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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GAMBIER LIMESTONE AQUIFER CHARACTERISTICS

Section 22, Hundred Hindmarsh

Military Sheet Millicent

INTRODUCTION

A supply of some 7.1 cusecs or 160,000 gallons per hour of groundwater is required for the increase in production of paper. In order to obtain this water supply, four 10 inch diameter boreholes Nos. 7 to 10 were drilled. They are located at 1060 feet distance from each other along the southern boundary of the property. To facilitate the calculations of the aquifer characteristics two observation boreholes were drilled at 50 and 150 feet distance from the 10 inch boreholes.

A multiple stage test was carried out on bore No. 7 followed by a recovery test. The remainder of the boreholes were tested at a single rate of 24 hours duration also followed by a recovery test. Pump testing started on 17th June 1965 and the testing programme was completed on 9th July, 1965.

GEOLOGY

Apcel's property is underlain by sediments of Tertiary age which overlie Cretaceous and Basement rocks. The Tertiary sediments consist of Gambier limestones which occur from 10 feet to 438 feet below the surface as evidenced by the samples of the bores No's. 7 to 9. Only 335 feet of Gambier limestone was penetrated in No. 10 borehole. This abrupt thinning of the Gambier limestone may be due to the Tartwaup fault zone which has been recognised further to the south east.

About one half mile to the north a 523 feet deep bore hole penetrated below the Gambier limestone 60 feet of lignitic clays which belong to the Knight group sediments. They overlie the sands of this group. It is recorded that this lignitic clay is extensive but its thickness is variable. It is assumed however that over this short distance these sediments are isotropic. The bores No's. 7 to 10 penetrated only the Gambier limestone and were discontinued just above the lignitic clays.

HYDROGEOLOGY

The Gambier limestone sequence, forming the aquifer, is not homogeneous. It consists of clastic limestones with flint concretions and is interbedded with marls and fine sandy beds. This is an important feature as all equations used to calculate field permeabilities are based upon infinite homogeneous and isotropic aquifers. In addition these formulae are developed for artesian aquifers. Although the groundwater was reported to rise slightly after it was encountered the pump testing proved that the Gambier limestone is an unconfined or free water table aquifer. These tests proved also that it is a leaky aquifer which will be further explained later. The raw field drawdown data of a free water table aquifer can not be used in the artesian aquifer formulae for the calculation of the field coefficient of transmissibility usually indicated by 'T' and the coefficient of storage, 'S'. Adjustments have to be made and a conversion table from field drawdown data 'S', to adjusted drawdowns 's', Figure 65-1135, is attached.

It was noted above that the Gambier limestones are not homogeneous beds. There is a good agreement between the calculated values of T and S from the pump-test on the four boreholes. It suggests that in its entirety, the aquifer could be considered to be homogeneous.

Drawdown levels measured in the observation boreholes are used to calculate the coefficients of transmissibility and storage. These two coefficients in turn are used to calculate the cone of drawdown which can be expected if prolonged pumping is anticipated.

Observation boreholes should penetrate the full aquifer as otherwise the drawdown levels measured would show effects similar to leaky aquifers, boundary conditions or even confining beds. The results obtained indicate leaky aquifer conditions and the drawdown levels of bore hole 10b suggest boundary conditions.

In order to eliminate possible errors the drawdown levels and recovery data measured in the pumped boreholes, which penetrate the aquifer in full, have been plotted and these show also that the aquifer is a leaky type but that boundary condition are not reflected in them.

A leaky aquifer is defined as an aquifer which is overlain or underlain by a confining bed through which there is some seepage of groundwater into the pumped aquifer. In this case it should be the underlying Knight Sands which is the only other aquifer from which ground water could move into the Gambier limestone.

A leaky type aquifer could be considered to be advantageous. The groundwater level in a nonleaky aquifer will decrease slowly but steadily under heavy pumping conditions. Groundwater levels will fall to a certain level in a leaky type aquifer after which the seepage through the confining bed will supply sufficient water so that no further decrease in groundwater level will occur. Alternatively the seepage may reduce the steady fall in groundwater level to a minimum.

The leakage or seepage is generally expressed in the vertical hydraulic conductivity, 'P, of the confining bed. Values of 'P are usually small but since seepage occurs through an extensive area the total quantity of water, which finds its way into the Gambier limestone aquifer, is quite large.

DESCRIPTION OF PUMP TEST RESULTS

A multiple stage test was made on bore No. 7 in an attempt to calculate the aquifer and well loss which would occur in the borehole pumped and also to calculate the maximum quantity which could be withdrawn from one single borehole under prolonged pumping conditions. This test was not a complete success as aquifer and well loss could not be calculated and therefore it was also difficult to assess the maximum pumping rate. The anticipated drawdown log time plots which would occur if this borehole was pumped from static level at rates $Q_1 = 0.59$, $Q_2 = 0.91$, $Q_3 = 1.34$ and $Q_4 = 1.99$ cusecs are shown on graph 65-1128. These drawdown curves however must be read with caution as the drawdowns per log cycle shown may be either greater or smaller but should reduce to zero after continuous pumping for a long period of time.

