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Collector Wells for Small-scale Irrigation: Modelling of pumping tests on a collector well at the Lowveld Research Station, Chiredzi, Zimbabwe.

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EXECUTIVE SUMMARY

This report describes the computer simulation of a series of pumping tests at a collector well near Chiredzi, Zimbabwe.

It was possible to simulate accurately the performance of the well both before and after drilling the radial adits. The horizontal permeability indicated by the simulations was in the range 0.7-1.0 m/day. The simulations also indicated that a void existed behind the corrugated screen used in the construction of the well.

1. INTRODUCTION

The construction and testing of the collector well at Chiredzi has been described in the Technical Report WD/90/20 by P J Chilton, J C Talbot and S L Shedlock.

Analysis of the pump tests by the method of Barker and Herbert and Herbert and Kitching yielded a range of values for the permeability and storage at the site.

In order to assess the values of aquifer parameters over the whole period of the tests, it was decided to model the tests using a similar method to that used in the previous BGS/ODA Collector Well Project 1983-88 in Malawi, Zimbabwe and Sri Lanka.

2. THE MODEL USED

The model used for all the simulations was a 2-dimensional radial/depth model developed at BGS Wallingford. It was a finite difference model with solution by a successive overrelaxation technique incorporating a predictor subroutine. The typical nodal network was 16 vertical by 26 radial. The vertical node spacings could be varied according to the aquifer layering present. The radial node spacing increased with the radius so that improved resolution was obtained in the region near the well where greatest variation took place. The distant radial boundary condition was no flow and the radial nodes were arranged so that this boundary was sufficiently far from the well for no significant drawdown to occur. Horizontal and vertical permeabilities could be varied independently of each other over all nodes. It was necessary to specify the specific yield at the water table and the storativity of the whole profile. A typical initial time step was 5 minutes increasing throughout a stress period. A change of pumping rate (e.g. cessation) required a new stress period and reversion to the initial time step. The model was run on a Cray computer at University of London Computer Centre.

The model was constructed to confirm the theoretical analyses of large diameter and collector well responses in homogeneous aquifers, and to reproduce drawdown and recovery curves for typical basic parameters of basement aquifers. The collector well was simulated by means of a thin disk of very high permeability but with radius rather less than that of the relevant collector wells. With this construction, the model provided good correlations with theoretical analyses.

3. THE FIELD PUMPING TESTS

3.1 Before Radial Drilling

Two pumping tests were carried out on the completed well.

	4 April	18 April
Static water level	5.06 m	5.33 m
Duration of pumping	90 mins	100 mins
Pump discharge rate	0.78 l/sec	5.58 l/sec
Final water level (bd)	5.73 m	12.30 m
Final drawdown	0.76 m	5.97 m
25% recovery	105 mins	195 mins
50% recovery	260 mins	-
75% recovery	-	-

The tests were analysed by the nomogram method developed by Barker and Herbert (1989) and the "50% recovery method" of Herbert and Kitching (1981), to give the following transmissivities (T, m^2/d) and storage coefficient (S):

		4 April	18 April	
		T	T	S
Barker and Herbert	25%	-	2.2	0.56
	50%	-	-	-
	75%	-	-	-
Herbert and Kitching	50%	5.5	3.6	

The results of the test of 4 April fall outside the range of values for which the nomogram is applicable.

3.2 After Radial Drilling

After the radials have been completed, the standard procedure is to carry out a test in which the water level is drawn down to pump suction, followed by a longer-term test at a lower pumping rate which simulates the possible operating schedule of the well. The former is compared with the similar test performed on the well before the laterals are constructed, and the latter is used to assess the long-term sustainable yield of the well.

