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Institute of Hydrology

Natural Environment Research Council

A Preliminary Hydrological Assessment of the Impact of the Proposed Quarry Extension, Bowling Green Farm, near Faringdon, Oxfordshire

Prepared for
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SUMMARY

Dewatering associated with the excavation of a new quarry site at Bowling Green Farm near Faringdon will result in a drawdown of the local groundwater table. Field and laboratory studies have show that in the worst situation and at the point of maximum quarry development water levels at the nearest groundwater abstraction site (Kitemoor Farm) would be drawn down by a maximum of 5 cms. Factors such as local recharge and remedial quarrying practices could reduce these drawdown effects to less than 3 cm at Kitemoor.

The sands beneath the proposed quarry site are not in hydraulic continuity with Frogmore Book. Hence, with the additional provision of sealing along the northern margins of the proposed quarry and recharge trenches it is unlikely that dewatering of the quarry will adversely effect surface flow.

Sealing and infilling of the quarry with less permeable material will result in only small very localised changes to groundwater levels. These changes are unlikely to affect areas more than a few tens of metres away from the site.

The direction of groundwater flow is towards the east-south-east and hence with adequate sealing of the quarry walls there are unlikely to be any adverse impact upon groundwater chemistry, and any minor changes are unlikely to affect local abstractors.

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INTRODUCTION

Hills Aggregates Ltd propose to quarry sands from a new site at Bowling Green Farm near Faringdon, Oxfordshire. It was considered that dewatering of this sand aquifer during quarrying may affect local groundwater abstractors. A pumping test was undertaken in February 1991 by STUART WELL SERVICES LTD in order to determine aquifer characteristics and provide a quantitative guide to the effects of quarry dewatering. The Institute of Hydrology was commissioned to assess the results of this pumping test in relation to the likely impact of quarry dewatering upon the local hydrological regime. Of particular concern was the possible effects of dewatering upon licensed groundwater abstractors in the area.

This assessment is based upon available published material, records from the National Borehole Archive, and data supplied by Hills Aggregates Ltd., and a one day site visit.

LOCATION

The proposed quarry extension is situated approximately two kilometres south-east of Faringdon, Oxfordshire. The location of the site relative to know groundwater abstractors is shown in Figure 1.

GEOLOGY

Bowling Green Farm is located on outcropping Upper Jurassic sands and limestones of the Corallian Formation and is underlain by Oxford Clay (Figure 2). The sequence may be summarised as follows:

	Description	Thickness
RECENT		
	Topsoil	0.25-0.35 m
	Silty Clay (only where limestone is absent)	0.00-0.25 m
CORALLIAN		
	White Grey Limestone	0.00-4.20 m
	Yellow Grey Silty Sand	5.40-8.50 m
OXFORD CLAY		
	Dark Grey Clay	>0.40 m

The Corallian Sand/Oxford Clay contact dips at progressively shallower angles to the south east as shown in Figure 3.

HYDROGEOLOGY

Aquifer Geometry

The Corallian Sand unit is the principal aquifer in the area. This unit consists of uncemented silty sands with thin intercalated clay bands. The underlying Oxford Clay is a basal aquiclude to this unit.

The water table lies between 2 and 7 metres below the site of the proposed quarry, and at shallower depths to the north. Water levels vary seasonally over a range of approximately one metre as shown in Figure 4.

Groundwater flow within these sands is from the north-west (Figure 5). There is a progressive increase in saturated thickness of sand towards the south east as shown in Figure 6. The mean hydraulic gradient across the site has been calculated by triangulation to be

Boreholes	Gradient
BG1 - 4 - 7	0.0077 to ESE
BG1 - 7 - 9	0.013 to SE

The dip of the basal contact of the Corallian Sands is higher along the western side of the site and hence it is possible that the hydraulic gradient may also be slightly greater in this areas.

Test pits between the pond and the northern boundary of the proposed quarry have shown topsoil resting directly upon Oxford Clay. This would indicate that in this area the Corallian Sand aquifer is not in direct hydraulic continuity with the pond or Fragmore Brook.

Aquifer Characteristics

Small scale falling head tests were used to estimate the permeability of the aquifer. Decay in heads induced by introduction of a volume of water were analysed by the formulae of Hvorslev, with results as follows :

Borehole	Permeability (m/d)
BG1/89	0.81
BG4/89	0.21
BG7/89	0.29
BG9/89	0.48
Average	0.45

Using the method of Boonstra and de Ridder a second estimate of permeability was made using grain size analysis data. The Boonstra and de

Ridder method is more applicable to courser sands and gravels and hence the estimates obtained by this method for the Bowling Green Farm site can only be considered as very approximate. Results obtained were as follows :

Sample	Permeability (m/d)
BG/1/89/2	6.8
BG/1/89/3	7.7
BG/1/89/4	9.9
BG/2/89/1	8.0
BG/2/89/2	7.8
BG/2/89/3	7.9
BG/10/89/1	7.9

The results of a two day pumping test and eight hour recovery test in the vicinity of borehole BG1 indicated a mean permeability of 4.75 x 10^{-5} with a specific yield of 6.0 per cent. The value determined for permeability by this pumping test method is considered to be the most accurate of the three methods employed. A full description of the test results are included in Appendix 1.

The radius of influence or zero drawdown for the two day pumping test was estimated to be 39.8 m.

IMPACT OF DEWATERING OF THE PROPOSED QUARRY

Using the parameters of aquifer geometry and characteristics derived from boreholes and the two day pumping test, the anticipated drawdown after 181 days pumping was calculated as follows :

Distance from Pumping Well	Drawdown (m)
10	0.83
20	0.67
50	0.46
100	0.31
200	0.16
300	0.09
400	0.05
500	0.03

The radius of influence or zero drawdown over this time period was estimated to be approximately 750 m.

