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# Collector Wells for Small-Scale Irrigation: Modelling of pumping tests on a collector well at Tamwa Kraal, Zimbabwe.

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## Contents

## EXECUTIVE SUMMARY

This report describes the computer simulation of a series of pumping tests at a collector well at Tamwa Kraal, 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 0.8 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 Tamwa Kraal is described in the Technical Report WD/92/27 by P J Chilton and J C Talbot.

Analysis of the pump tests by the method of Barker and Herbert 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 Convex 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.

| | 20 March | 21 March |
|---|---|---|
| Static water level (bd) | 5.70 m | 5.84 m |
| Duration of pumping | 70 mins | 100 mins |
| Pump discharge rate | 0.6 l/sec | 4.38 l/sec |
| Final water level | 6.36 m | 11.60 m |
| Final drawdown | 0.66 m | 5.76 m |
| 25% recovery | 160 mins | 230 mins |
| 50% recovery | 350 mins | 560 mins |
| 75% recovery | 1200 mins | 1300 mins |

The tests were analysed by the nomogram method developed by Barker and Herbert (1989) to give the following transmissivities (T, $m^2/d$) and storage coefficient (S):

| | | 20 March | | 21 March | |
|---|---|---|---|---|---|
| | | T | S | T | S |
| Barker and Herbert | 25% | 0.50 | 1.0 | - | - |
| | 50% | 0.63 | 0.06 | - | - |
| | 75% | 1.76 | 0.10 | 1.04 | 0.80 |

### 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 (similar to the test on 21 March), followed by a longer test at a lower pumping rate to simulate a possible operating schedule for the well. The former is compared to the similar test performed before the radial drilling and the latter is used to assess the long-term sustainable yield of the well.

| | 4 April |
|---|---|
| Static water level (bd) | 5.92 m |
| Duration of pumping | 100 mins |
| Pump discharge rate | 4.38 l/sec |
| Final water level | 11.37 m |
| Final drawdown | 5.45 m |
| 25% recovery | 210 mins |
| 50% recovery | 540 mins |
| 75% recovery | 1220 mins |

Recovery from 11.35 m to 11.0 m took 40 minutes after the radial drilling, compared to 50 minutes before. Similarly, recovery from 11.25 m to 9.50 m took 310 minutes after the radial drilling compared to 340 minutes before. The improvement in yield achieved by the radial drilling is less than at Chiredzi.

The test was analysed in the same way, to give the following transmissivity (T, $m^2/d$) and storage coefficient (S):

| | | 4 April | |
|---|---|---|---|
| | | T | S |
| Barker and Herbert | 25% | - | - |
| | 50% | - | - |
| | 75% | 0.98 | 1.30 |

## 4. SIMULATION OF THE PUMPING TEST

### 4.1 Before Radial Drilling

The pumping tests on 20 and 21 March 1991 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).