	4 May	3 June
Static water level	5.38 m	5.21 m
Duration of pumping	130 mins	240 mins
Pump discharge rate	5.58 l/sec	1.23 l/sec
Final water level (bd)	12.43 m	7.49 m
Final drawdown	7.05 m	2.28 m
25% recovery	69 mins	60 mins
50% recovery	175 mins	147 mins
75% recovery	365 mins	-

Recovery from 12.0 m to 10.0 m took 94 minutes, compared to 240 minutes for the depth interval before the laterals were drilled. This represents an increase of inflow from 0.44 l/sec before the drilling of the laterals to 1.1 l/sec afterwards, an improvement in yield of 150%.

The tests were analysed in the same way, to give the following transmissivities, (T, m^2/d) and storage coefficients (S):

		4 May		3 June	
		T	S	T	S
Barker and Herbert	25%	0.5	-	3.7	0.56
	50%	1.4	0.56	9.3	0.1
	75%	8.6	0.18	-	-
Herbert and Kitching	50%	7.0		7.1	

The increasing transmissivity implies a degree of partial penetration by the collector well, and the reducing storage coefficient suggests leaky aquifer conditions. The 75% recovery results are therefore most representative of the aquifer characteristics (Wright, 1988). The calculated transmissivities fall within the range (2-10 m^2/d) of the two nearest exploratory boreholes.

4. SIMULATION OF THE PUMPING TEST

4.1 Before Radial Drilling

The pumping tests on 4 April and 18 April 1989 were simulated using a range of parameters for the horizontal permeability and diameter of the pumped well. A good agreement between the field results and the computer simulation was obtained for the following sets of parameters (see Figs 1 and 2).

	4 April	18 April
Horizontal permeability	1.0 m/day	1.0 m/day
Anisotropy	0.1	0.1
Specific yield	0.1	0.1
Pumping rate	0.78 l/sec	5.58 l/sec
Diameter of well	2.42 m	2.50 m
Duration of pumping	90 mins	100 mins

As the well is only partially penetrating, the full depth of the aquifer being up to 37 m below surface, values of permeability adjacent to the well rather than overall transmissivity have been quoted. For the saturated section of the aquifer, corresponding to the depth of the well, the appropriate transmissivity is 7.0 m^2/day which gives reasonable agreement with the method of Herbert and Kitching.

In order to simulate accurately the drawdown at the end of pumping it was necessary to use a well diameter greater than 2.0 m on the model, otherwise drawdowns considerably in excess of the observed were obtained. It was felt that the method of construction of the well with corrugated sheet screen being installed within a dug section could have led to voids behind the screen which would tend to reduce drawdowns after pumping.

4.2 After Radial Drilling

The pumping tests on 4 May and 3 June 1989 were simulated using a similar range of parameters for horizontal permeability and diameter of the pumped well. The horizontal adits were represented by an equivalent thin high permeability disk near the bottom of the simulated well.

Good agreement between the modelled and field pumping tests were obtained (see Figs 3 and 4).

	4 May	3 June
Horizontal permeability	0.7 m/day	0.8 m/day
Anisotropy	0.1	0.1
Specific yield	0.1	0.1
Pumping rate	5.58 l/sec	1.23 l/sec
Diameter of well	2.4 m	2.2 m
Duration of pumping	130 mins	240 mins

In general similar values of horizontal permeability and well diameter were obtained to those before radial drilling. Slight differences in these parameters may be attributed to differences in drawdown and the approximations made in simulating the radial adits.