These anticipated drawdowns from a pumped borehole were used in preparing the areal representation of drawdown associated with quarry dewatering shown in Figure 7. Drawdown would not be symmetrical round the proposed quarry as the Corallian Sand aquifer lenses out against the Oxford Clay to the north and because of the narrow saturated thickness of the aquifer to the west.

These conditions are considered to approximate to a worst case situation where continuous pumping was occurring throughout a summer period, from a fully developed quarry, where there is limited recharge. Drawdown would however be appreciably reduced by phased development, sealing of the quarry walls and the operation of recharge trenches.

As can be see from Figure 7 the maximum drawdown that could be expected at Kitemoor Farm at the time of full quarry development would be approximately 5 cms. In all probability drawdown could be expected to be appreciably less than this due to the effects of periodic recharge and remedial quarry development practices.

IMPACT OF INFILLING OF THE PROPOSED QUARRY

The sealing of the quarry walls and infilling with less permeable waste material will partially obstruct the present groundwater flow. As a result groundwater levels will be slightly raised to the west of the site and slightly reduced to the east. As the Corallian Sand has a low permeability and the hydraulic gradient across the area is also relatively low the replacement of this sand with less permeable material will have a minimal effect.

The water level changes that will occur are likely to be up to a maximum of a few centimetres immediately adjacent to the quarry walls and would be negligible severals tens of metres away from the walls.

With adequate sealing of the reclamation site and selective use of different fill materials it is unlikely that the quality of local groundwaters will be adversely effected by the infill material. The predominant direction of groundwater flow is to the east-south-east and therefore any possible contaminant plume from the reclamation site will not be moving towards any local abstractors.

APPENDIX 1

DESCRIPTION OF PUMPING TEST AND RESULTS

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REPORT ON A PUMPING TEST AT BOWLING GREEN FARM, FARINGDON

FOR HILLS AGGREGATES LIMITED

Introduction

Stuart Well Services Limited (SWS) received an order from Hills Aggregates Limited to carry out a pumping test at Bowling Green Farm, Faringdon, near Swindon, Wiltshire and to interpret the data measured during the test. A test specification was provided by Geoplan Limited. This report provides a factual description of the test and an interpretation of the data obtained.

Hydrogeology

The test site was located on the east side of what is designated the 'southern area'. At this location the Corallian Series extends to approximately 12m below ground level where the Oxford Clay is encountered. The Corallian comprises soft and hard limestone to 3m depth followed by uncemented silty fine sand with thin seams of laminated clay.

The base of the sand formation is approximately 93.0m OD at the test site according to information received from Geoplan. The test pumping well and 3 standpipe piezometer boreholes were terminated in the Oxford Clay with a previous borehole BG1 adjacent to them terminating at 93.65m OD in the sand.

At the start of testing on 5/2/91 the rest water level in these boreholes was 98.15 ± 0.025m OD. This level was exactly 0.1m lower than the rest water level recorded during the boring of BG1 on 20/2/89.

A water-table is maintained therefore in the sand formation approximately 7m below ground level at the test location. The local saturated thickness of this aquifer was thus approximately 5.15m at the start of the pumping test.

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From information obtained when other trial borings were made in the southern area in 2/89 the water-table level in the sand aquifer rises to the west and north of the test site and falls to the south. The top of the impermeable Oxford Clay also rises to the west producing a reduction in saturated thickness which is summarised by the following for 2/89.

Borehole	Top of Clay	Water level	H
	mOD	mOD	m
BG1	93.0	98.25	5.25
BG4	98.3	99.8	1.5
BG7	100.6	101.0	0.4
BG9	94.3	98.0	3.7

H is saturated thickness of the formation

At the test locale the saturated thickness is therefore a maximum in the designated area.

The corresponding mean hydraulic gradients of the water-table across the entire southern area were calculated by triangulation to be

Boreholes	Gradient
BG1 - 4 - 7	0.0077 to ESE
BG1 - 7 - 9	0.013 to SE

The steeper hydraulic gradient is clearly related to the reduced saturated thickness of the sand aquifer. It is unlikely that the hydraulic gradient prevailing at the test site exceeds 0.0075.

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Test Programme

The configuration of the test site was a line of boreholes parallel to the eastern boundary of the area. From south to north the test well was succeeded by piezometers P1 P2 and P3 and then the original borehole BG1.

The test borehole was drilled at 200mm nominal diameter with a 2 m section of geotextile wrapped slotted wellscreen placed at the base of the sand aquifer.

The standpipe piezometers were located at distances of 5m, 10m, 20m and 30m from the test well.

The line of monitoring points were aligned normal to the prevailing direction of groundwater flow and hence no 'gradient corrections' were necessary.

The test commenced at 09.30 on 5/2/91 with pumping maintained continuously for 48 hours. A steady discharge of approximately 30 l/min was developed for the first 90 minutes of the test which produced a pumping water-level of 4.2m below rest water-level or virtually at the base of the aquifer in the well. In order to avoid pump surging and cooling problems the discharge was reduced slightly at this time to approximately 25 l/min. The pumping water level recovered by 1.5m in the next 10 hours and then declined slowly by 150mm to 200mm during the remainder of the test.

During the latter 32 hours of the test the discharge, indicated by flowmeter, remained sensibly constant at 21 l/min.

Water levels were monitored in the piezometers and declined slowly to quasi-equilibrium drawdown levels during the latter stages of the test.

After pumping stopped on 7/2/91 recovery levels were monitored for a further 8 hours at which time the water-levels had attained those measured at the start of the test.

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Drawdown analysis

The quasi-steady state drawdown levels at the end of pumping were

	Radius	Level	Drawdown
	m	mOD	m
PW	0.075	95.26	2.86
P1	5	97.64	0.48
P2	10	97.83	0.31
P3	20	98.02	0.15
BG1	30	98.06	0.07

For the water-table aquifer the appropriate drawdown expression is

$$H^2 - h^2 = (Q/\pi k) \ln (r_e/r) \quad (1)$$

where

H is the saturated thickness above an impermeable bed

h is the height of the water-table above an impermeable bed

Q is the discharge

k is the formation permeability

r is the radius from the well

r_e is the radius of influence (zero drawdown)

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which, for a period of pumping t from rest is expressed by

$$r_e = 1.5 \sqrt{kHt/S_y} \qquad (2)$$

where S_y is the specific yield of the formation.