Figure 1

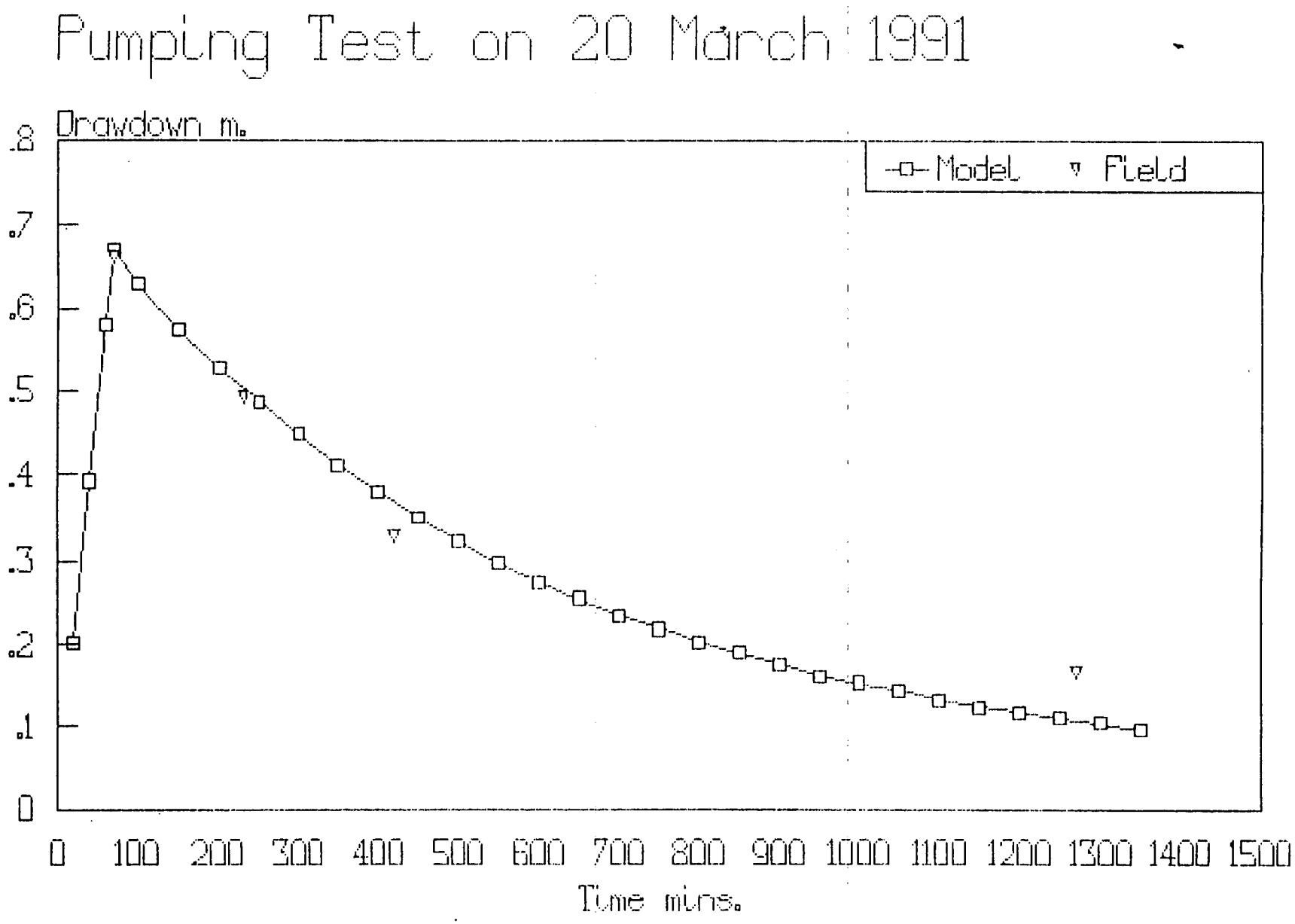
