the gold industry. For each ton of gold ore yielding only a few grams of gold, about a ton (1000 litres) of water is used. A portion of the water can be recycled from the tailings, though it becomes more saline. Saline groundwater from palaeochannel aquifers is also used for nickel ore processing. Nickel mines generally use five to ten times more than gold mines, but prefer to have a salinity much less than sea water.

Groundwater from the palaeochannel aquifers is often acidic, and lime has to be added as a neutraliser.

wetrocks

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Environmental consequences of using saline water

Use of saline water has several potential environmental consequences. If a pipeline breaks, the spillage of saline water immediately kills the vegetation it comes into contact with. Consequently, pipelines have to be fitted with pressure detectors that shut off the pumping if a leak occurs.

Disposal of the ore tailings and the hypersaline water results in infiltration of the hypersaline water and a rise of the water table beneath the tailings. In the Kalgoorlie area, the natural groundwater is saline, so use of the resource is not compromised. However, the saline water must not be allowed to rise up into the root zone of trees, therefore strict monitoring of water levels around the tailings is necessary.

FIGURE 5 TREE DEATH DUE TO RISING SALT WATER NEAR A TAILINGS DAM

Open pits which are excavated below the water table gradually fill with saline water, or in some cases where the inflow is much less than the evaporation, salt crystallises out on the pit walls.

Going further

You are a senior engineer with a mining company. Your gold mine is to process 30,000 Tonnes of ore each year to be profitable. Your mine requires a permanent camp of 60 people. Using figures in this case study, plus other information, estimate the water budget you would need to support the mine for a year. Start by thinking about all the things that need water.

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