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PUMP TEST ON STOCKHOLM MINESHAFT

FOR

GREAT MINES LIMITED

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Summary

A pump test was performed on the Stockholm mineshaft to provide data to assist in estimating the long term yield of the shaft as a water supply source for processing of ore at the Black Jack Mine operated by Great Mines Limited near Charters Towers. The main shaft was pumped for two days at a discharge rate varying from approximately 9 litres/sec to approximately 6 litres/sec. Water levels were monitored in the shaft and observation bores for the duration of pumping and during the initial phase of the recovery period when the water levels rose steadily toward their initial values. The level in the shaft was recorded for over two weeks after cessation of pumping until the water level rose to within 1.6 metres of its original value.

Interpretation of the results poses several difficulties. There is much more storage in the mineshafts than in a normal well or bore but the exact location and volumes of openings are unknown because of inadequate records of shaft and stope dimensions and uncertainty of caveins. The aquifer supplying water to the shafts is in fractured rock which produces nonhomogeneity and non-uniformity in the response to drawdown. The test was conducted relatively soon after local rain but, in terms of a longer timescale, after several years of rainfall significantly below average for the region. The effects of these climatic conditions cannot be estimated from the data obtained.

The data do not indicate radial symmetry of flow, a fact which is not surprising given the elongated shape of the mine cavities when viewed in plan. Assumptions have been made about the nature of the aquifer and the connectivity to the mine. Based on these assumptions, the parameters governing recharge to the mine have been identified and obtained using mathematical inversion techniques. These inversion methods are quite sophisticated and a new approach incorporated in the analysis allowed for non-uniform discharge.

Using the parameters estimated from the pump test results, the steady state inflow at a drawdown of 16 m (the maximum reached during the test) is calculated to be 2.3 litres per second (2.3 L/s). At a proposed production level of 600 000 tonnes per annum of ore at Black Jack Mine, it is estimated that water requirements will be 120 meglitres (ML) per year, which if pumped at a constant rate, equates to 3.8 L/s. Also, using the parameters obtained from the pump test, it is estimated that an inflow rate of 3.8 L/s to the old workings would be achieved at a drawdown of approximately 26m, provided that the aquifer supplying the inflow does not intersect the old mine above that

level. There is therefore a reasonable probability that the required supply could be obtained with a moderate drawdown of somewhat less than 30m. Because the pumping only lasted for 2 days and because of the deficiencies in knowledge of the aquifer (a factor common to fractured rock aquifers), it is difficult to predict how long such an inflow rate could be sustained without substantially depleting the storage in the country rocks which act as the source of the inflow. Longer pumping and more intensive monitoring would improve that prediction.

The storage in the old mine workings has been estimated by considering mine plans and by extrapolating from results of the pumping test. Both procedures are fraught with difficulties and lead to a wide range in the estimate, namely 20 to 50 ML of water storage. In view of the requirement of 120 ML per year therefore, it is obvious that most of the supply would have to be obtained from inflow from aquifers to the mine shafts and stopes.

In summary, therefore, it is possible that the required supply of 3.8 L/s could be obtained with a drawdown of less than 30m. It is probable that a supply of approximately 2.3 L/s would be provided with a drawdown of approximately 16m in the old shaft. The duration for which these rates could be pumped without significantly depleting the source in the surrounding aquifers could be predicted from a longer pumping and monitoring period. Unless it is considered critical to obtain a more reliable estimate of longer term availability of water immediately, it is recommended that pumping of water for processing at Black Jack Mine be put into effect and that careful monitoring of water levels be performed during the pumping operation. Predictions of the longer term supply available from the Stockholm shaft could then be continually upgraded as additional data are obtained and processed.

1. INTRODUCTION

The output of Black Jack Mine operated by Great Mines Limited near Charters Towers is to be substantially increased. An increase in the production level to process 600,000 tonnes of ore per annum will result in an expected water requirement of 120 megalitres (ML) per year on average. Black Jack Mine is located near the highway to Clermont approximately 10 km from Charters Towers. A potential source of water for the mining operation at Black Jack is water stored in the old mine workings associated with the Stockholm shaft which was used to mine the Stockholm and Cross reefs. The Stockholm shaft is approximately 2 km from the Black Jack Mine.

Water from the Stockholm shaft will come partly from storage in the old mine workings and partly from aquifers feeding those workings provided that such aquifers exist. In order to assess the ability of the old mine workings at the Stockholm shaft to supply significant quantities of water, it is necessary to estimate both the volume in storage and the potential inflow from aquifers in the surrounding geologic formations. The quantity of water in storage could be assessed by inspection and calculation of volumes from plans of the old mine workings provided that such plans were available and accurately dimensioned and that there have been no caveins which effectively block the flow of water to the shaft from which dewatering occurs. To help estimate the quantity of water in storage but more particularly the potential inflow from aquifers, a pump test was conducted at the Stockholm shaft.

2. TEST DESIGN

The main shaft at the Stockholm site is still open and, with the aid of a platform and support cables a pump was suspended in the shaft below water level so that pumping could occur. The pump powered by a portable electric generator was mounted in the shaft and the outlet from the pump was by way of two black polythene pipes discharging the water over 100 m away into a natural gully leading away from the mine shaft area.

Bores were drilled to monitor water levels away from the shaft itself. In all four bores were monitored for water level changes during the course of pumping. Two of these bores were intended to intersect old stopes of the Stockholm workings. Three of the monitoring bores were in the direction of the main mine workings relative to the shaft while the other was relatively close to the shaft on the side away from the mine workings. A plan of the area giving the location of the shaft and monitoring bores is shown in Figure 1.

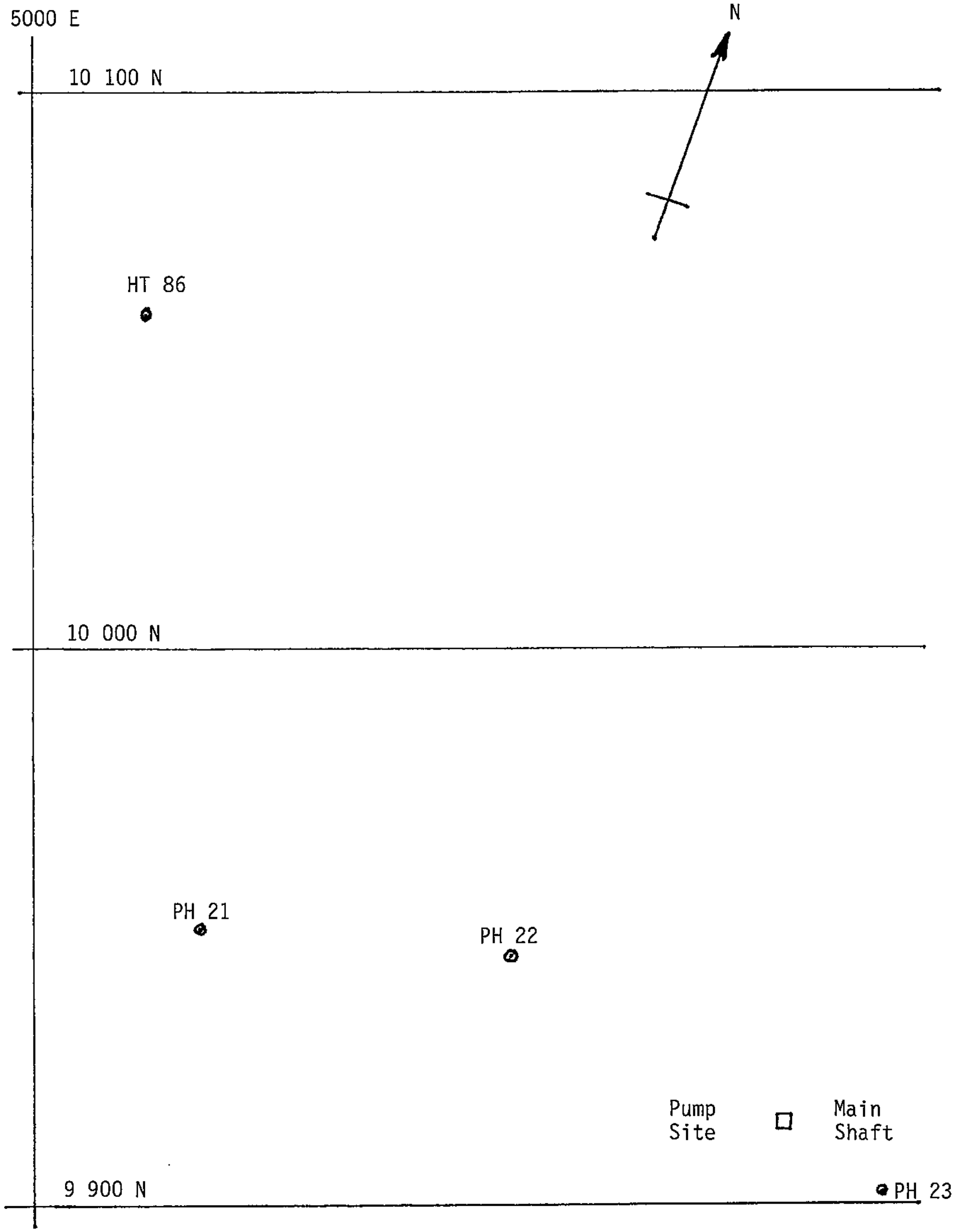

FIGURE 1 PLAN OF PUMP TEST LOCATION

The pump used was located at approximately 30 m below the water level and its capacity was initially about 9 L/s. As the water level declined during the course of the test, the pumping capacity was reduced so that at the end of the test it was approximately 6 L/s. Pump discharge rates were measured with the aid of an in-line flowmeter fitted into the 75 mm nominal diameter outlet pipe. An orifice meter was used to check the flowrate at one particular stage during the test.

Water levels were measured both manually and with an automatic datalogger which recorded pressures measured with a pressure transducer. The manual water level measuring device was a standard commercial instrument causing closure of a circuit when probes intercepted the water, resulting in a noise and a light flashing. This instrument was used to measure water level drops in both the main shaft from which pumping occurred and in the monitoring bores. The automatic datalogger (which had a range of approximately 0-10 m of water head above the instrument) was inserted in the water at the shaft and was lowered twice during the course of the pump test. This instrument was self-contained in that a circuit board on which the data was recorded was housed within a PVC watertight container which was lowered into the water in the shaft. The pressure sensor of the transducer was open to the water in the shaft and the pressures monitored by it were then recorded initially at half minute intervals for approximately three days. At that stage the datalogger was retrieved and the data extracted from it onto a microcomputer, following which the datalogger was reinitialised and placed back in the shaft for monitoring of water levels at half hour intervals for a further approximately nine days.

Pumping commenced at approximately 3.30 pm on Friday, 13 May, 1988 and was discontinued at approximately 3.30 pm on Sunday, 15 May, 1988. Water levels were continually monitored during the recovery period as well as during the pumping period as indicated above. Water level measurements have continued up until 3 June, 1988.

3. INTERPRETATION OF RESULTS

In order to evaluate the parameters governing the rate of drawdown in the shaft under the influence of pumping, assumptions had to be made about the nature of the aquifer supplying water to the shaft. The model assumed was one involving a confined aquifer supplying water to the old workings from the surrounding country rocks, and one in which the old workings were hydraulically connected to the shaft from which pumping occurred. Once the model had been assumed it was possible to apply mathematical inversion techniques to determine the values of the parameters which enabled predictions from the model to fit most closely with the measured drawdowns in the shaft and monitoring bores. The details of the interpretation and the nature of the model assumed are given in Appendix A, which also provides tables of the best estimates of relevant parameters together with the parameter range corresponding to a given confidence interval for each of those parameters.

Once parameters were obtained it was possible to apply them in a steady state asymptotic model to predict the long term inflow to the old mine workings on the assumption that there would be adequate storage of water in the regional aquifer lying within the country rocks to maintain its inflow. The pump test results enabled a reasonable estimate to be made of the transmission properties of aquifers feeding the old mine workings. The regional aquifer storage properties, however, could not be adequately assessed; two of the bores (HT86 and PH23 in Figure 1) which were monitored showed practically no change in water level during the test, suggesting that they were not necessarily indicative of water level behaviour in the regional aquifer, while the other two (PH21 and PH22) appeared to reflect the behaviour of the water in the old stopes and in a local aquifer comprising fractures very close to the stopes rather than in the more extensive regional aquifer. This illustrates an inherent problem in attempting to assess yields of fractured rock aquifers because of the random nature of connections from one part to another.

Using the "best estimate" parameters from set 2 in Table A3 and substituting in eq. (3) in Appendix A, yields a value for Q, the steady rate of inflow into the mine, corresponding to a specified drawdown s_m. For s_m of approximately 26 m, the inflow into the mine is calculated to be 3.8 L/s, the required average annual supply rate for Black Jack Mine. This rate can only be expected provided that the aquifers feeding the shalf do not intersect the mine above the level to which the water is drawn down by pumping. A perusal of the bore logs for the monitoring bores did not provide any firm evidence as to the vertical location of significant aquifers.