From the graph, fig 1, r_e is extrapolated to a value of 39.8m.

Solving the equation (1) above for each piezometer the following are derived

r	$H^2 - H^2$	$Q/\pi k$	k
m	m^2	m^2	m/sec
5	4.99	2.4	2.2×10^{-5}
10	3.19	2.3	4.8×10^{-5}
20	1.32	1.9	5.8×10^{-5}
30	0.92	3.3	3.4×10^{-5}
MEAN			4.75×10^{-5}

Substituting in equation (2) for r the value of S_y is calculated to be 6.0 per cent.

The efficiency of the test well defined by

$$e = \frac{\text{theoretical drawdown}}{\text{actual drawdown}}$$

is calculated to be 59 per cent, using the parameter values derived above.

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Discussion and conclusions

The horizontal permeability of the Corallian sand aquifer is determined to be

$$4.75 \times 10^{-5} \quad m/sec$$

The specific yield of this aquifer is estimated to be 6 per cent.

While the permeability is considered to be quite accurately determined the value of the specific yield is unlikely to be so reliable. The test was of relatively short duration and it is probable that the clay seams impeded total desaturation at the falling water-table within this period.

The value of specific yield is therefore conservatively low.

The well efficiency of approximately 60 per cent is unexpectedly high for completion was a partially screened well (less than 50 per cent of saturated thickness).

The aquifer transmissivity (permeability x saturated thickness) was 2.45 $\times 10^{-4}$ m^2/sec at the time of testing. This value increases according to the effect of antecedent recharge on raising water-table level, for example on 2/89 it was 2.50 $\times 10^{-4}$ m^2/sec. Adopting representative values of transmissivity and hydraulic gradient the total quantity of groundwater flow crossing the eastern boundary of the site in normal conditions is estimated to be approximately 25 l/min with a peak value not exceeding 50 l/min.