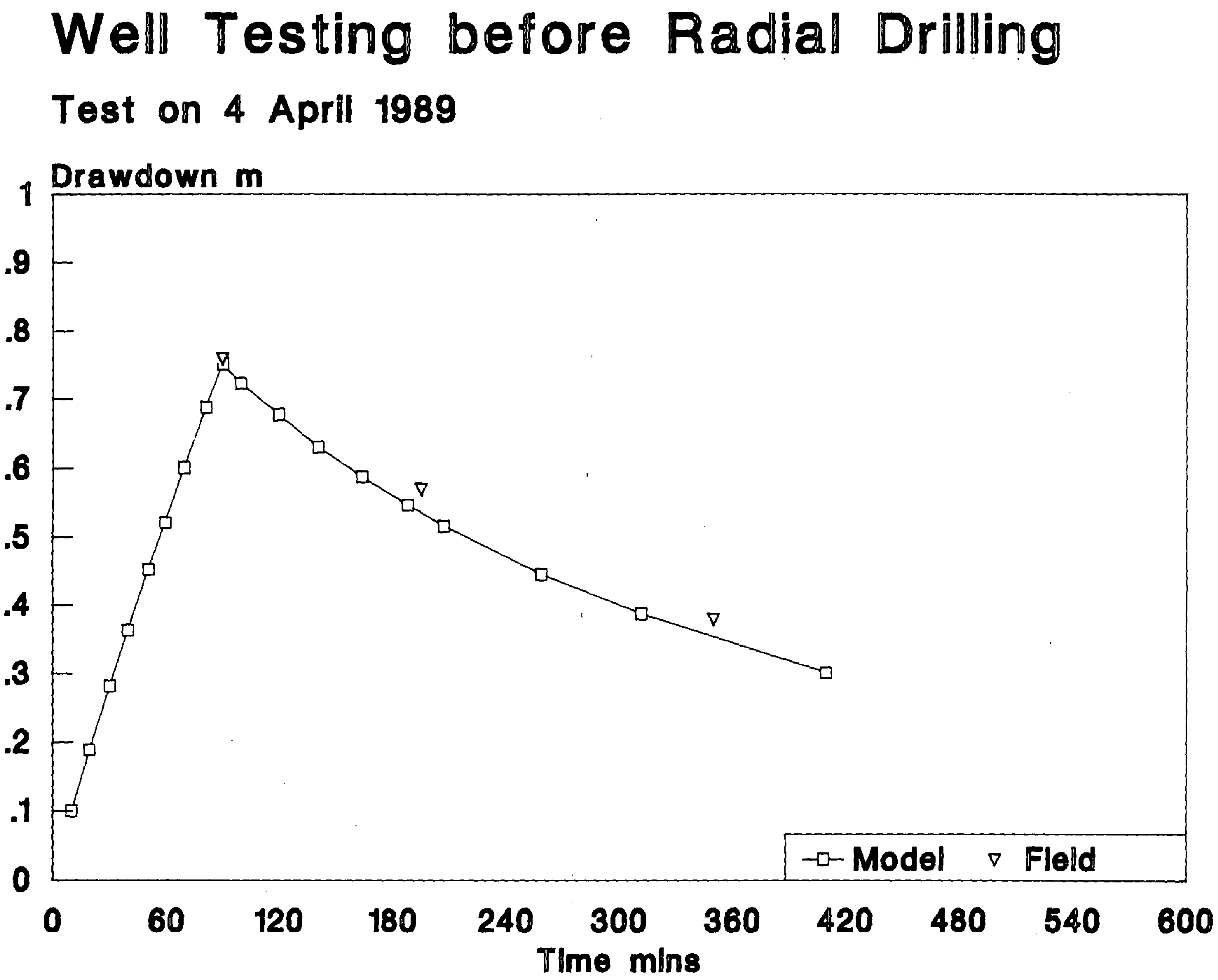

Well Testing before Radial Drilling
Test on 4 April 1989
Drawdown m
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Model
Field
0
60
120
180
240
300
360
420
480
540
600
Time mins

Figure 1.

