GROUNDWATER ABSTRACTION
GREENSAND AQUIFER
HILLINGTON, NORFOLK

PRIVATE HEARING: FEBRUARY 1991

PROOF OF EVIDENCE: D B BURGESS

National Rivers Authority (Anglian Region)

Groundwater Abstraction, Greensand Aquifer, Hillington

Private Hearing 19th February 1991

PROOF OF EVIDENCE OF D. B. BURGESS

Introduction

1. My name is David Brompton Burgess. I hold the degrees of Bachelor of Science and Doctor of Philosophy from The University of Hull and am a Member of the Institution of Water and Environmental Management. I have been employed by the National Rivers Authority as a Principal Hydrogeologist since its formation in September 1989 and during the previous sixteen years in the Hydrology and Water Resource departments of the then Anglian Water Authority.

2. My evidence will review the current state of knowledge of the groundwater resources of the Greensand aquifer around the Hillington area. It is my view that our current understanding of how groundwater flows beneath and away from the area is inadequate. Consequently, the issue by the National Rivers Authority to Anglian Water Services Ltd of the licence to

abstract from the Greensand at Hillington for a period of 10 years is justified. This will "enable a full assessment to be made of the resources of the area"(statement given within licence no. 6/33/64/47). In particular my evidence will cover :

- the complexities within the underlying geology of the area.
- the limited information available on groundwater flow and discharge within the Greensand aquifer.
- the possible impact of the abstraction on river flows.
- estimates of the groundwater resource available for abstraction and to maintain river flows.
- the decision to time limit the Hillington Licence.
- proposed investigations to be carried out to improve the understanding of the groundwater resources of the area.

Geological Structure

3. The Greensand borehole at Hillington was drilled and constructed in 1965 by Messrs. Le Grand, Sutcliffe and Gell Ltd. It is 79 metres deep. The location, construction and geological log of the borehole are shown in documents NRA 21 and NRA 22. The borehole is constructed so as to exploit groundwater only drawn from the Greensand aquifer and not from the overlying Chalk aquifer. A description and map of the rocks encountered by this borehole and within the surrounding

area is given in documents NRA 23 and 24. The rock sequence may be divided into three parts the Jurassic-Cretaceous solid rocks, the Glacial deposits and the Recent deposits .

4. The Jurassic and Cretaceous rocks dip gently eastwards to east-north-eastwards, mostly at half a degree or less (document NRA 25). The Chalk forms a low escarpment running roughly north-south. It outcrops east of Hillington village and directly underlays the catchment area of the Babingley River from there to the topographic divide at Harpley and Little Massingham (document NRA 24). The Chalk is underlain by the Gault clays and mudstones that may be traced at the base of the escarpment. The Gault is up to 8 metres thick in the area but is thought to be absent 4 or 5 km northwards around Sandringham (Gallois and Morter 1982). The Gault is underlain by the Greensand series which is divided into the Carstone, the Dersingham Beds and the Sandringham Sands. The Carstone is a 'gingerbread' coloured sandstone seen in the buildings of the area. The Greensand series can be traced west of Hillington as heaths and forests established on the poor sandy soils of the outcrop. The Sandringham sands are further divided into the Leziate, Mintlyn and North Runcton Beds (Gallois 1984). Of these, only the Leziate Beds of fine, water-bearing sands are penetrated by the Hillington borehole. The Sandringham Sands lie uncomformably on the Kimmeridge Clay (Casey and Gallois 1973).

5. The solid geological structure is complicated by the Glacial deposits that vary laterally, vertically and in composition throughout the area. Thin patches of glacial drift may be traced over much of the higher ground of both the Chalk and Greensand outcrops. By contrast the valley floor and sides of the Babingley River are filled with thicker glacial deposits consisting of gravels, the Chalk-Jurassic Till and fluvial silts and clays. These can attain considerable thicknesses in places and within a pre-glacial valley system. A pre-glacial buried valley underlies the present course of the Babingley River at the Old Flax Mill (TF 693 256) where a borehole showed the drift to be more than 30 metres thick (Gallois 1979) . From here the buried valley is thought to run westwards with a centre axis about 500 to 700 metres north of the present course of the Babingley River. The pre-glacial valley was cut to a level of below -60 m.ODN beneath the Wash. It dissects the base of the Sandringham Sands just west of Whalley Farm (TF 685257) (I.G.S. 1978).

6. The Recent deposits are restricted to alluvium and peats within the Babingley valley which overlie the thicker glacial drift. Between Hillington and Harpley Dams the Recent deposits lie directly on the Chalk.