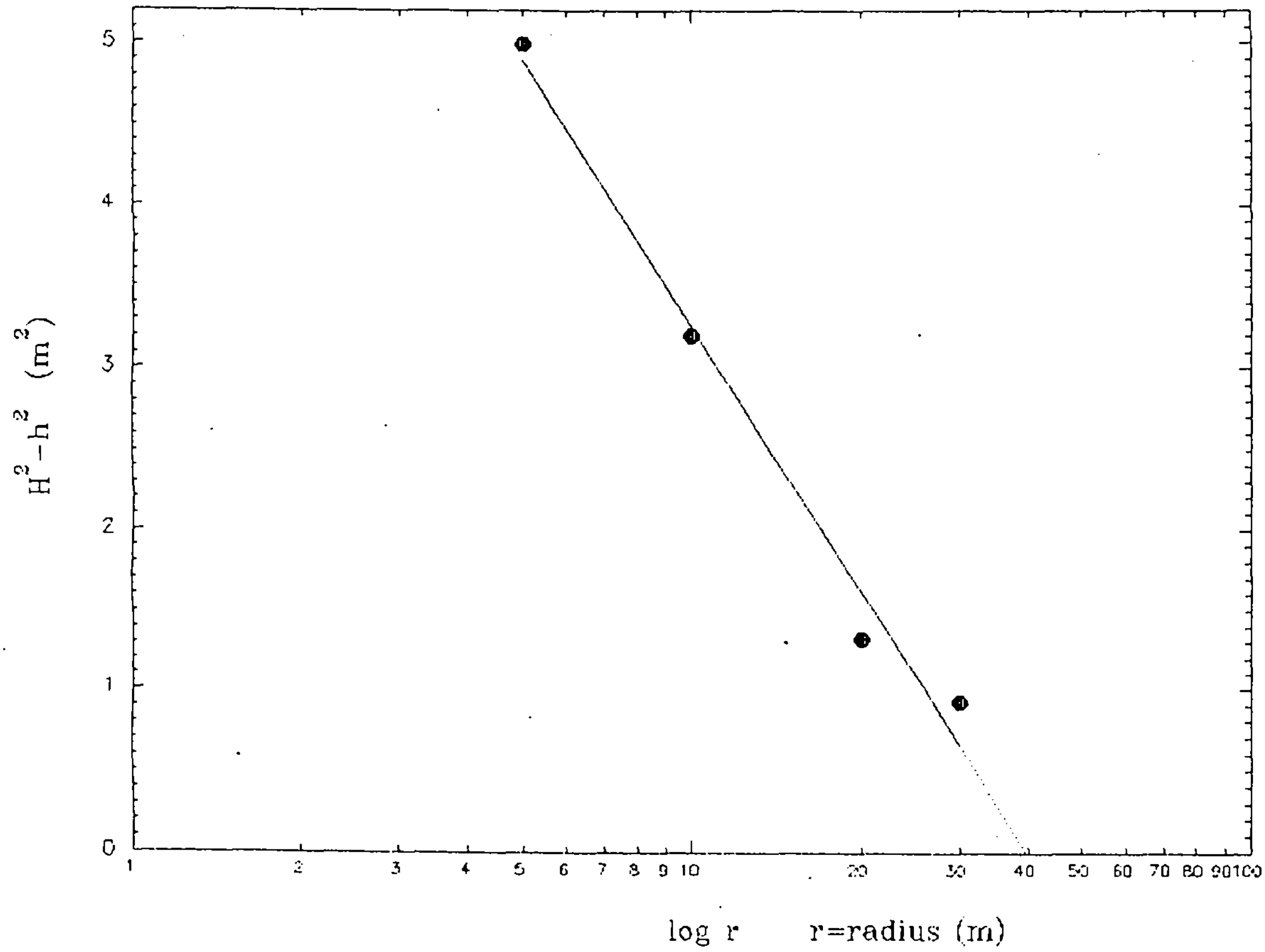
Reference

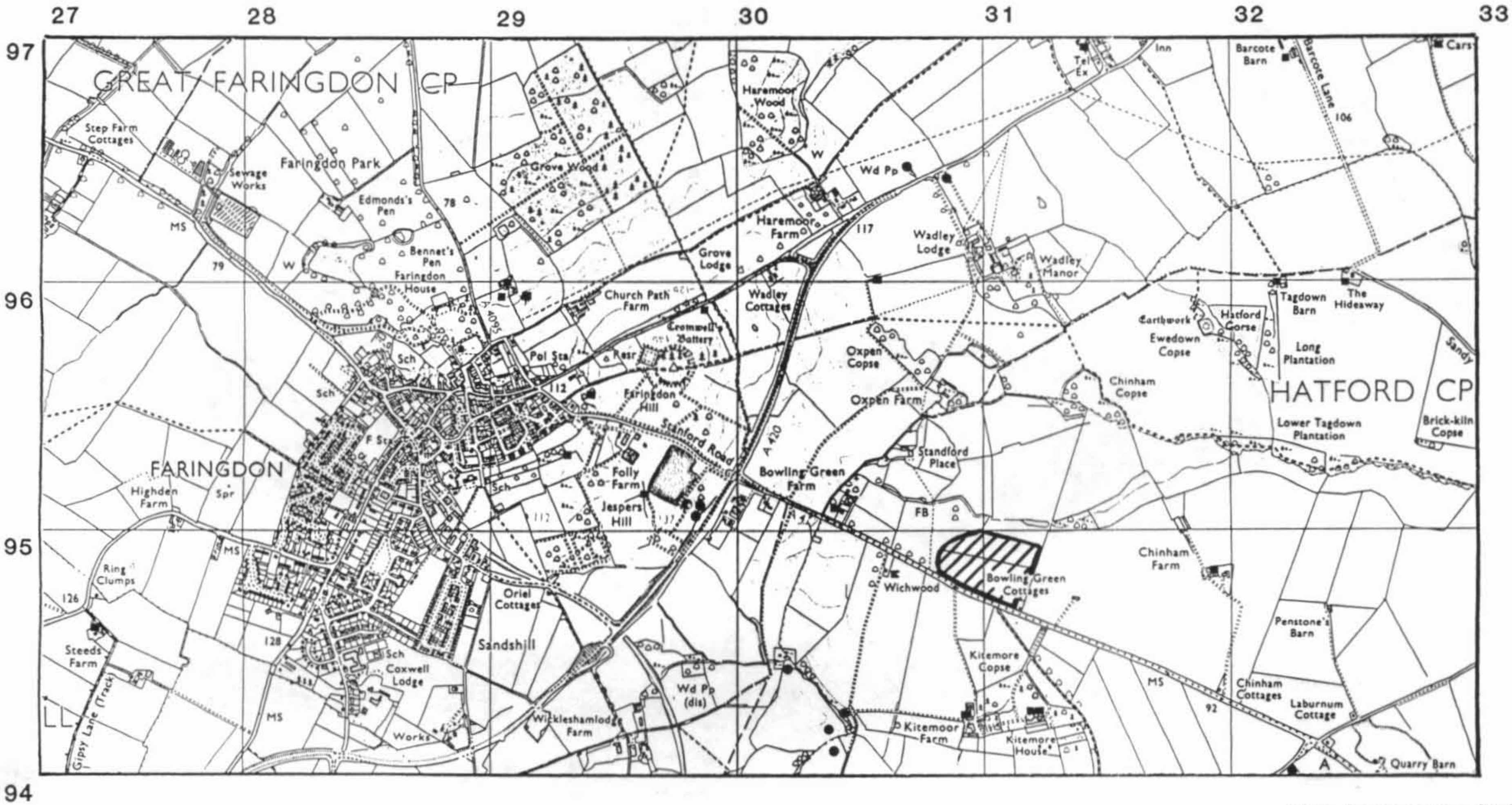
M. S. Hantush. Hydraulics of Wells in Advances in Hydroscience, Voll, 1964.

J. M. A. PONTIN
Consulting Hydrogeologist

Stuart Well Services
May 1991 (revised)

BOWLING GREEN FARM FARINGDON
(After 48 hours pumping)