During the pump test, a maximum drawdown of approximately 16 m was achieved. For this value of s_m, the steady inflow rate to the old workings is estimated to be 2.3 L/s, on the basis of the "best estimate" parameters from Table A3. This would supply only about 73 ML over a year and would leave a deficit of approximately 50 ML to be supplied from storage or from other sources.

If, from Table A3, the parameters from the 67% confidence interval are chosen to give the maximum drawdown for a steady discharge of 3.8 L/s, this drawdown is 33 m. Similarly if parameters are chosen to give minimum drawdown for a 3.8 L/s discharge, this drawdown is 21 m. Hence a drawdown of approximately 30 m would seem to be a reasonable estimate of that required to produce a steady inflow of 3.8 L/s provided that storage in the regional aquifer is sufficient to maintain this rate for an extended period.

Estimates of the volume of water contained in storage in the old workings in the Stockholm site were obtained from perusal of old mine plans together with assumptions about the average cross sectional area of the openings. Estimates were also made based on an extrapolation from the volumes assessed from the drawdown and recovery phases of the pump test. Because of the many assumptions which have to be made in both calculations, there is a wide range in the possible values, namely 20 ML to 50 ML of storage. It is clear, nevertheless, that the major part of an annual water supply of 120 ML would therefore have to be met from aquifer recharge of the old mine workings rather than from storage in those workings.

A simplified analysis of the results was also made for purposes of comparison with the more sophisticated mathematical approach. The total water level change of approximately 16 m was divided into 2 m increments. For each increment, the amount of water pumped during the drawdown phase was calculated. The time required for the water level to fall over each 2 m increment on drawdown and the corresponding time for the water level to rise during recovery were also determined. On the assumption that, for any particular 2 m interval, the inflow rates from the surrounding aquifers would have the same average values on drawdown as on recovery, estimates of those values could be made. This procedure also enabled estimates to be made of the volumes of water contained in storage in the same intervals. The results obtained from this approach were in reasonable agreement with those obtained from the mathematical inversion process. It should be noted, however, that a similar model structure was assumed in each case.

4. CONCLUSIONS

The results of the pump test indicate that inflows to the old mine workings are likely to be significant in comparison with the required supply rates of water for the Black Jack Mine operations. On the basis of the model assumed and the parameters estimated for that model, it is calculated that a steady discharge of approximately 2.3 L/s would enter the old workings when the drawdown in the shaft corresponds to the maximum value reached during the course of the pump test, namely about 16 m. Using the same model and parameters and assuming that the aquifer response to drawdown can be predicted over a further 15 m of water level drop, the calculations suggest that an inflow rate of approximately 3.8 L/s could be produced at a total drawdown of approximately 30 m. This inflow rate should be sufficient to provide the required water supply for the Black Jack Mine operations. It has not been possible, however, to assess accurately the amount of storage in surrounding regional aquifers replenishing the water drawn from the old mine shaft. Assessment of storage would require pumping and monitoring over a longer time period.

It appears likely that the major part, if not all, of the required water for Black Jack operations could be obtained from the Stockholm shaft at least for a considerable period of time. It is recommended that pumping from Stockholm proceed, and that water levels as well as pump discharge rates be carefully monitored so that additional data can be accumulated and used to assist in a more accurate prediction of the capacity of the shaft to supply water on a long term basis.

APPENDIX A

INTERPRETATION DETAILS

A.1 General

An analysis of the field data [see Figs. A1(a) to A3(d)] reveals the following points:

1. The water level response in HT86 is almost zero; this has not been plotted because a change of only 140 mm occurred over the whole duration of the test.

2. A few measurements of the water level in the hole drilled next to the shaft were taken once the water level in this hole had stabilized following drilling. Again, it did not vary with the water level in the shaft.

3. In contrast, the water level in PH21 followed that in the shaft almost exactly. During both pumping and recovery the drawdown in this hole was always about 30-50 mm less than that in the shaft. This indicates that water flowed from the vicinity of hole PH21 to the shaft even when the pump was switched off. The conclusion to be drawn from this is that water flows from the rocks into the workings intersected by PH21, i.e. the intersection of the aquifer by the mine workings lies closer to PH21 in the shallower part of the workings, than to the shaft and the deeper parts of the mine to which it is connected.

4. Hole PH22 obviously intersects the aquifer drained through the mine by pumping. Its water level is always above that in PH21. Its drawdown follows that of PH21 during pumping, though with a head change difference of about 1 m. Its recovery lags behind that of PH21, though the drawdown difference reduces with time.

The data of Figs. 1-3 cannot be fitted to a model that assumes radial symmetry. This is not surprising in view of the elongated shape of the stopes that are thought to be connected to the aquifer. Also, it is unlikely that much inflow from the ground into the shaft occurs. Its surface area is much smaller than that of the stoping near PH21; also, PH23 drilled nearby was nearly dry. As well, as has been mentioned, the recovery data indicates that water flows into the old workings around the shallow stopes. Hence the drawdown data taken in

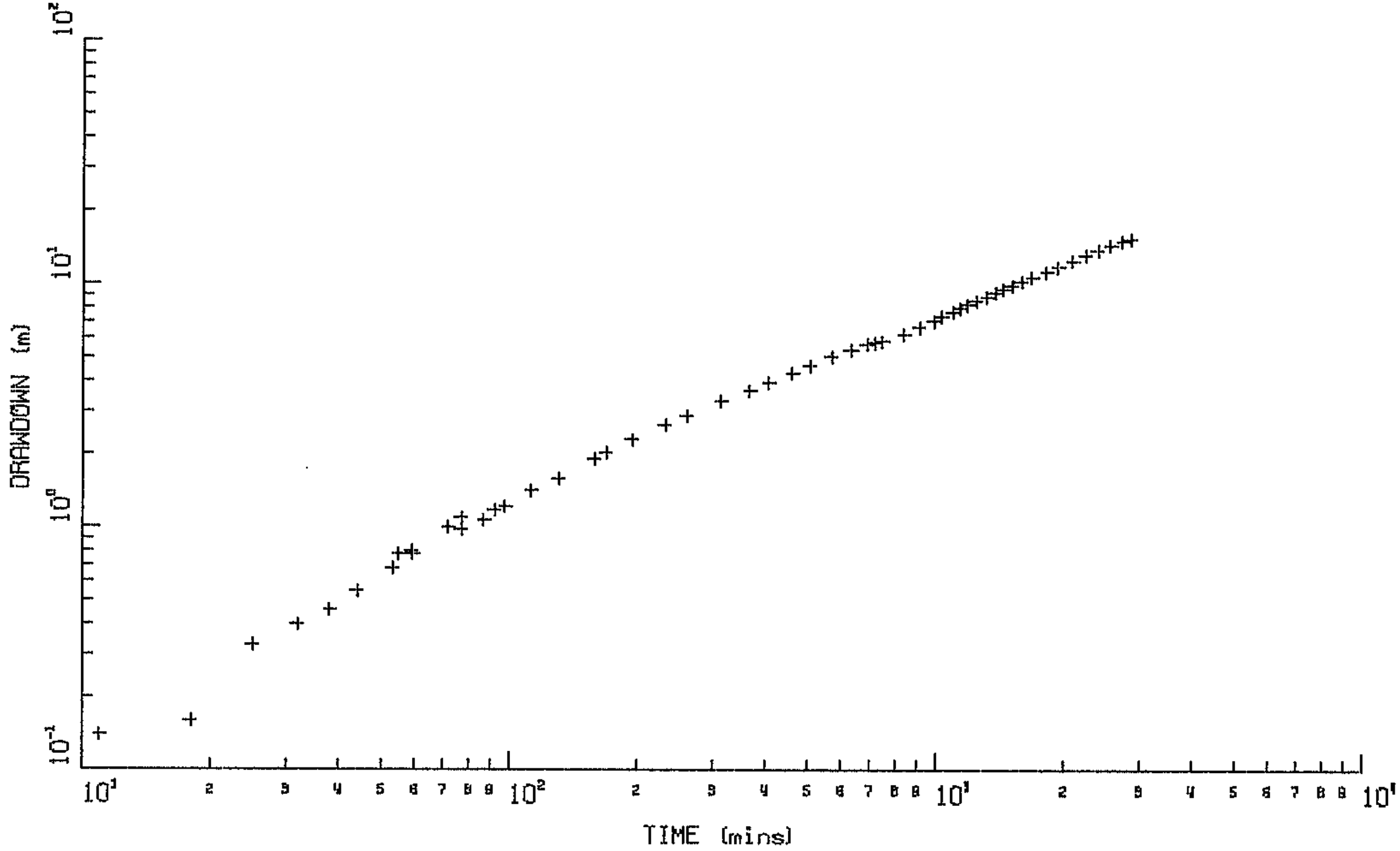

Fig. A1(a) Log-log plot of drawdown in the shaft while pumping.

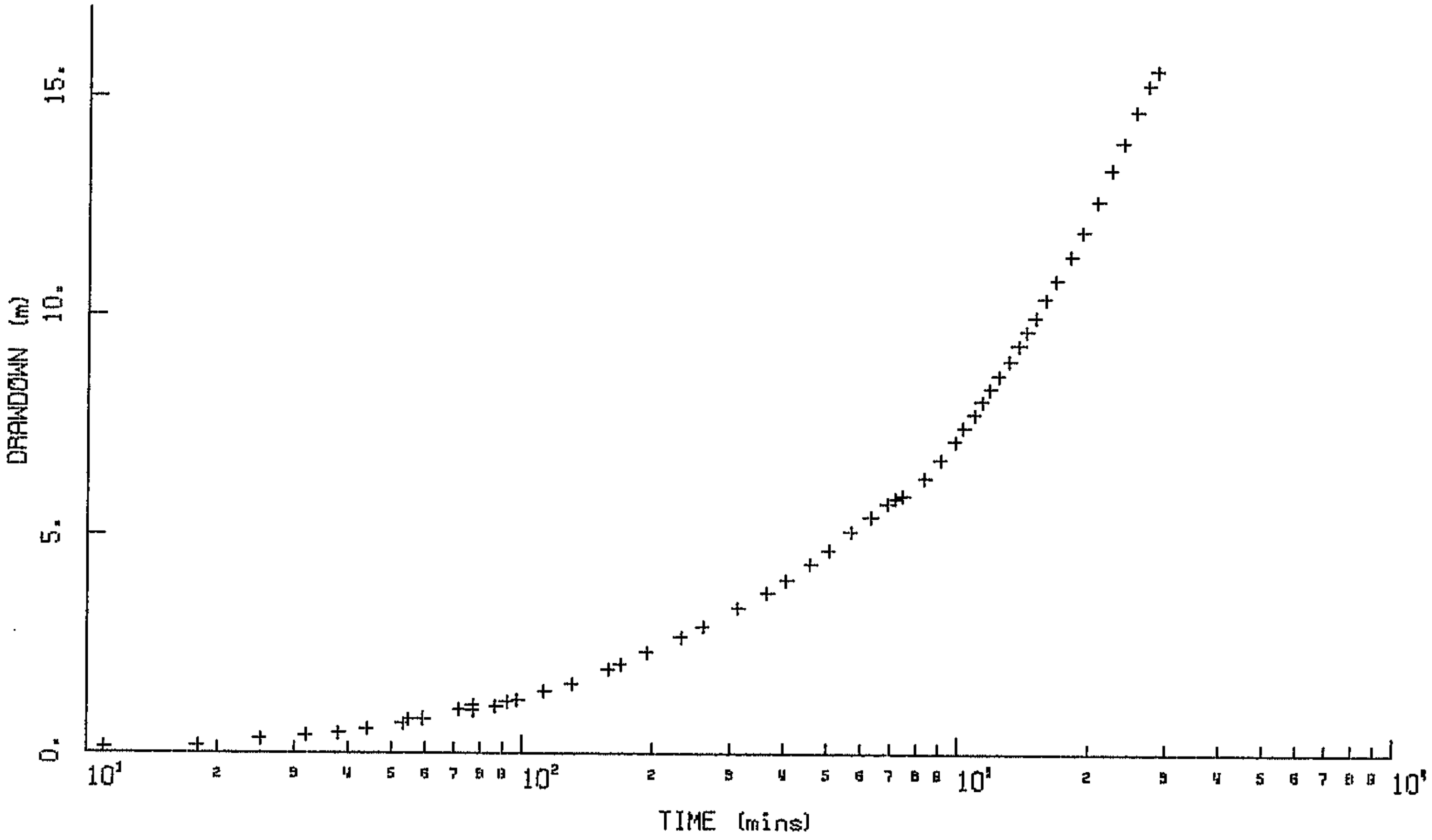

Fig. A1(b) Semilog plot of drawdown in the shaft while pumping.