Hydrogeology and River Flows

7. There are two aquifers beneath the Hillington site : the Chalk and the Greensand (document NRA 22). The Chalk aquifer at Hillington has been used for Public Water Supply from 1947 onwards. Licence number 6/33/64/25 allows for abstraction up to 3,746 t.c.m.a. from two boreholes within the Chalk on the Hillington site. Document NRA 26 is a graph that shows the amount of groundwater abstracted from the Chalk at this site since 1970. Groundwater within the Chalk is unconfined with a restwater level at about 25 m.ODN. The Chalk groundwater discharges as springs along the Babingley valley from immediately adjacent to the pumping station to about 1.5 kilometres to the west at the B1153 road bridge. The natural flow of these springs has been depleted as a result of the abstraction from the Chalk boreholes at Hillington P.S.

8. Beneath the Chalk, it is known that 8 metres of Gault clay forms a relatively impermeable barrier or aquitard separating the Chalk aquifer from the underlying Greensand aquifer. However, the Gault is discontinuous some 4 or 5 kilometres to the north of the Hillington site and thereafter vertical flow is possible between the two aquifers.

9. The Greensand aquifer lies beneath the Gault clay. It is composed of the Carstone, Dersingham Beds and Sandringham Sands. Groundwater within the Greensand aquifer beneath the

Hillington site is confined. The rest water level within the Greensand borehole at Hillington is at about 18 m ODN which is about 28 metres above the base of the Gault (document NRA 22). Within the Greensand aquifer it is the upper component of the Sandringham Sands, the Leziate Beds that are likely to yield the most groundwater. The results from an investigation borehole recently drilled by the British Geological Survey at Hillington Patch, 980 metres to the south east of the pumping station (TF 751256) suggest that up to 75% of the yield of the Greensand is from the Leziate Beds (Buckley *et al.* 1989).

10. The confined conditions within the Greensand persist for some 2½ kilometres to the west of the Hillington site where the base of the Gault outcrops (document NRA 24). There is insufficient information on the piezometric levels within the Greensand to determine the natural pattern of groundwater flow around the Hillington site. However, in general terms it may be inferred :

- that there is little flow to the east, there being no discernable outlet within the geological structure.
- there is the possibilty of flow from the area to the north of the site where the Gault thins and the Greensand and Chalk are in hydraulic contact.
- there is a strong likelihood of groundwater flow to the west as the Greensand aquifer becomes unconfined.

11. Groundwater levels beneath the Greensand outcrop vary from about 12 m ODN to about 26 m ODN at wells and boreholes within the Babingley valley (document NRA 27). Again there is insufficient information available to determine the groundwter flow pattern within the Greensand aquifer beneath the outcrop in any detail. However, it may be inferred that the pattern of natural groundwater flow is :

- towards the Babingley valley and discharging either directly to the river or via springs along the valley sides.
- locally disrupted by the course of the preglacial valley filled with glacial till.

12. The flow in the Babingley River has been measured by the Authority at Castle Rising (TF 680 252) from 1976 to date. The flow records indicate that over 90% of the riverflow is derived from groundwater discharge and that a flow of 300 litres/second (about 26 t.c.m.d.) is experienced for 95% of the time (document N.R.A. 30). The lowest mean daily flow for the station is 126 litres/second (11 t.c.m.d.) and was measured on 24th October 1990.

13. The groundwater flow into the Babingley River is from discharges both from the Chalk and Greensand aquifers. The Babingley River rises near the base of the Middle Chalk just to the north of the Hillington P.S. (TF 744263). From there the river gains baseflow from gravels on Lower Chalk as far

west as Flitcham Abbey (TF 721 264). The impermeable Gault clay underlies the valley from Flitcham Abbey to just south of Flitcham Hall (TF 717 262) From there the Babingley River runs on glaciofluvial deposits overlying the Greensand aquifer and about 500 to 700 metres to the south of the pre-glacial buried valley. The height of the river bed as it flows over the Greensand at the B1440 road bridge is 12.8 m ODN and falls to 8.6 m ODN at Castle Rising gauging station. This is lower than the surrounding groundwater levels in the Greensand aquifer and it follows that groundwater flows will be towards the river. River gauging under low flow conditions carried out during October 1989 gave a flow at the B1440 bridge (just downstream of the Gault/Carstone junction) of 105 litres/second (9.1 t.c.m.d.) while the flow at Castle Rising gauging station was 148 litres/sec (12.8 t.c.m.d.). This suggests that about 29% of the baseflow of the Babingley is derived from the Greensand aquifer.