Hills Aggregates Ltd

Boreholes and Wells

Bowling Green Farm

- ▪ Wells
- • Boreholes

Institute Of Hydrology Sept 1990

LOCATION

FIGURE 1

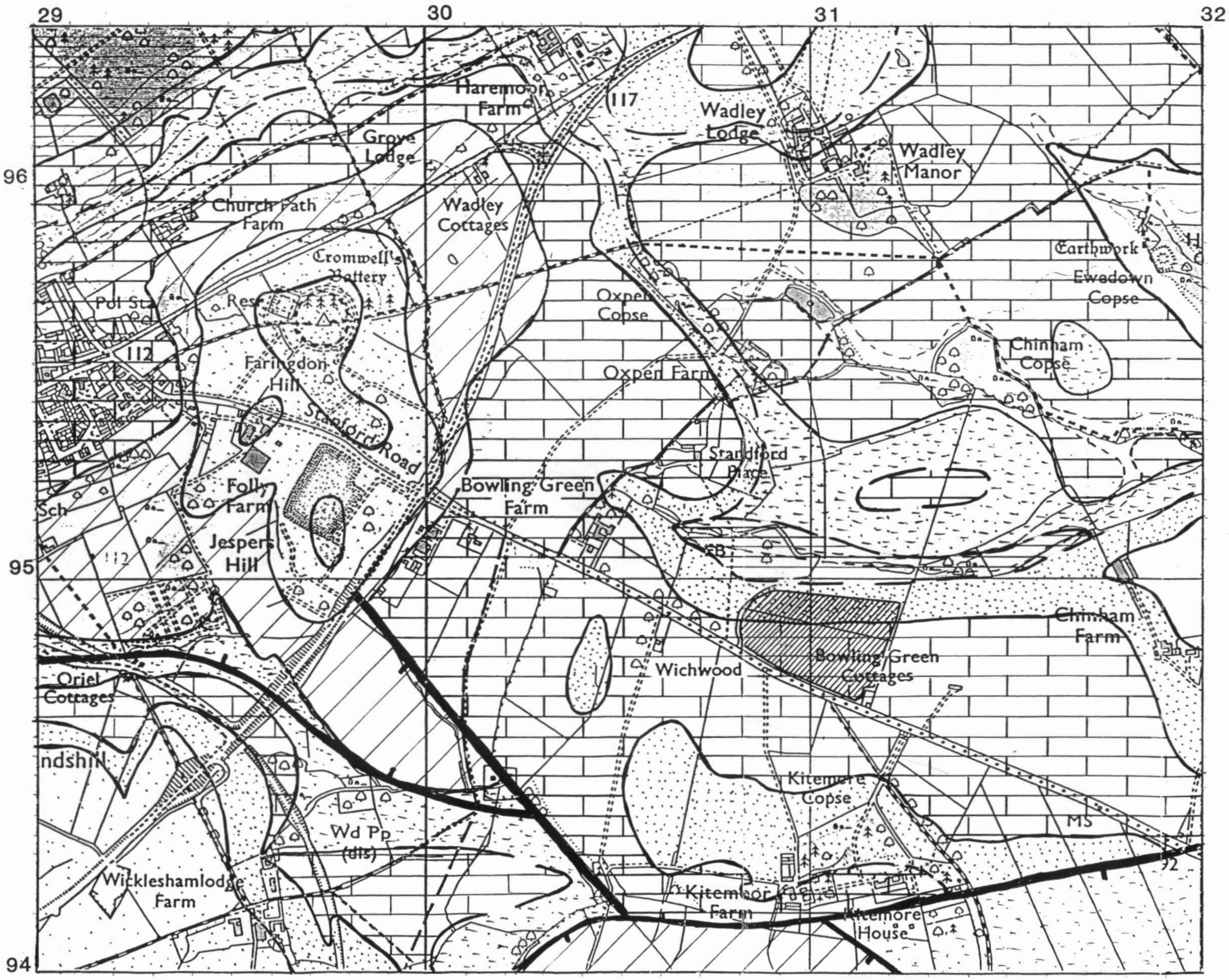
Basemap From O.S SU29/39

SCALE 1:25,000

Hills Aggregates Ltd

Bowling Green Farm

GEOLOGY



LOWER GREENSAND

SANDSTONE

FERRUGINOUS SANDSTONE

KIMMERIDGE CLAY

CORALLIAN SAND

LIMESTONE

SILT & SAND

CLAY

OXFORD CLAY

Basemap From O.S SU29/39

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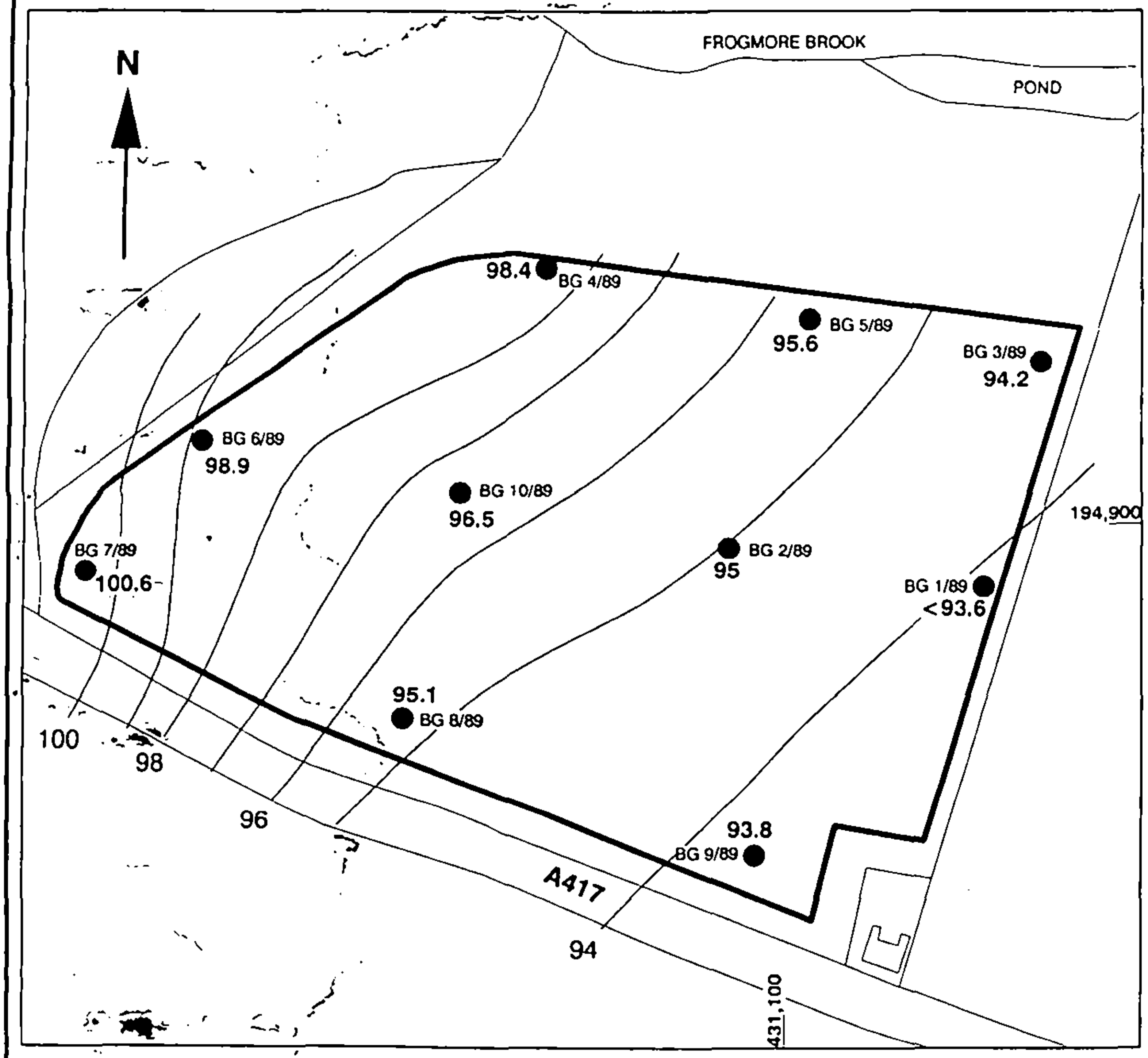
FIGURE 2