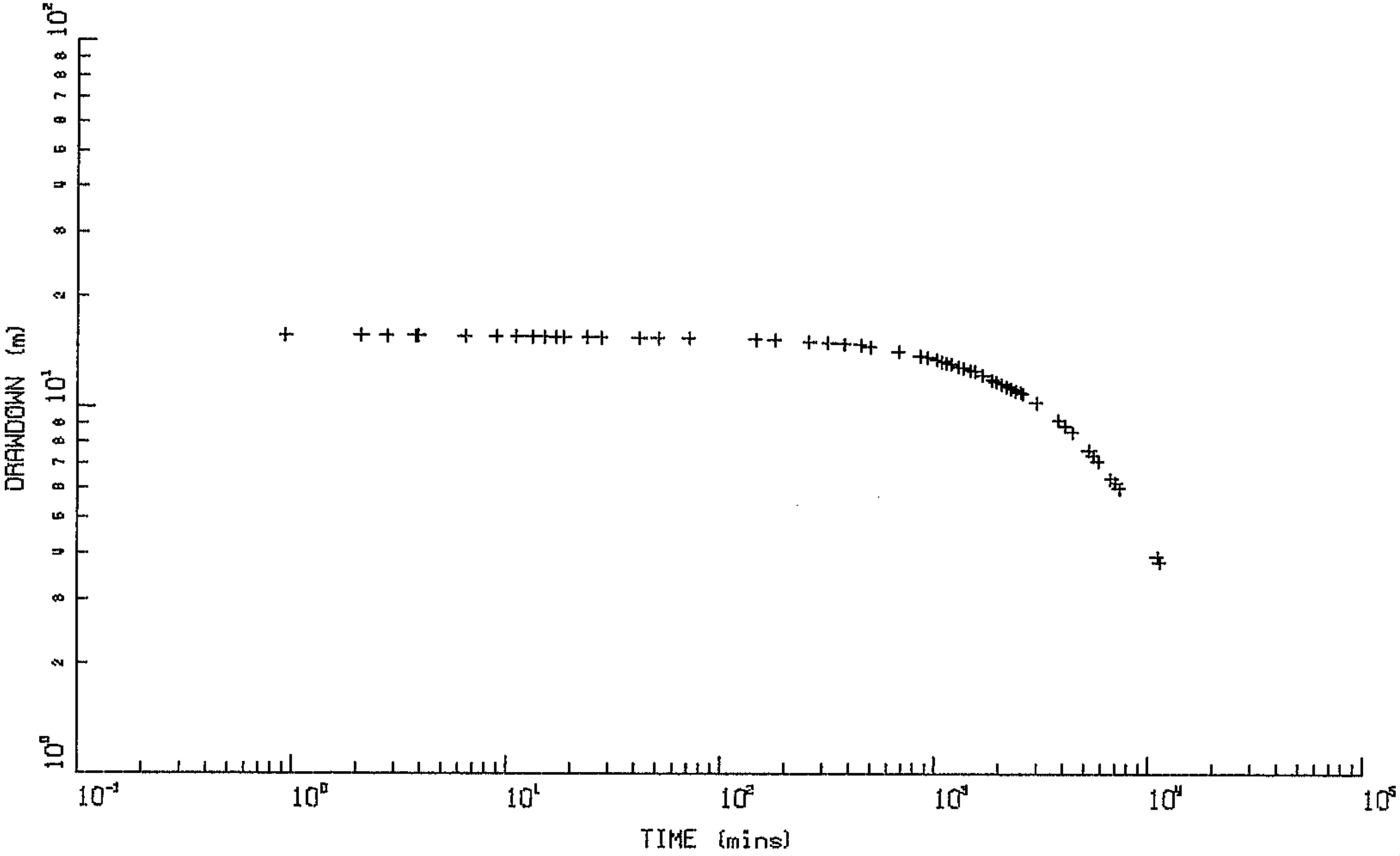

Fig. A1(c) Log-log plot of drawdown in the shaft during recovery.

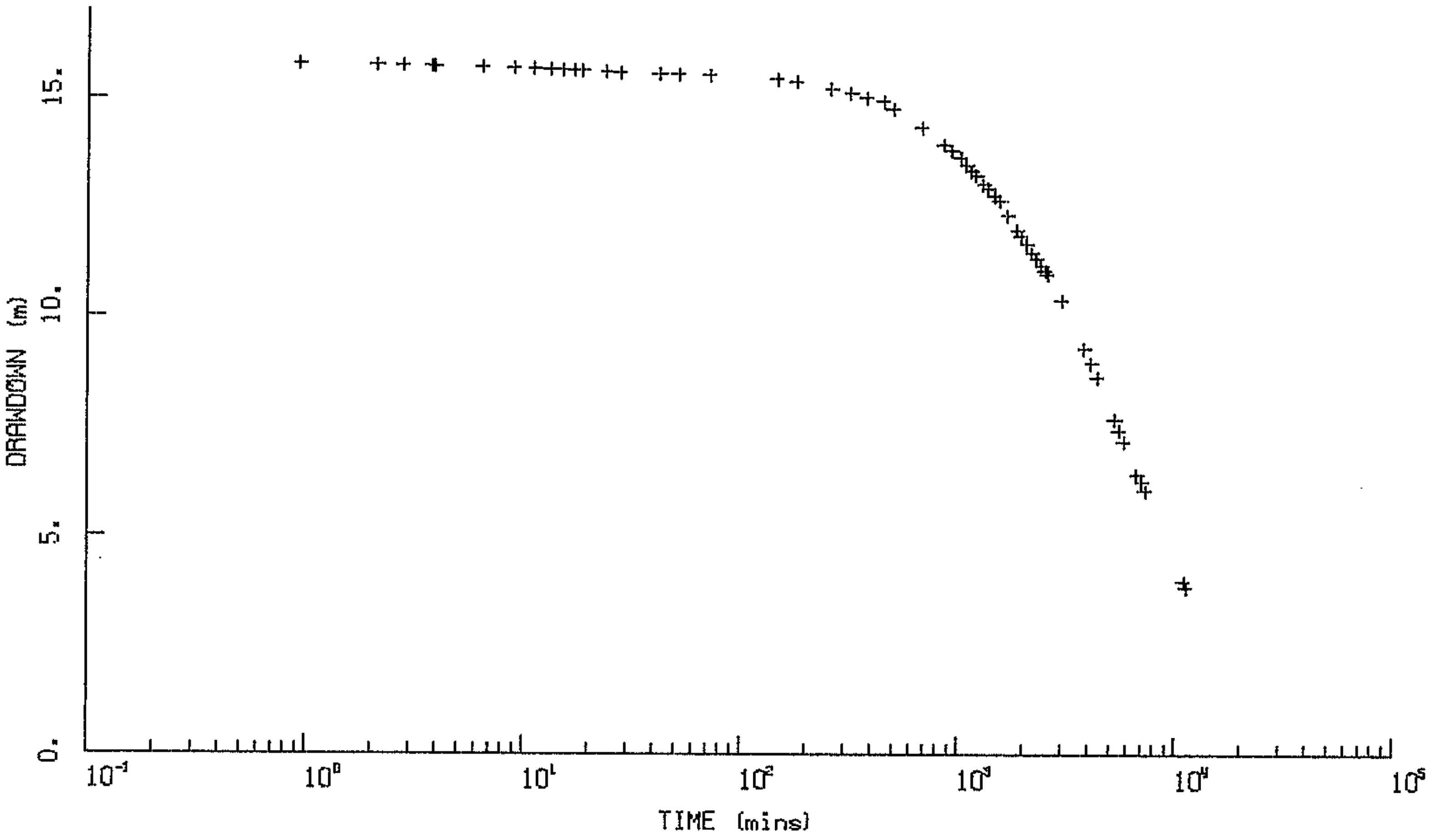

Fig. A1(d) Semilog plot of drawdown in the shaft during recovery.

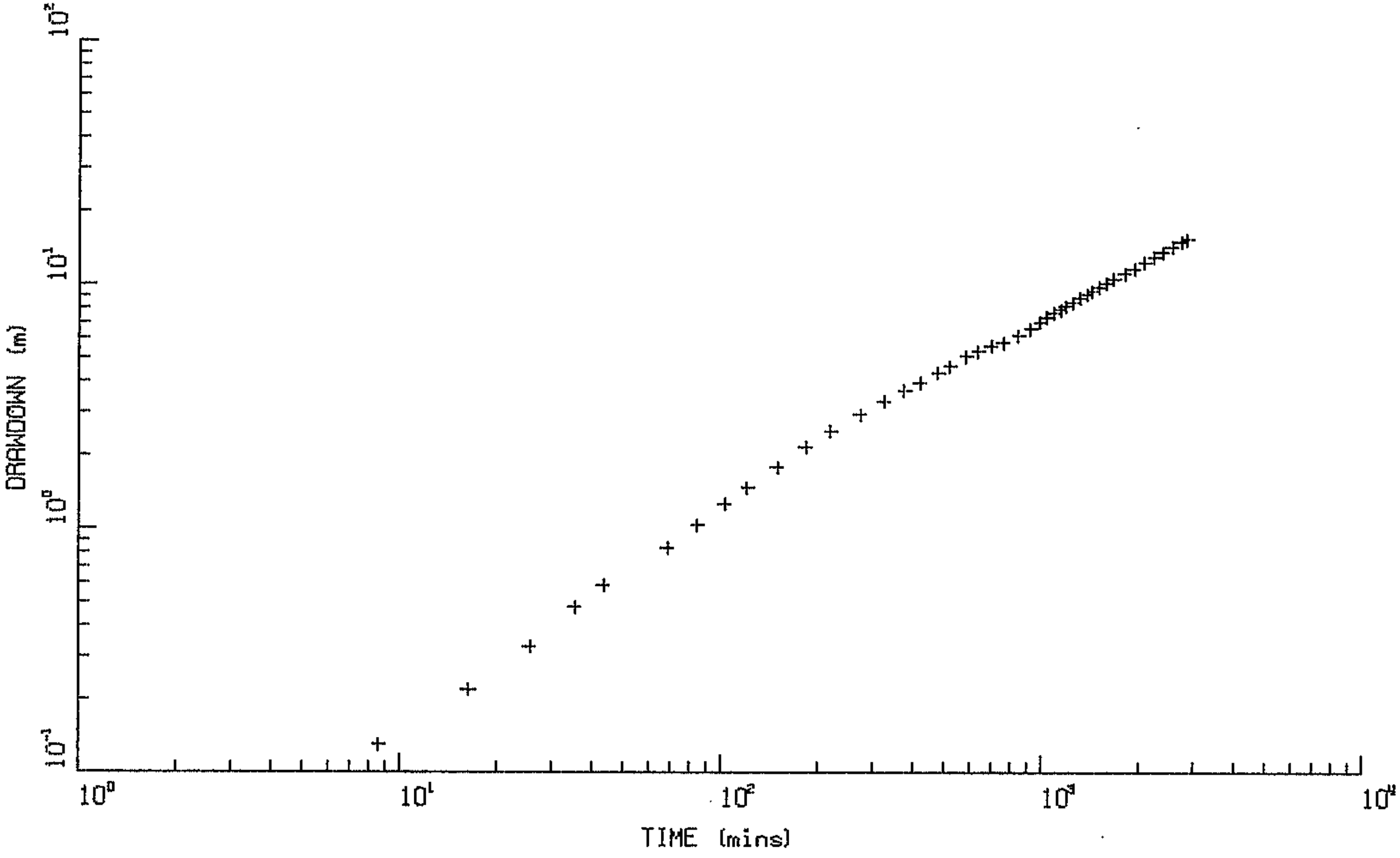

Fig. A2(a) Log-log plot of drawdown in PH21 while pumping.