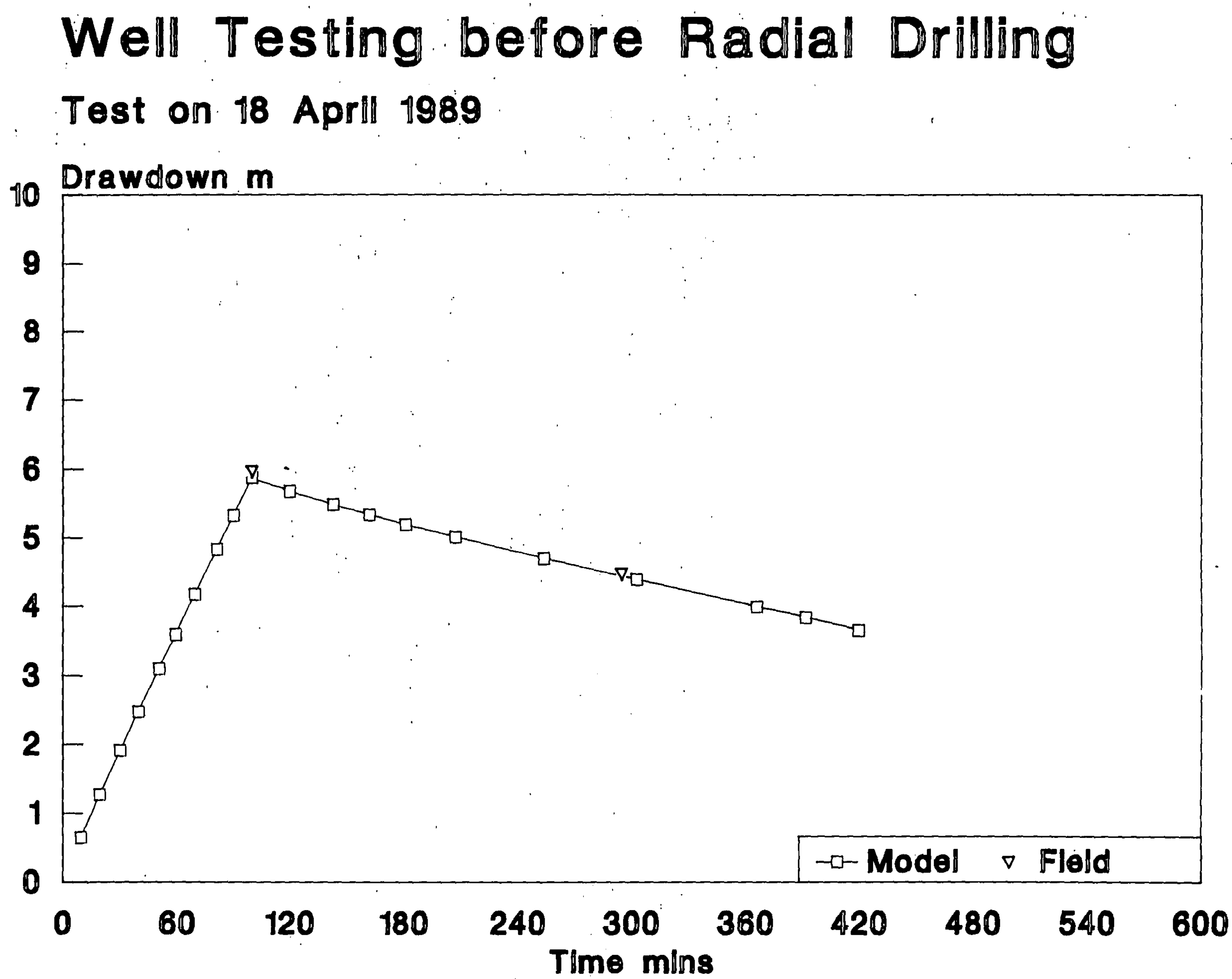

Well Testing before Radial Drilling
Test on 18 April 1989
Drawdown m
10
9
8
7
6
5
4
3
2
1
0
0
60
120
180
240
300
360
420
480
540
600
Time mins
Model
Field

Figure 2.