As the results of the multiple stage test were inconclusive the recovery data of observation borehole No. 7a have been used to arrive at values for T and S and the vertical coefficient of hydraulic conductivity P'. The calculations made are given on graph 65-1134. This graph indicates the leaky aquifer type. To ascertain that this calculation is not based upon effects of partial penetration a plot has been made of the log of drawdown against log t of the pumped hole No. 7a, Graph 65-1134. This shows a curve which proves the occurrence of the leaky aquifer as a curve has been obtained instead of a straight line.

Bores No. 8, 9 and 10 were pumped at a single rate for 24 hours. This method of pump testing immediately shows the aquifer type. However the observation borehole b of No. 10 indicated a boundary condition. To eliminate all doubts on the possible effects of partial penetration the semilog plots of drawdown versus log t and the recovery versus log t have been made for the pumped bore holes 8, 9 and 10. Figs. 65-1129, 65-1130 and 65-1131.

The drawdown data are scattered over the graphs for which no good explanation has been found except that normally the drawdown data are less reliable than the recovery data. Plotting of the recovery data yielded a curve instead of a straight line. A straight line would have resulted if the Gambier Limestone was a nonleaky aquifer.

Calculations of values for T, S and P' were made on the drawdown results of the observation boreholes. These are shown on the accompanying graphs Nos. 65-803, 65-804, 65-806, 65-1133, and the values are tabulated below.

Borehole No.	T in ft^2/Sec.	S nondimensional	P' in ft./sec.
7a	1.24×10^{-1}	7.3×10^{-4}	2.7×10^{-6}
8a	4.42×10^{-2}	1.13×10^{-4}	1.8×10^{-7}
8b	6.96×10^{-2}	1.9×10^{-5}	7.4×10^{-9}
9a	1.03×10	5.95×10^{-2}	
9b	1.2×10^{-1}	1.43×10^{-3}	1.6×10^{-5}
10a	1.95×10^{-1}	1.02×10^{-3}	4.2×10^{-5}

The coefficients of transmissibility, T, resulting from the plots of the bores 9a is considered very high. In addition it did not show any effects of a leaky aquifer. This observation bore hole may have penetrated a very cavernous portion of the Gambier limestone hence the different values obtained for T.

Calculating the cone of drawdown which could be expected if the boreholes are pumped at a rate of 1.8 cusecs or 40,000 gallons per hour is difficult owing to the aquifer type.

An attempt has been made to construct the anticipated cone of drawdown which would occur due to heavy pumping conditions between the bore holes 8 and 9. To construct this cone time drawdown graphs for bores 8 and 9 were made. The drawdown in a nonleaky aquifer can be obtained from this type of graph at any time and any distance. The time at which no further drawdown would occur in both boreholes was established from the log log curves of the observation bore holes. It is at about 1,000 minutes or 0.69 days. With the use of the time drawdown graph the anticipated cone of drawdown has been constructed showing the situation when bore No. 8 is pumped at a rate of 1.8. Similarly the cone of drawdown for bore No. 9 has been constructed. These are shown as broken lines on graph 65-1132. The anticipated cone of mutual interference is given as a solid line. It shows that the drawdown in bore No. 8 will be about 1 foot more if both bores are pumped at the same time while the drawdown in borehole No. 9 will be about 6 feet more. This composite cone of drawdown indicates that probably the bores No. 7, 8, 9 and 10 are capable of yielding as much as 1.8 cusecs or 40,000 gallons per hour. It depends however on the capacity of the underlying Knight sands aquifer.

The Knight Sands contain large quantities of good quality water which are not extensively developed in this area. Therefore there are good prospects that water from the Knight Sands will continue to supply the overlying aquifer with large quantities of water equal to the withdrawal.

The water levels reached during the pump test in bores No. 7, 8, 9 and 10 were 90 ft., 128 ft., 92 ft. and 146 ft. respectively. With a pump setting at 190 ft. and assuming that through mutual interference as much as 10 ft. extra drawdown will occur the lowest water level while pumping would be in the order of 160 ft.

A safe pump setting is considered to be 190 ft. as was done during the pumping testing as even under heavy pumping conditions about 30 ft. of water would stand above the pump.

It is considered that the borehole should not be pumped at a rate higher than 1.8 cusecs or 40,000 gallons per hour.

CONCLUSIONS

The Gambier Limestone is a leaky aquifer and therefore the drawdown will reach a certain level below the surface and remain at that level under heavy pumping conditions provided that the underlying Knight Sand aquifer continues to supply large quantities of water by means of seepage.

A maximum yield of 40,000 gallons per hour from each bore hole is warranted. The intake area of the pumps should be set at 190 feet to ensure that they are sufficiently submerged.

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