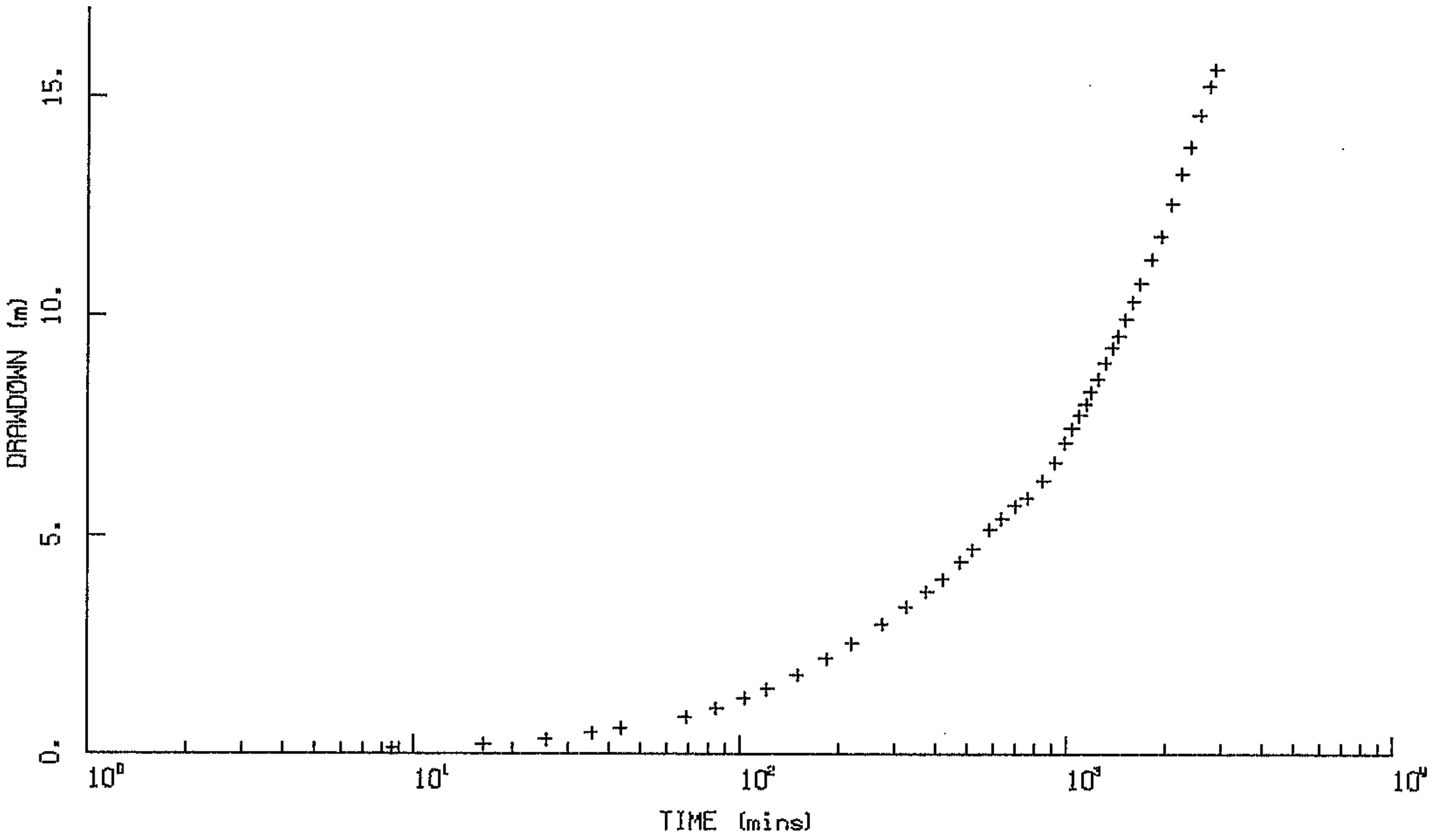

Fig. A2(b) Semilog plot of drawdown in PH21 while pumping.

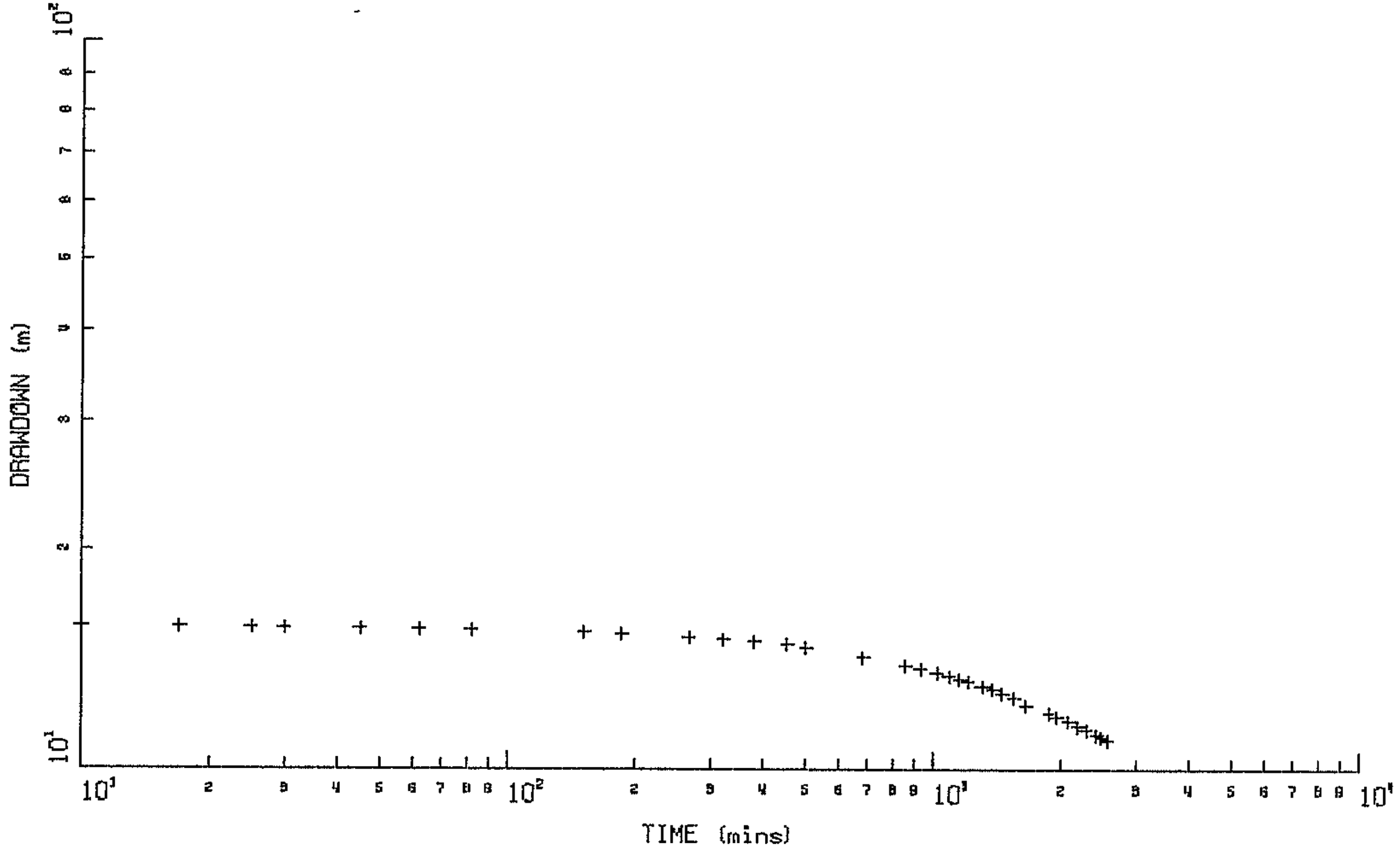

Fig. A2(c) Log-log plot of drawdown in PH21 during recovery.

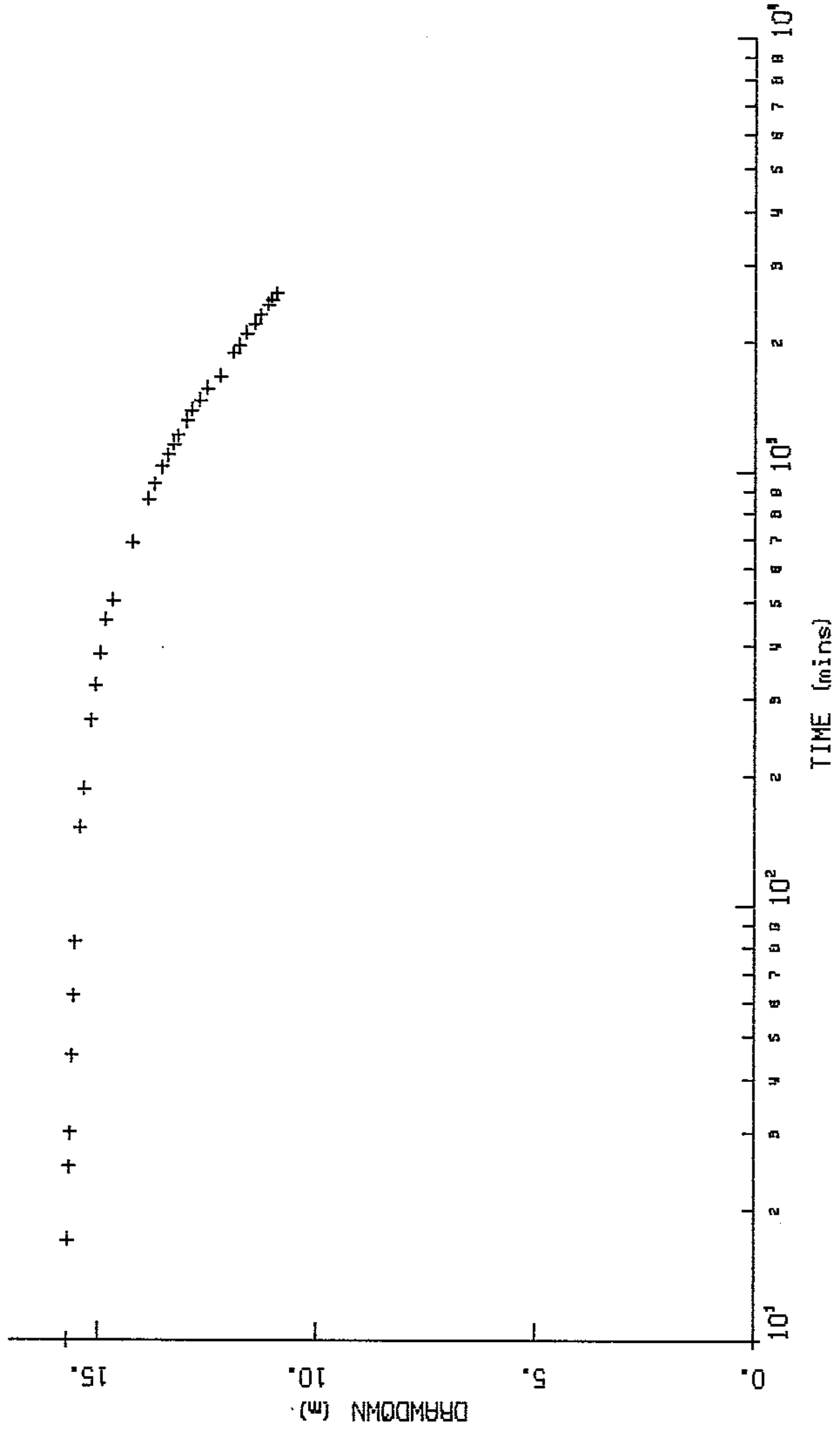

Fig. A2(d) Semilog plot of drawdown in PH21 during recovery.

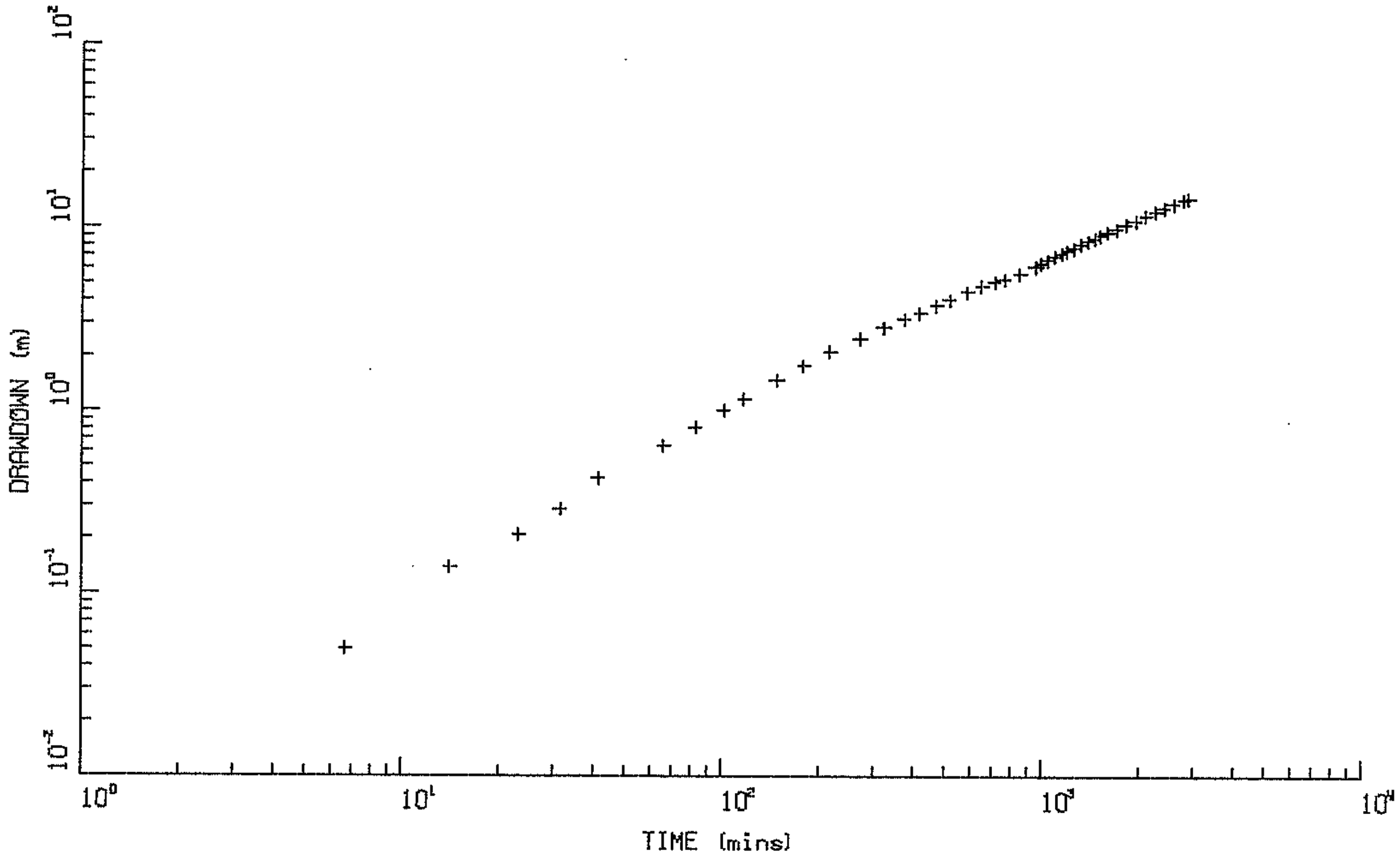

Fig. A3(a) Log-log plot of drawdown in PH22 while pumping.