SCALE 1:10,000



HILLS AGGREGATES LTD

BOWLING GREEN FARM

BASE OF CORALLIAN SAND
(m.O.D)

SCALE 1:2500

MAY 1991 **FIGURE 3**

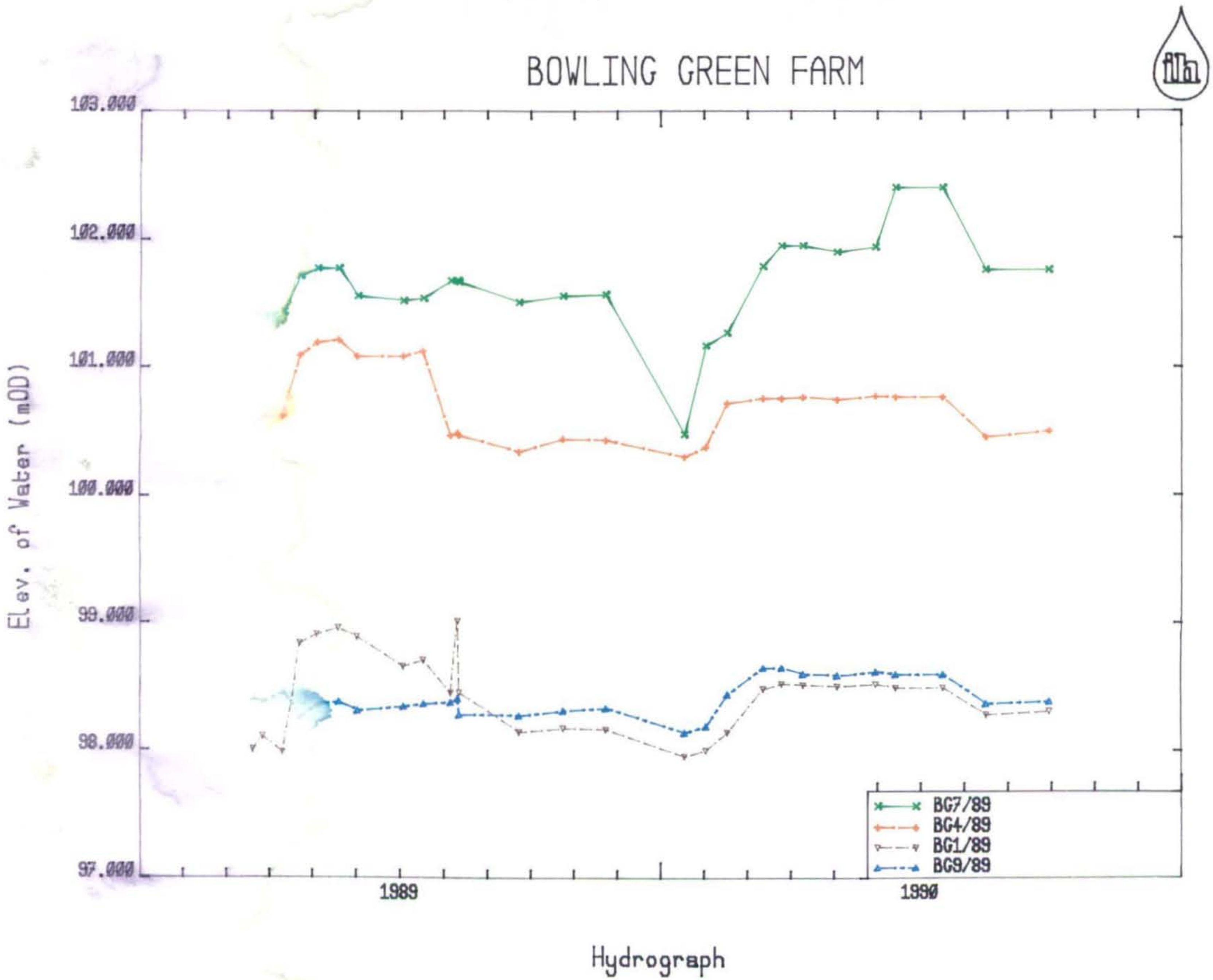
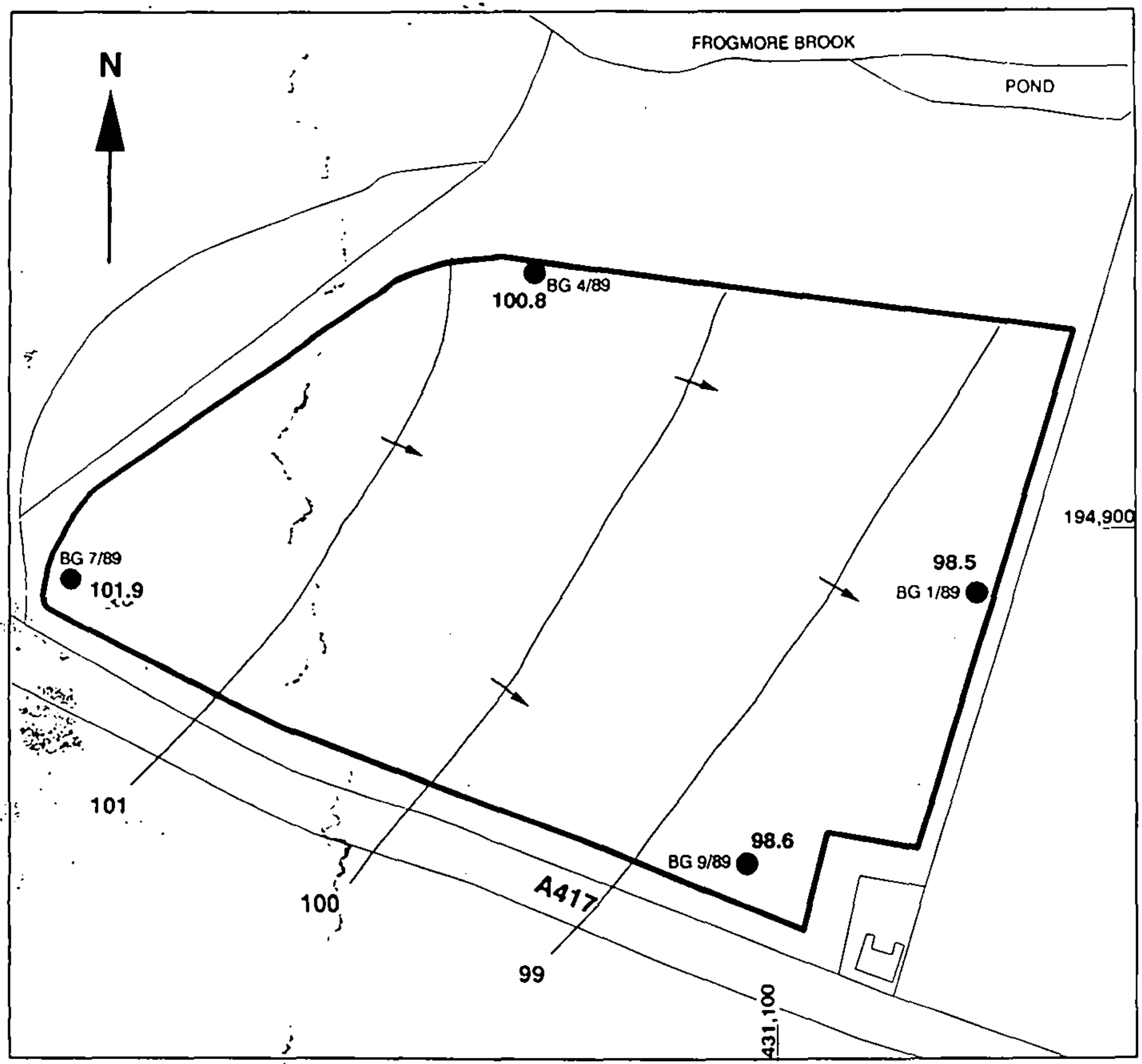