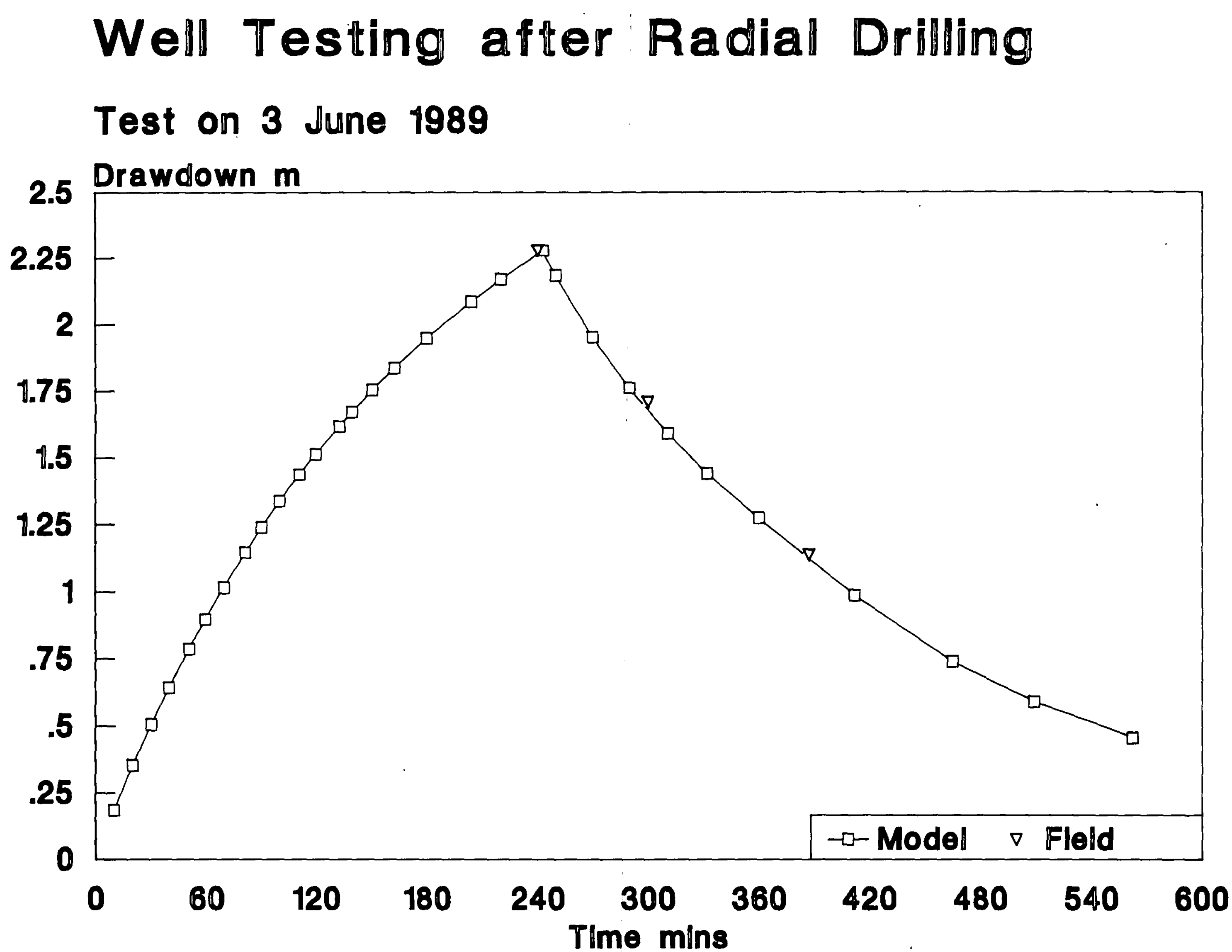
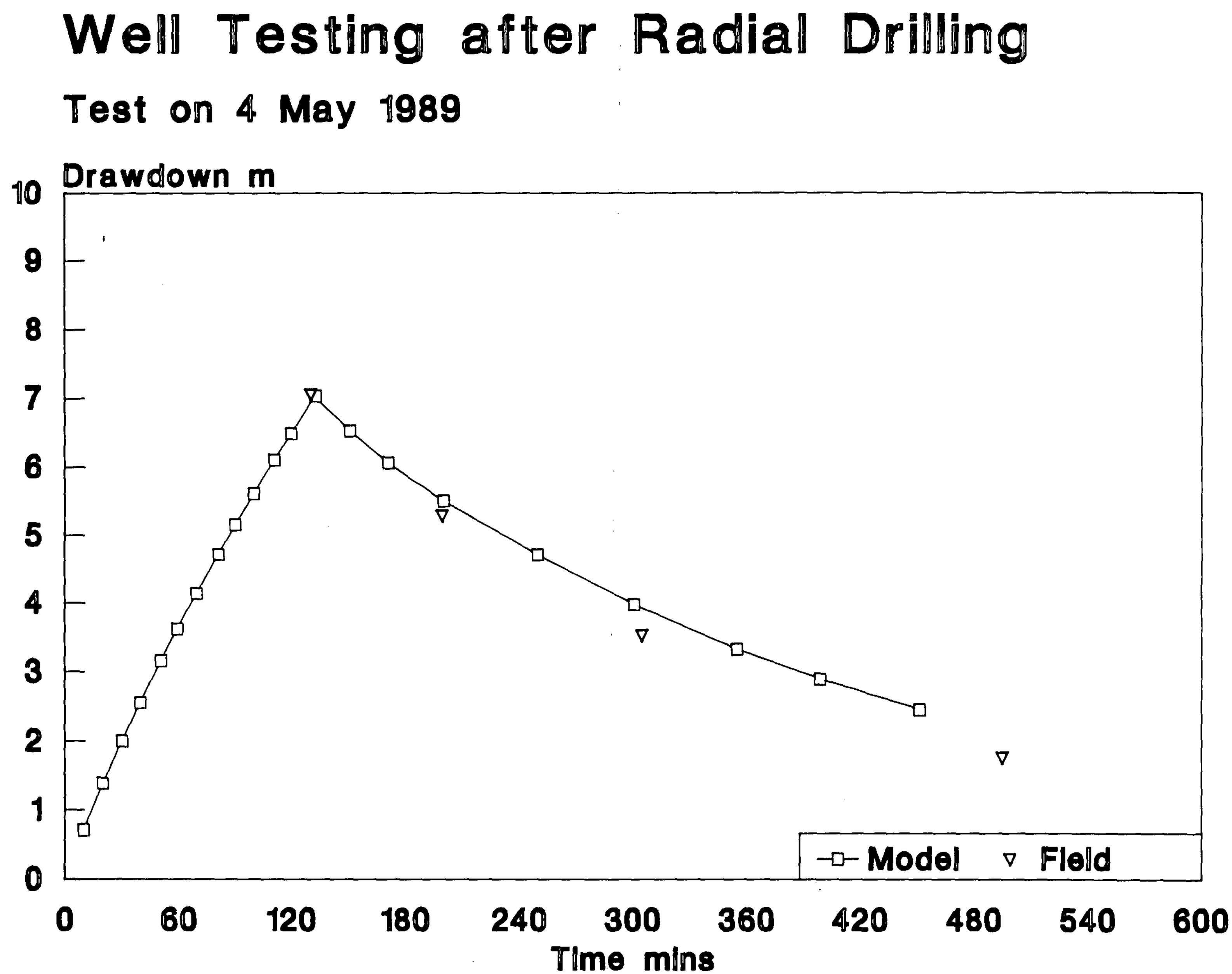

Well Testing after Radial Drilling
Test on 3 June 1989
Drawdown m
2.5
2.25
2
1.75
1.5
1.25
1
.75
.5
.25
0
0
60
120
180
240
300
360
420
480
540
600
Time mins
Model
Field

Figure 3.



Well Testing after Radial Drilling
Test on 4 May 1989
Drawdown m
0
1
2
3
4
5
6
7
8
9
10
0
60
120
180
240
300
360
420
480
540
600
Time mins
Model
Field

Figure 4.

5. CONCLUSIONS

It has proved possible to simulate the pumping tests on a collector well at Chiredzi both before and after drilling the radial adits. The horizontal permeability indicated is 0.7-1.0 m/day which corresponds to a transmissivity of 5-7 m^2/day for the aquifer section next to the well.