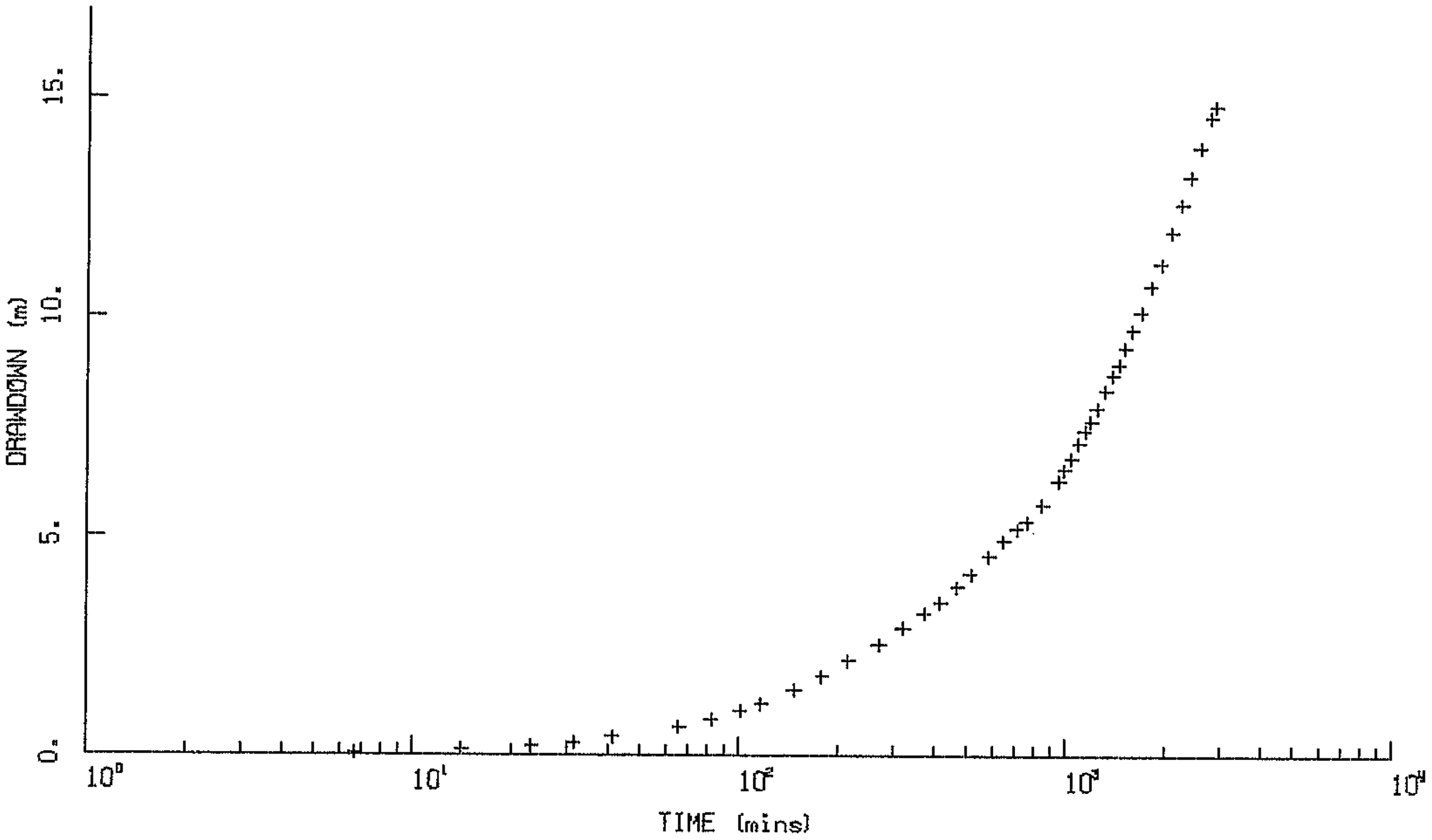

Fig. A3(b) Semilog plot of drawdown in PH22 while pumping.

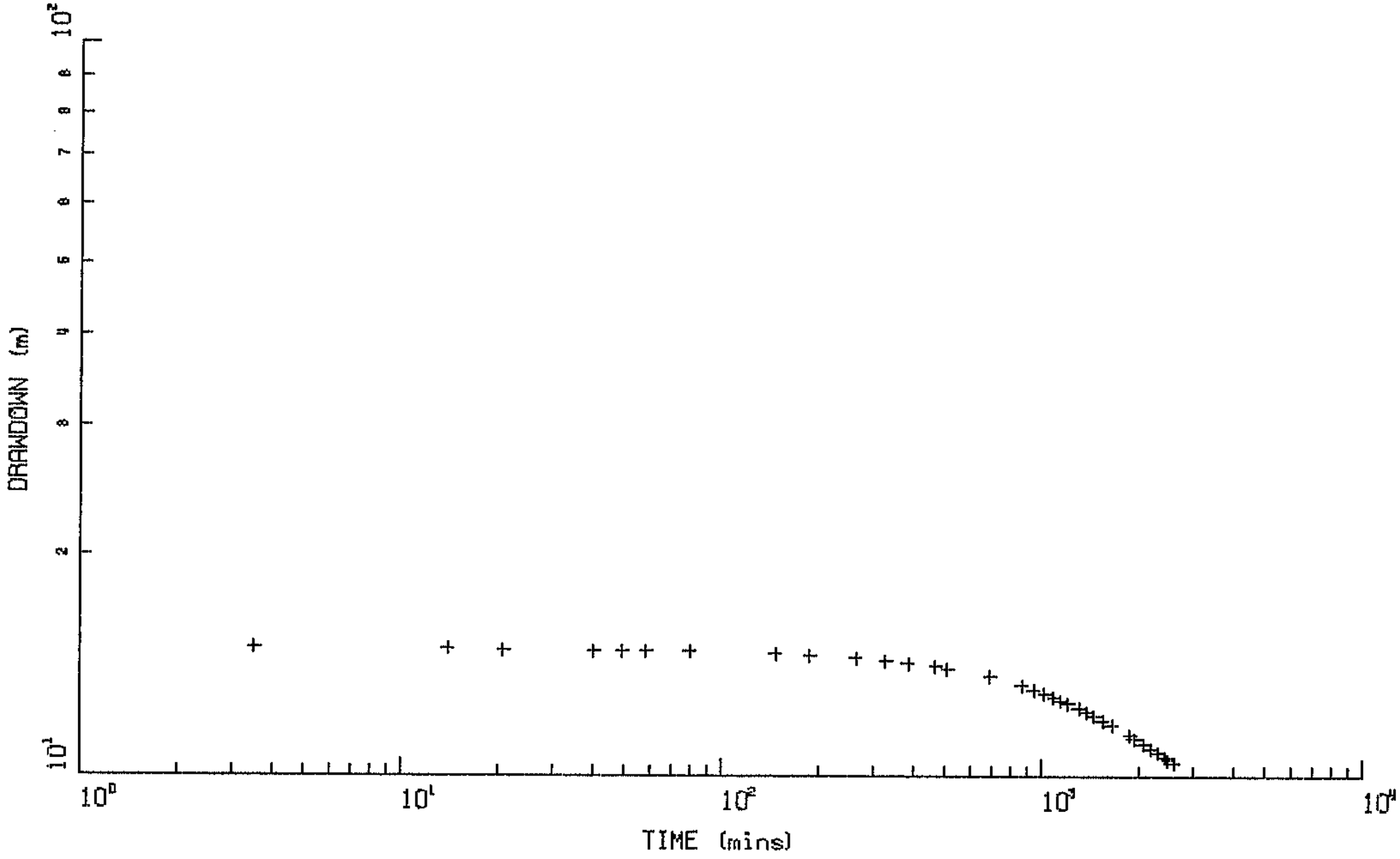

Fig. A3(c) Log-log plot of drawdown in PH22 during recovery.

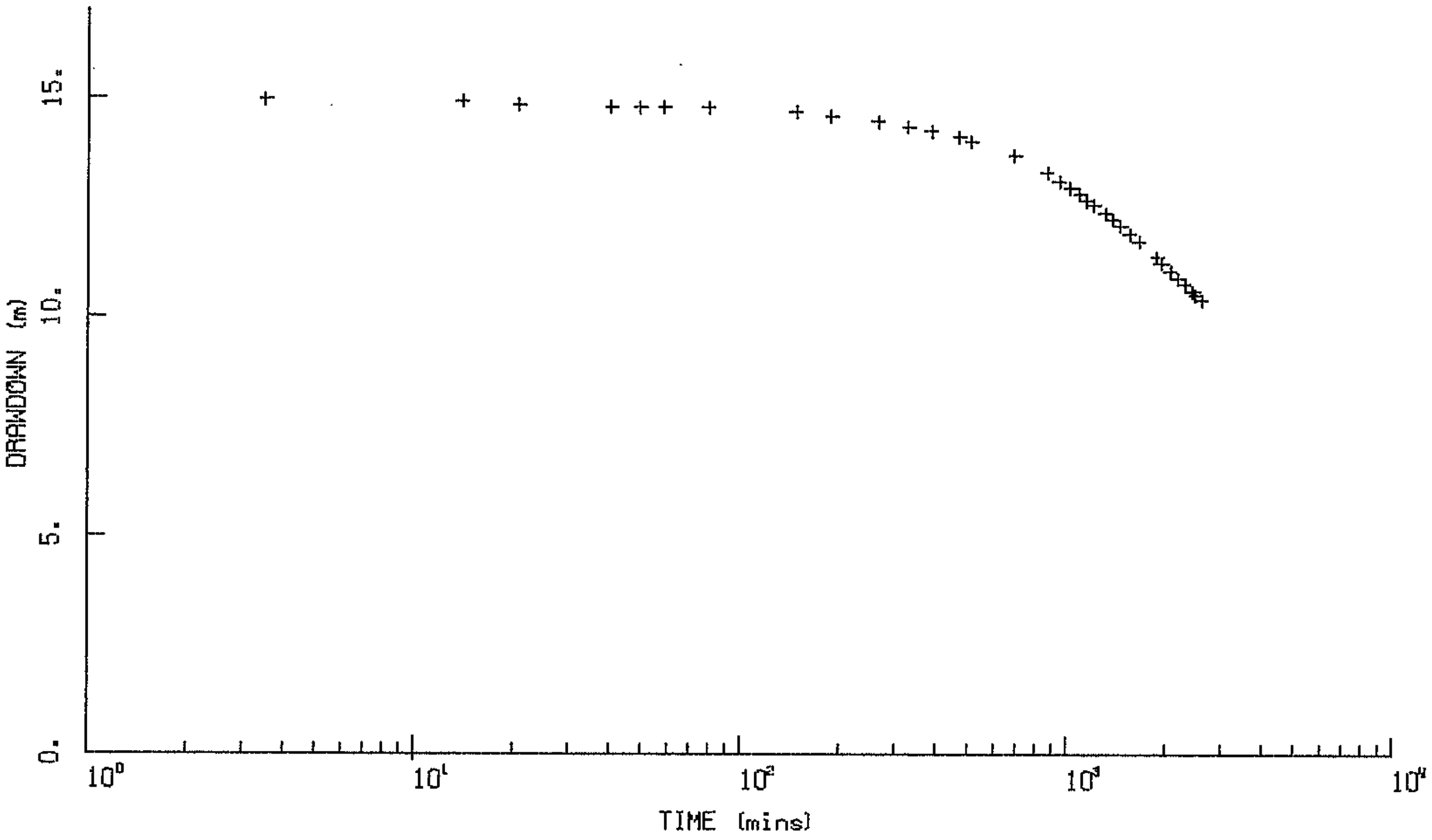

Fig. A3(d) Semilog plot of drawdown in PH22 during recovery.

the shaft were not used directly in the interpretation procedure described below. The data was used, however, to supplement the PH21 data where the latter was missing, i.e. during that part of the recovery phase when measurements were not taken down hole PH21, but where the data logger was still in the shaft. This was possible because the water levels in the shaft and in PH21 were always so close together, as has been mentioned.