BOWLING GREEN FARM
103.000
102.000
101.000
100.000
99.000
98.000
97.000
Elev. of Water (mOD)
1989
1990
BG7/89
BG4/89
BG1/89
BG9/89
Hydrograph

FIGURE 4



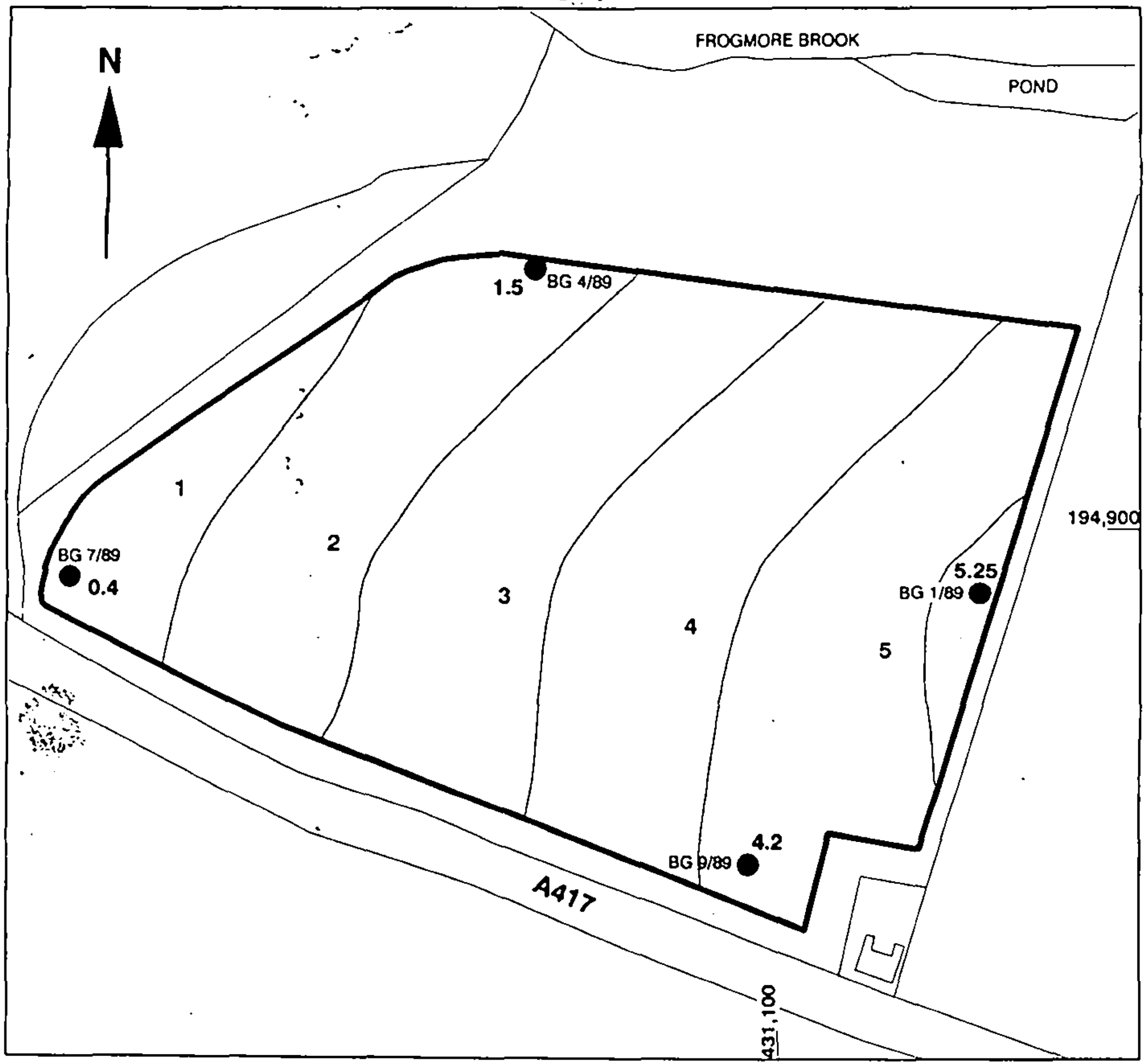
HILLS AGGREGATES LTD

BOWLING GREEN FARM

WATER LEVEL CONTOUR AND FLOW DIRECTIONS

SCALE 1:2500

MAY 1991 **FIGURE 5**



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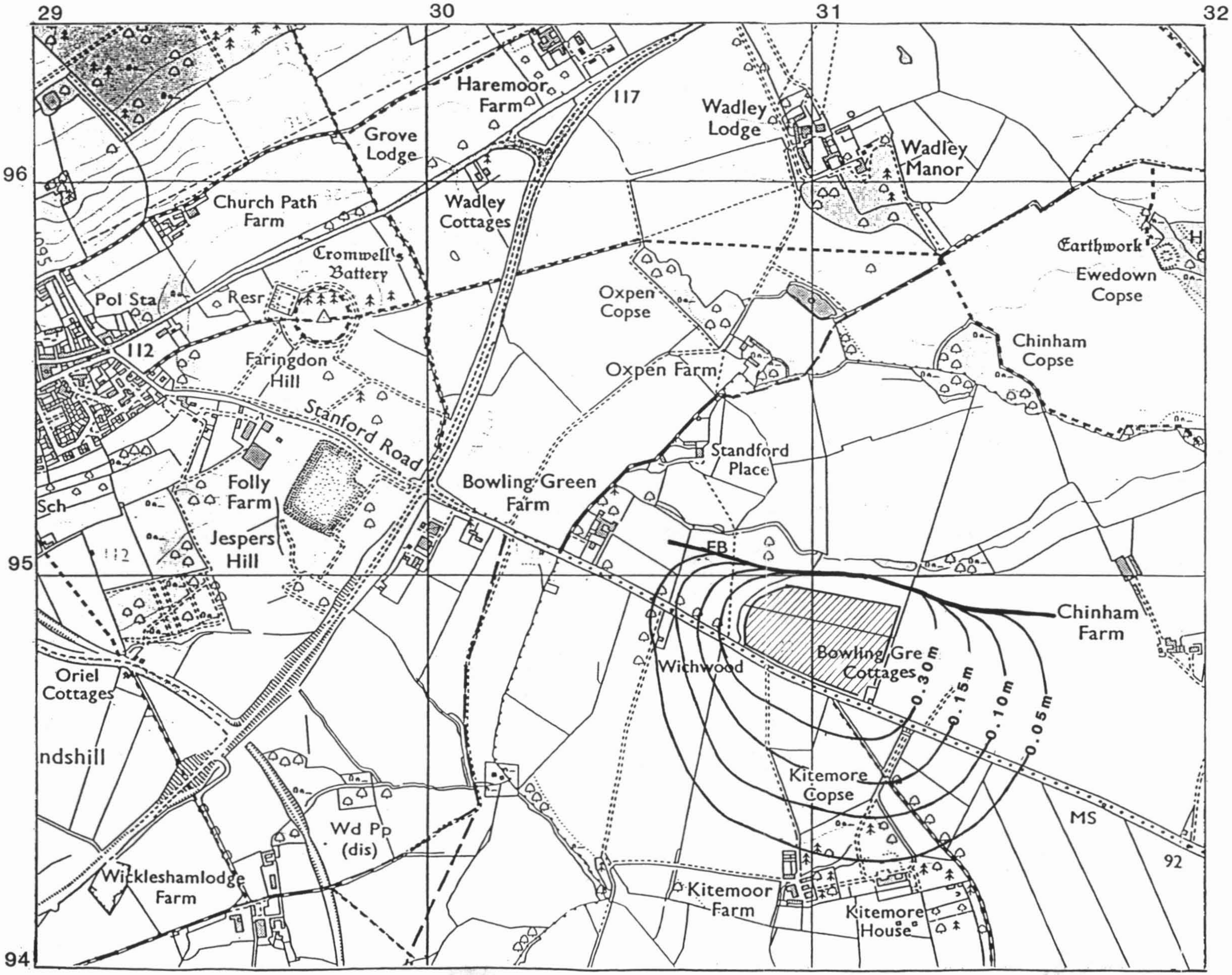
BOWLING GREEN FARM

SATURATED THICKNESS (m)

SCALE 1:2500

MAY 1991 **FIGURE 6**



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Bowling Green Farm

PREDICTED DRAWDOWN

(AFTER 181 DAYS PUMPING)

FIGURE 7

Basemap From O.S SU29/39

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SCALE 1:10,000

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