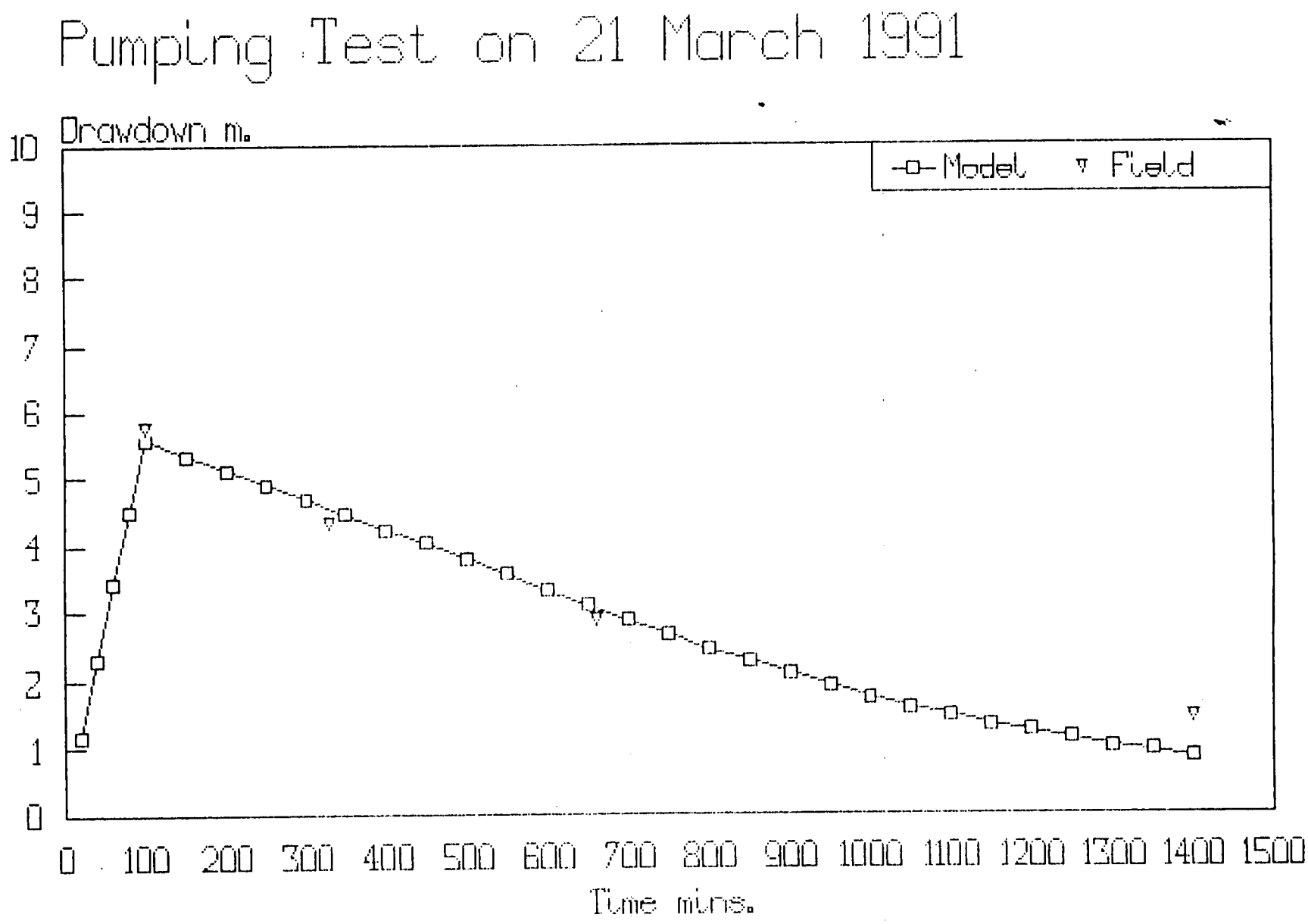