A.2 The Model

A linear flow model, taking account of the elongated nature of the interface between the stopes and the ground, was developed to describe the drawdown information in PH21 and PH22. It should be emphasized that, as far as replicating ground conditions goes, this model is a first approximation only. A complete description of the flow regime in the minesite would require water level measurements at a large number of bores together with a complete knowledge of the locations, dimensions and extent of infilling of all the old stopes. However such a 1-D model does serve to reproduce the main properties of the flow regime. Its salient features are (see Fig. A4) as follows:

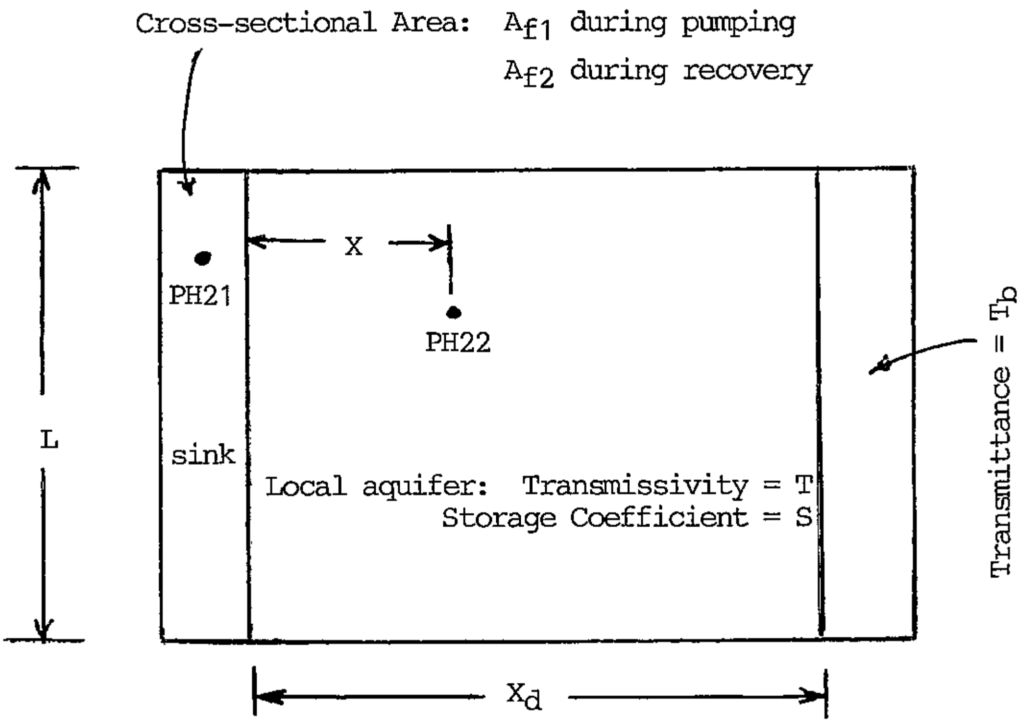

Figure A4. Flow model for the Stockholm mine site.

1. An elongated sink, intersected by PH21, out of which the water is pumped, in this case via the shaft; flow is uniform into the sides of this sink at a rate of Q/L per unit length. Note that although the sink contains PH21 in Fig. A4, it need not necessarily coincide with it at the minesite. It is only required that PH21 be hydraulically connected to the sink by old workings.

2. The sink has a cross-sectional area of A_{f1} while it is being pumped and of A_{f2} during recovery. As the water level at the start of recovery is more than 15 m lower than that at the start of pumping, the difference in these areas accommodates the possibility of variable stoping cross-section with depth. The effect of the storage associated with these cross-sectional areas affects predominantly that data taken soon after pumping or recovery begins. Hence allowing for a difference between A_{f1} and A_{f2} allows for closer fitting of the "early" portion of the drawdown and recovery curves.

3. Linear flow takes place through an aquifer of horizontal width L, transmissivity T and storage coefficient S; confined conditions are assumed. Actually, the products L x T and L x S determine the aquifer response, and only these can be determined from the model unless L is known beforehand. Borehole PH22 is situated at a distance X from the sink (though not necessarily from PH21).

4. The aquifer has a horizontal extent perpendicular to the sink of X_d. At this distance, a transmittance of T_b connects the aquifer to an infinite reservoir (the water in the regional aquifer set in the country rocks). T_b is defined as the flow through the barrier per unit head drop across it. This property represents the ability of the region to supply long term flow of water into the mine. Note that as it also represents the rocks surrounding the local aquifer, it could be argued that a storage term should be included. It was decided not to do so because

   (a) as none of the bores are located in these rocks it would be virtually impossible to determine the magnitude of the storage term and,

   (b) predictions of inflow to the mine using the model of Fig. A4, will be the upper limit that can be expected based upon the data gathered during the test.

5. Fig. A5 shows the pump discharge from the sink plotted against time. In the model, this is represented by three linear segments defined by the samples shown in Table A1.

Table A1: Endpoints of linear segments used to represent pump discharge.

Time (mins)	Discharge (L/s)
0	9.47
243	8.91
1520	7.54
2898	6.24
>2898	0

A.3 Mathematical Formulation

It can be shown that the Laplace transform of the drawdown (i.e. s) at a distance x from the sink (including at x = 0) in Fig. A4 is given by

$$\bar{s}(x,p) = A(p)e^{-kx} + B(p)e^{kx} \qquad (1)$$

where $k^2 = \frac{Sp}{T}$

$$B(p) = \frac{\bar{Q}(p)}{Z(A_f p + kLT) + (A_f p - kLT)}$$

$$A(p) = ZB(p)$$

where $Z = \frac{[kLT + T_b]e^{2kX_d}}{[kLT - T_b]}$

$\bar{Q}(p)$ = Laplace transform of the pump rate and p is the Laplace transform variable.

A_{f1} is substituted for A_f to calculate drawdown during pumping, or to extrapolate the effects of continued pumping after the pump is shut off. The negative of this pumping rate is then superimposed on the solution to simulate recovery; A_{f2} is then substituted for A_f.

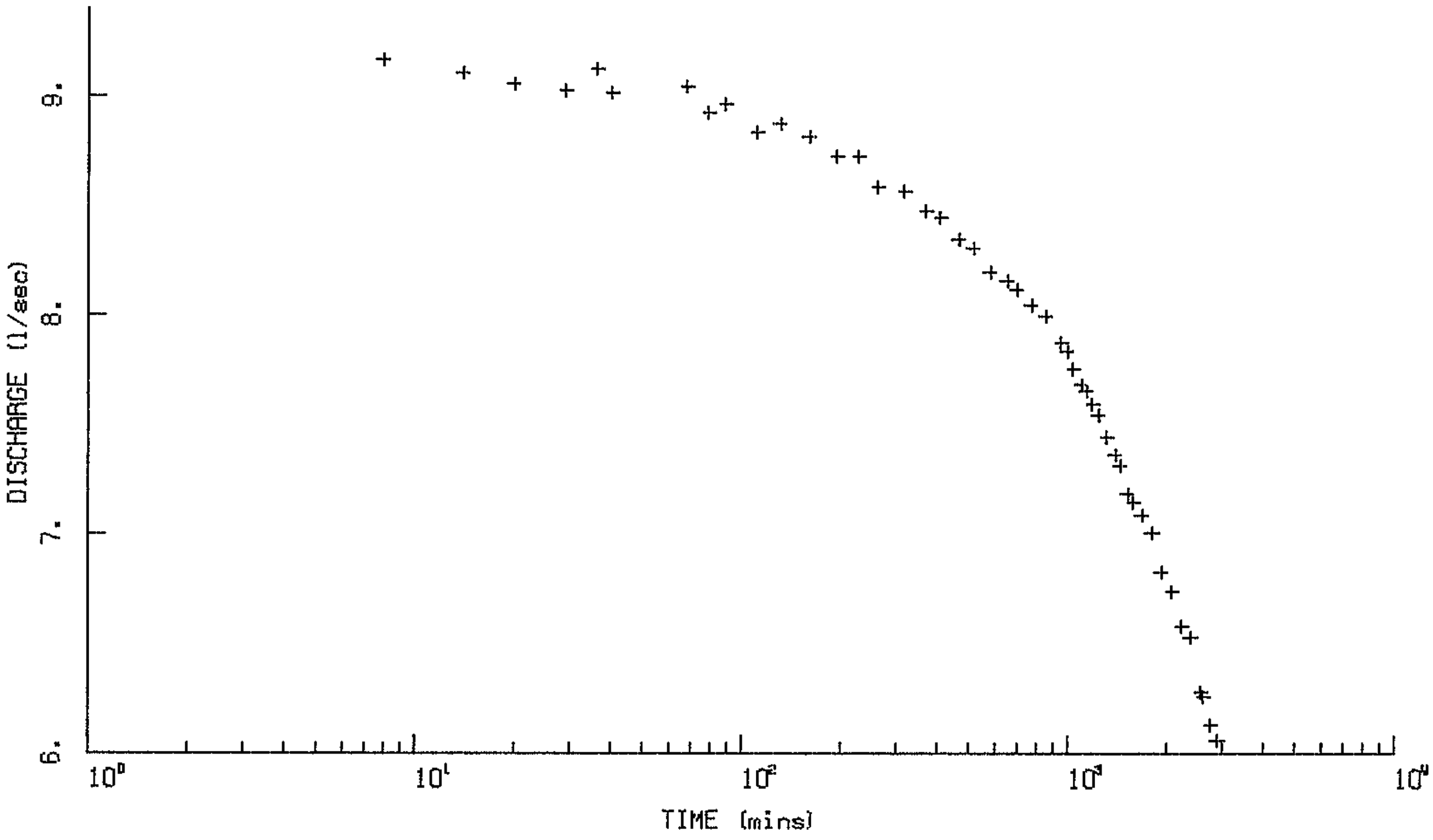

Fig. A5 Semilog plot of pump discharge.

The solution for drawdown as a function of time is obtained from the above equation by numerical inverse Laplace transformation. In the present instance this was achieved by expressing the inverse Laplace transform as a cosine transform, expressing the latter as a convolution integral with a change of variables, and then using a set of filter coefficients to perform the integration. The method is fast, stable and highly accurate.

A.4 Interpretation.

Physical property estimation (i.e. the estimation of the model parameters shown in Fig. A4) was achieved using a numerical inversion program - see Kuczera (1987). This allowed for the estimation of the most likely values of the model parameters, given the field data, together with an estimate of the uncertainties associated with these estimates. Two such estimates of the model parameters were made in this way. For the first, yielding parameter set 1, the drawdown (pumping and recovery) data from PH21 and PH22 were simultaneously inverted; parameter estimates and the approximate 67% confidence limits (one standard deviation) are shown in Table A2. In the second case, yielding parameter set 2 given in Table A3, only the data from PH21 was inverted. Figs. A6(a) to A6(d) show the field data together with drawdowns predicted using the model with parameter set 1. Figs. A7(a) and A7(b) show the PH21 data together with the best-fit model curve using parameter set 2.

Table A2: Model parameter set 1 derived through numerical inversion of PH21 and PH22 pumping and recovery drawdown data.

Parameter	Best Estimate	67% Confidence Interval
X_d	79.1 m	31 m - 200 m
A_{f1}	30.5 m^2	13.5 m^2 - 69 m^2
A_{f2}	34.8 m^2	14.6 m^2 - 83 m^2
T x L	9.77×10^{-2} m^3/s	1.4×10^{-2} m^3/s - 6.8×10^{-1} m^3/s
S x L	5.57×10^{-1} m	2.2×10^{-1} m - 1.4 m
T_b	1.97×10^{-4} m^2/s	1.2×10^{-4} m^2/s - 3.2×10^{-4} m^2/s
X	14.86 m	3.3 m - 43 m

The parameter estimates obtained from the two inversions are consistent in that the best estimates shown in Table A3 all lie within the confidence limits shown in Table A2. The confidence limits in Table A2 are wider, reflecting the fact that compromises in model estimation had to be made in order to fit all the data. This indicates that the model of Fig. A4 is not a perfect replication of reality, as has already been noted. This can also be appreciated from the fact that the fits between model curves and field data are not perfect in Fig. A6.

An inspection of the S x L values from Tables A2 and A3 indicates best estimates of about 6×10^{-1} m. If L is of the order of 200 m, this would give a storativity S, for the aquifer close to the old workings, of approximately 3×10^{-3}. This is relatively high for a confined aquifer and it is possible that an unconfined aquifer in fractured rock may give a better model. There is insufficient data on depth to impermeable base and other necessary parameters to justify attempting to analyse on the basis of an unconfined aquifer. Another possibility is a leaky confined aquifer, but the extra model complexity would not be likely to yield more reliable long term inflow estimates compared with the adopted model.

Table A3: Model parameter set 2 derived through numerical inversion of PH21 data only - pumping and recovery

Parameter	Best Estimate	67% Confidence Interval
X_d	84.2 m	69 m - 108 m
A_{f1}	23.6 m^2	17 m^2 - 33 m^2
A_{f2}	22.1 m^2	14 m^2 - 35 m^2
T x L	1.81×10^{-1} m^3/s	1.1×10^{-1} m^3/s - 3.1×10^{-1} m^3/s
S x L	5.92×10^{-1} m	4.7×10^{-1} m - 7.4×10^{-1} m
T_b	1.57×10^{-4} m^2/s	1.3×10^{-4} m^2/s - 1.9×10^{-4} m^2/s

An inspection of the late-time segment of the PH21 recovery curves from Fig. A6(b), reveals that the model predicts more water entering the mine than seems to be indicated by the field data (remember PH21 is hydraulically connected to the mine); the recovery drawdowns in PH21 are slightly underestimated by the

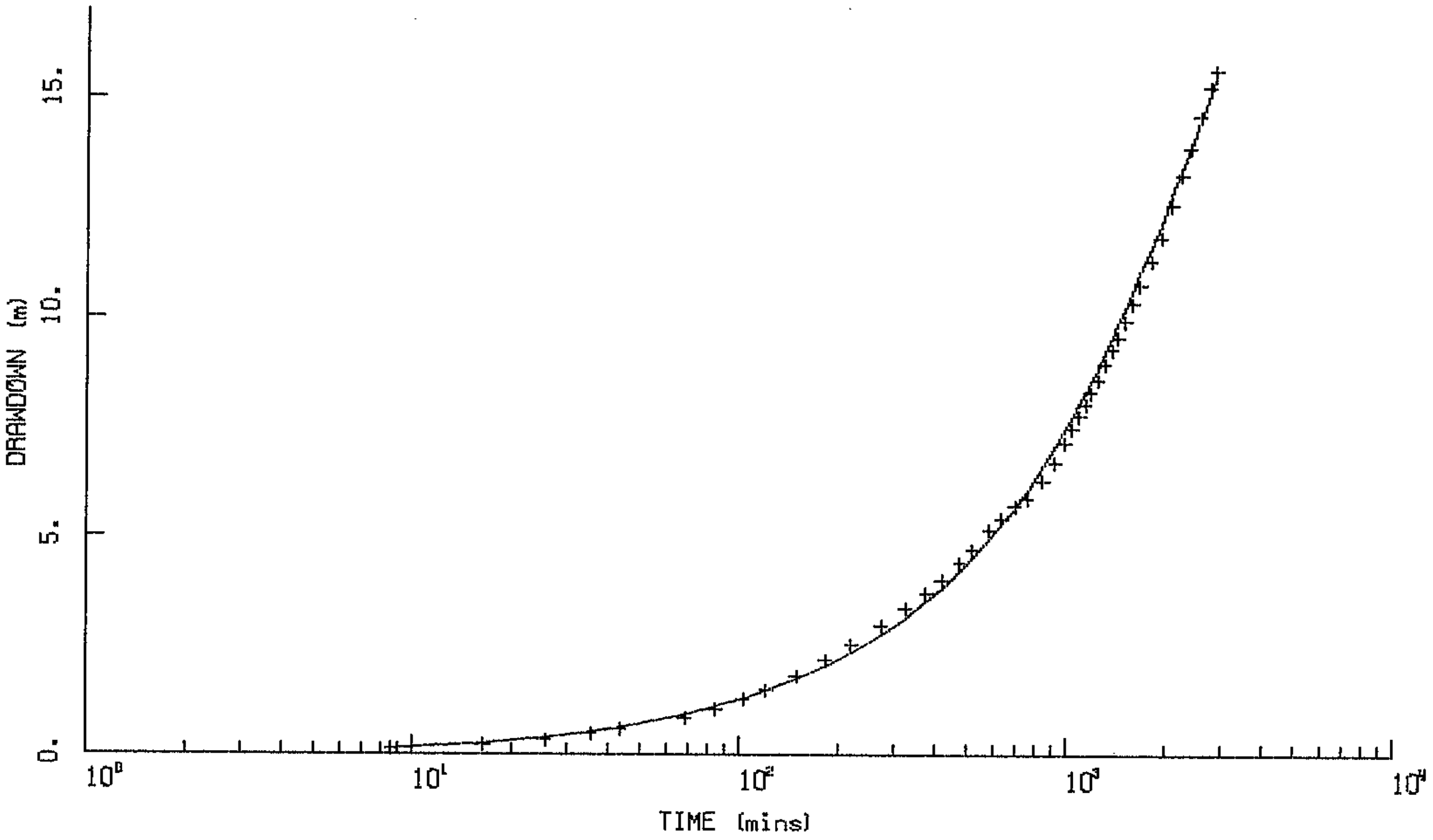

Fig. A6(a) Field and model data (parameter set 1) for PH21 while pumping.

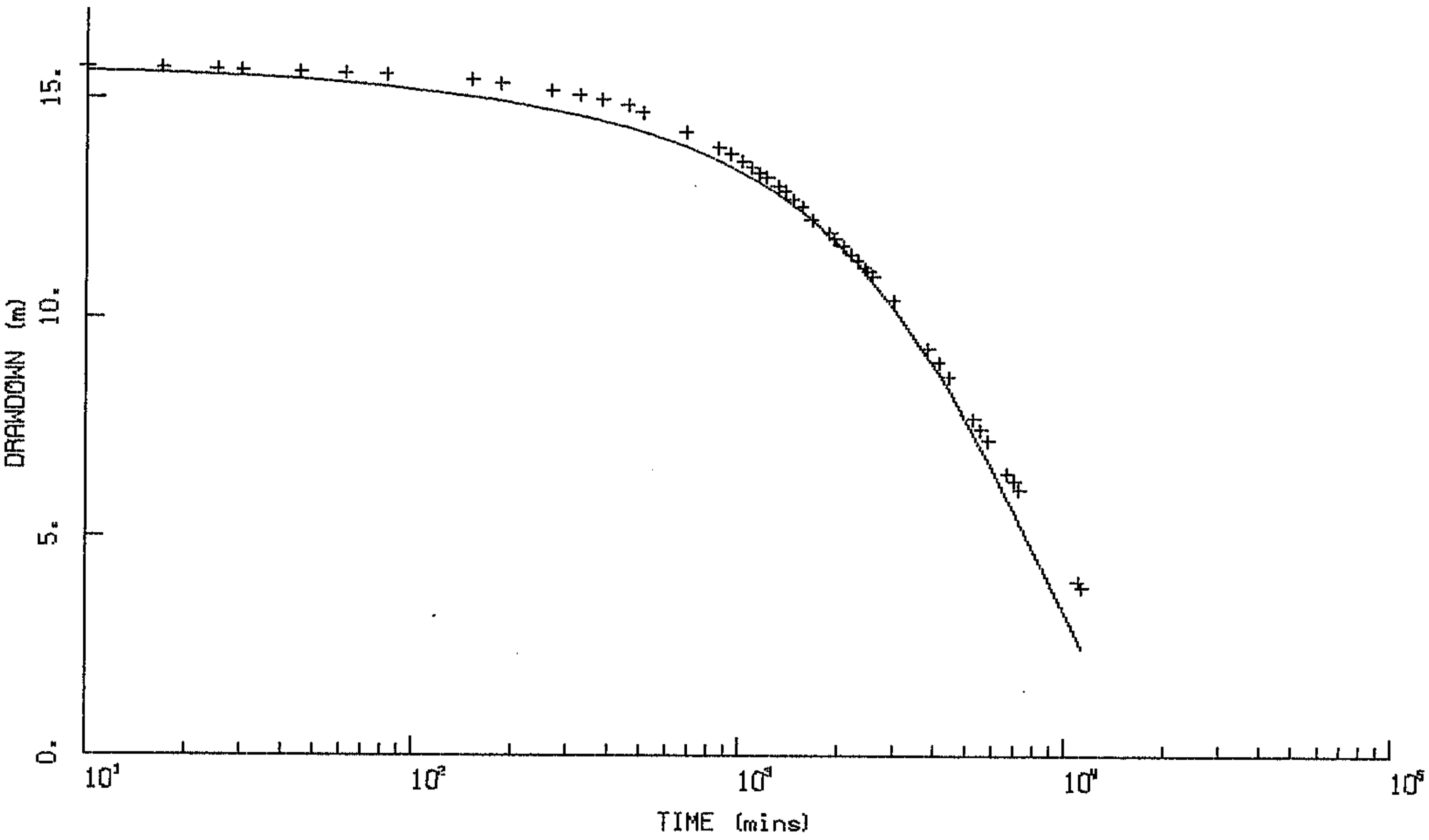

Fig. A6(b) Field and model data (parameter set 1) for PH21 during recovery.

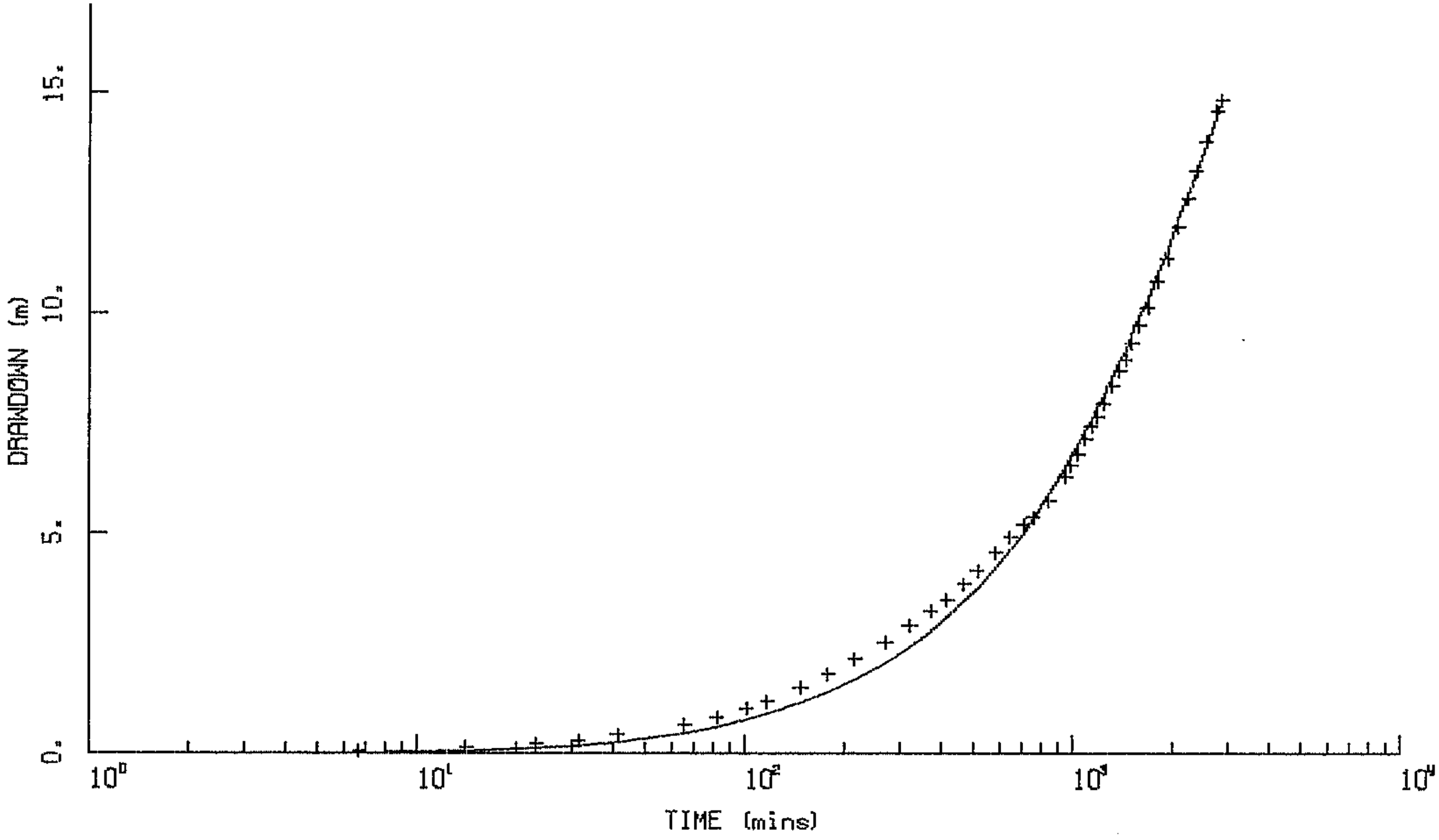

Fig. A6(c) Field and model data (parameter set 1) for PH22 while pumping.