Pumping Test on 20 March 1991
Drawdown m.
.8
.7
.6
.5
.4
.3
.2
.1
0
Model
Field
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Time mins.

Figure 2


Pumping Test on 21 March 1991
Drawdown m.
Model
Field
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Time mins.

| | 20 March | 21 March |
|---|---|---|
| Horizontal permeability | 0.5 m/day | 0.8 m/day |
| Anisotropy | 0.1 | 0.1 |
| Specific yield | 0.1 | 0.1 |
| Pumping rate | 0.6 l/sec | 4.38 l/sec |
| Diameter of well | 2.1 m | 2.34 m |
| Duration of pumping | 70 mins | 100 mins |

As the well is only partially penetrating, 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 8.0 $m^2$/day.

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 test on 4 April was 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 test was obtained (see Fig 3).

| | 4 April |
|---|---|
| Horizontal permeability | 0.8 m/day |
| Anisotropy | 0.1 |
| Specific yield | 0.1 |
| Pumping rate | 4.38 l/sec |
| Diameter of well | 2.34 m |
| Duration of pumping | 100 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.

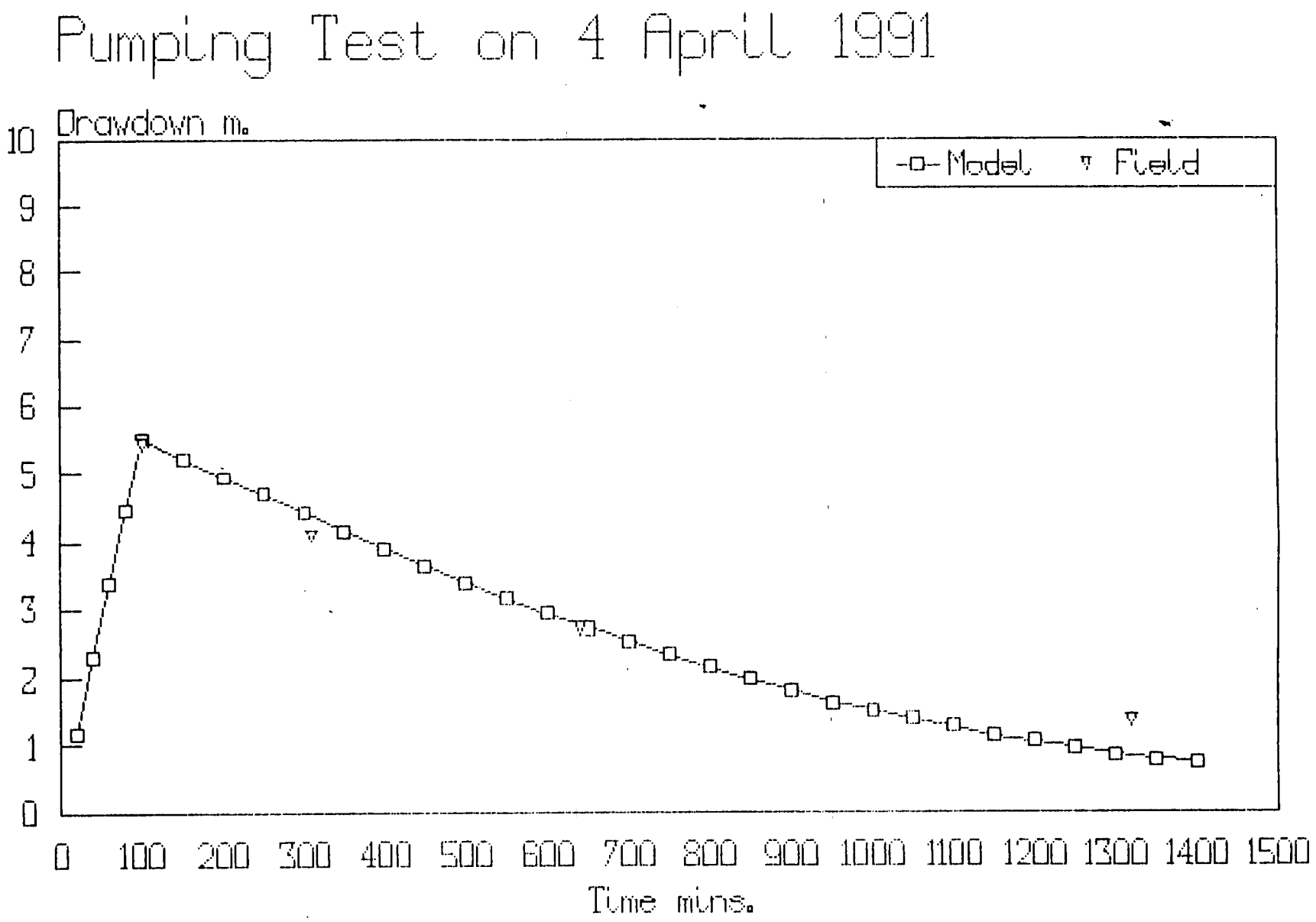
## 5. CONCLUSIONS

It has proved possible to simulate the pumping tests on a collector well at Tamwa Kraal both before and after drilling the radial adits. The horizontal permeability indicated is 0.8 m/day which corresponds to a transmissivity of approximately 8 $m^2$/day for the aquifer section next to the well.

## 6. REFERENCES

Barker, J A and Herbert, R 1989. Nomograms for the Analysis of Recovery Tests on Large-Diameter Wells. Q. J. Eng. Geol. Vol. 22, No. 2, p 151-158.

Figure 3


Pumping Test on 4 April 1991
Drawdown m.
Model
Field
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Time mins.

Chilton, P J and Talbot, J C 1992. Collector Wells for Small-Scale Irrigation: Construction and Testing of a Well at Tamwa/Sihande/Dhobani Kraals and Further Work at Chiredzi. BGS Technical Report WD/92/27.

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