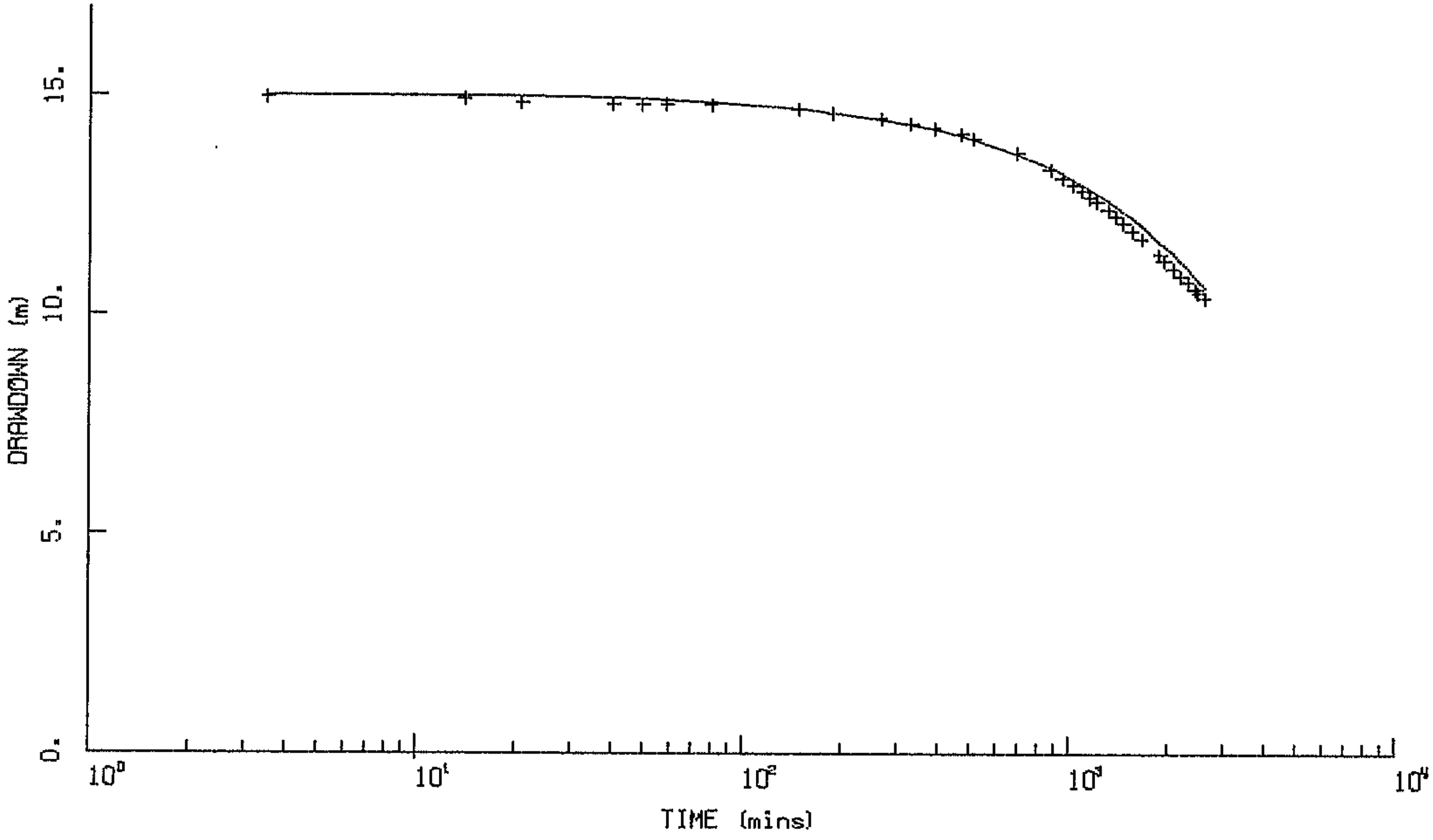

Fig. A6(d) Field and model data (parameter set 1) for PH22 during recovery.

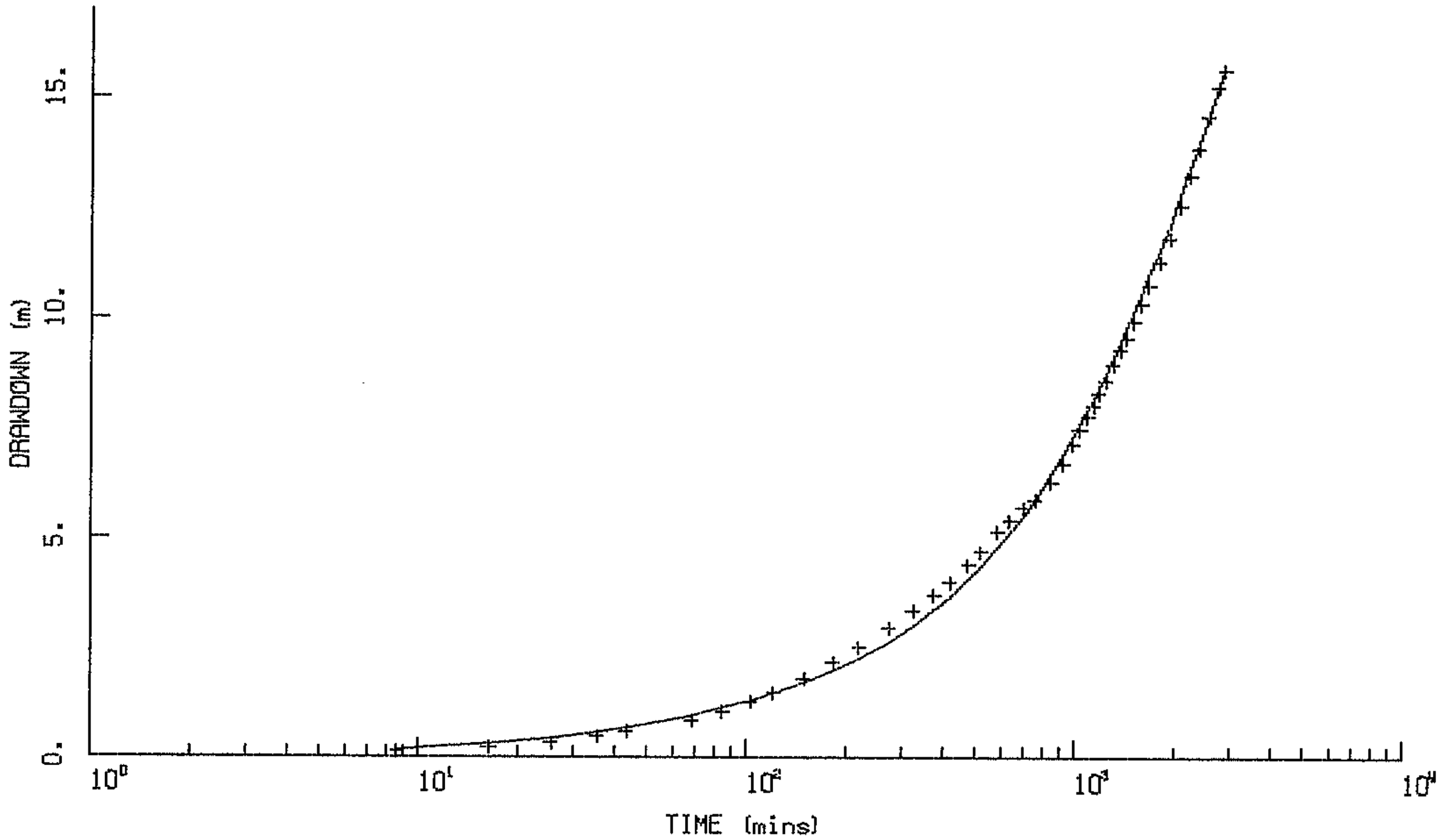

Fig. A7(a) Field and model data (parameter set 2) for PH21 while pumping.

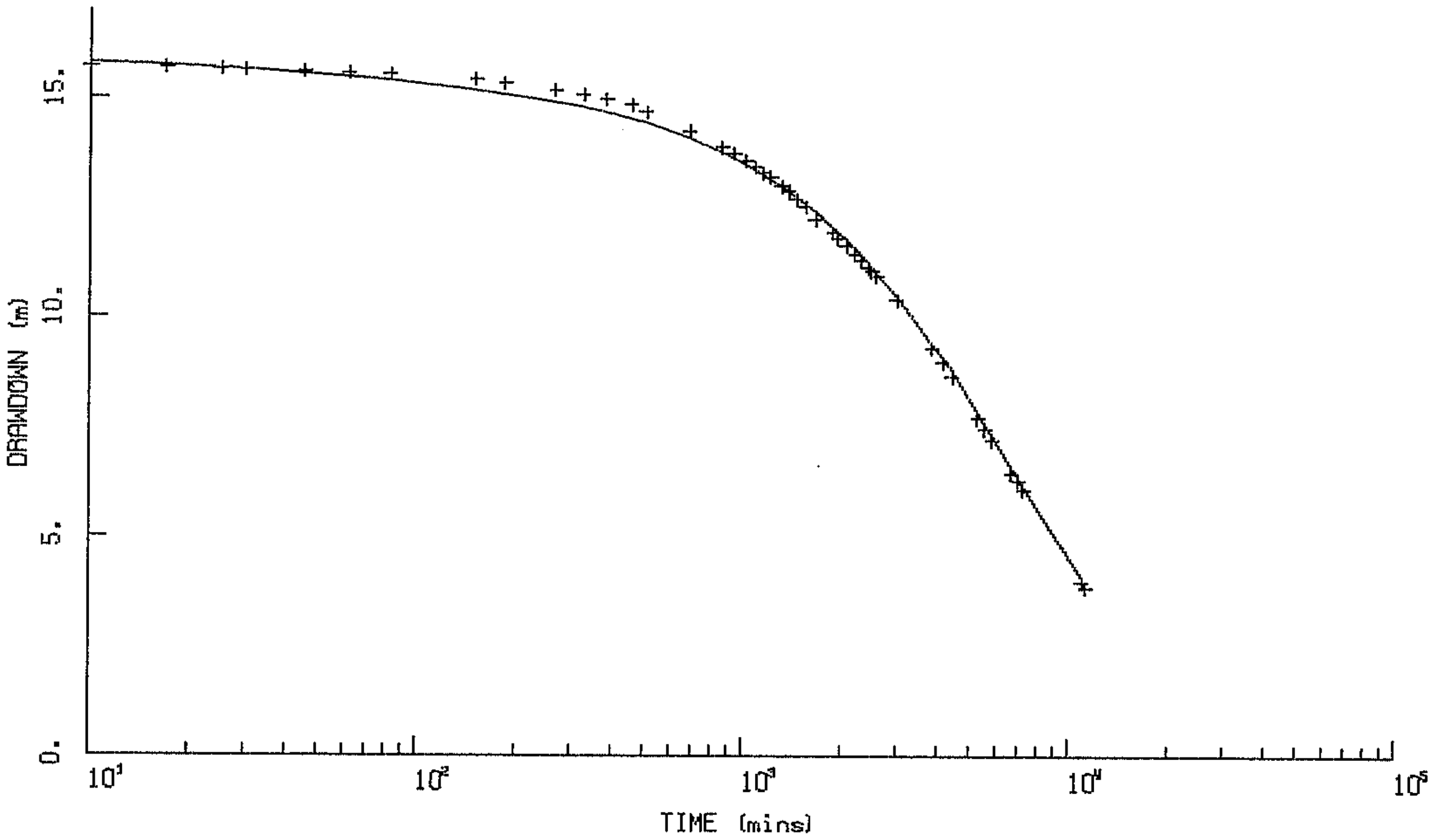

Fig. A7(b) Field and model data (parameter set 2) for PH21 during recovery.

model. This discrepancy reflects predominantly an error in the value of T_b and results, once again, from the compromises that had to be made in fitting this, and all the other parameters to a model which is not perfect. Fig. A6(b) indicates that the estimate of T_b may be slightly too large, a discrepancy not at odds with the model's earlier stated intention of supplying the upper bound of long term water inflow to the mine.

Fig. A7 shows a better fit between the field curve and model data; less data had to be accommodated to the model, and compromises in making a fit were fewer. Also, water inflow is not overestimated. Thus it is suggested that the parameters of Table A3, i.e. parameter set 2, be accepted as best describing the model of Fig. A4 as it pertains to the minesite. This does not entail a rejection of the parameter set 1 for, as has been mentioned, parameter set 2 lies well within the error bounds of parameter set 1.

A.5 Predictions based on the model.

For predicting long-term inflow, the steady state form of Eqn. (1) can be used; this can be written most easily by an inspection of the model. Under steady state conditions, storage effects represented by A_{f1}, A_{f2} and S have no effect on the flow. A constant drop in head given by Q/T_b takes place across the transmittance and the head drops linearly from there to the sink. The equation describing this is

$$s(x) = Q \left[\frac{(X_d - x)}{TL} + \frac{1}{T_b} \right] \qquad (2)$$

Now if sufficient water has been pumped from the mine such that the water level is below the intersection of the workings with the aquifer, then the drawdown at the sink in Fig. A4 will be maintained at a constant level. Let this level be Sm. Then

$$Q = \frac{Sm}{[\frac{1}{T_b} + \frac{X_d}{TL}} \qquad (3)$$

where Q is the inflow to the mine.

Sm in eqn. (3) is measured relative to the ambient water level. It is given by $(d_m - d_w)$ where d_m is the depth below the surface at which the mine intersects the aquifer, and d_w is the depth of water at the site that would occur if the mine were not being dewatered. Hence

$$Q = \frac{d_m - d_w}{\left[\frac{1}{T_b} + \frac{X_d}{TL}\right]} \qquad (4)$$

It is necessary to re-emphasize that eqn. (4) provides an upper limit of inflow only. Apart from the effects of neglecting to account for water storage in the regional aquifer while interpreting the pump test data, it does not account for the fact that flow conditions near the mine may become unconfined as the water level drops. However it is not possible to estimate the magnitude of this effect in the complex flow regime of a heterogeneous fractured rock aquifer surrounding a mine.

REFERENCE

Kuczera, G., 1987 Fitting and testing mathematical hydrologic models: a user manual for program suite NLFIT. University of Newcastle.