The Impact of Abstraction from the Greensand on River Flows

14. The Greensand borehole at Hillington P.S. was test pumped after construction in 1965 but thereafter has not been used. The original diagram summarising this test is presented as document NRA 28 (The units in this diagram are imperial). The test was for 15½ days at an average rate of 52 litres per second (4.5 t.c.m.d., c.f. 4.0 t.c.m.d. allowed within the Anglian Water Services licence). The drawdown during this

period was 29.2 metres below restwater level. The results of this test have been analysed to give a transmissivity value of 240 m^2/day (Jackson 1983). A transmissivity value of 270 m^2/day and a storativity value of 3.2×10^{-4} were obtained while testing the nearby Hillington Patch borehole (Buckley *et al* 1989). Other values for the Greensand range from 438 m^2/day to 70 m^2/day for transmissivity and from 5.7×10^{-4} to 3.1×10^{-4} for storativity. Otherwise, little is known as to how the aquifer characteristics of the Greensand vary in the area around the Hillington site and how these may control groundwater flow to the Greensand borehole or the Babingley River.

15. Attempts to measure the effect of abstraction from the Greensand on flows in the Babingley River were made during the pumping test of 1965. However, any depletion of river flows during the test was masked by the pumped water being discharged back to the river, fluctuations in the water stored in Flitcham lakes and variable amounts of rainfall throughout the duration of the test (document NRA 28). The pumped water level at the end of this test and after 15½ days pumping at 52 litres/sec (4.5 t.c.m.d.) was at -13m ODN. The groundwater level in the aquifer adjacent to the Hillington borehole at the end of the test may be estimated to be -3 m ODN. This is considerably below the bed level of the Babingley River (< 12.83 m ODN see paragraph 13 above). The difference in groundwater levels implies that the cone of depression

developed around the Hillington borehole while pumping, would capture baseflow discharge to the river and could possibly also result in leakage from the river into the Greensand aquifer. It is therefore quite likely that abstraction from the Hillington Greensand borehole would be at the expense of flows within the Babingley. However, given the complications and uncertainties in our understanding of the hydrogeology of this area, it is not possible to estimate the amount of flow loss with the data currently available.

Groundwater Resources Available for Abstraction and to Maintain River Flows

16. The groundwater resource available to the Hillington borehole will ultimately be derived from the residual rainfall (rainfall - evaporation) that seasonally recharges the Greensand outcrop area to the west. Estimates of the mean annual residual rainfall for the area vary from 170mm for square 119 of the Meteorological Offices MORECS data set to 205mm as the estimate within the survey of water resources of the area (Van Oosterom 1974). The amount of residual rainfall that infiltrates to groundwater is complicated by the areas of glacial drift that cover parts of the Greensand outcrop. Infiltration through the drift has been estimated as only 35mm.

17. The above values of residual rainfall have been used to estimate the available resources of the Greensand under the Babingley surface water catchment. The drift-free outcrop of the Greensand outcrop is approximately 19 km^2. and the area of drift-covered outcrop is approximately 3km^2. The renewable resource of the Greensand covered by the Babingley catchment is then estimated as between 3,300 t.c.m.a. and 4,000 t.c.m.a. Of this, 1,200 t.c.ma. is within the A.W.S. licence which is the subject of this hearing, a further 27 t.c.m.a. are allocated to other Greensand licences (document NRA 29) and an estimated 2,600 t.c.m.a. is required to maintain the baseflow of the Babingley River (the Greensand discharge component of the 95% riverflow). It follows that if the lower resource estimate of 3,300 t.c.m.a. is taken, the abstraction at Hillington would be at the expense of riverflows. However, if the higher resource estimate of 4,000 t.c.m.a. is taken, a small surplus of the Greensand resource remains.

18. The 10 km stretch of the Babingley river between Flitcham Abbey (TF 724 263) and the A149 road brdge (TF 674 252) is a high grade fishery and is one of the few river stretches within the Anglian Region classified as a salmonid fishery requiring protection under the relevant EC Directive (78/657/EEC). The Hillington borehole could in my view deplete baseflows from this stretch of the river. However, just as there are insufficient data to estimate the amount of baseflow

depletion, there are also insufficient data to judge the riverflow requirements of the fishery.

Decision to Time Limit the Hillington Licence

19. The foregoing has highlighted the complexities and uncertainties in the understanding of the hydrogeology and how this may control flows in the Babingley River. It is therefore impossible to predict the effects of the Hillington abstraction on the surrounding water environment and it was for this reason that it was decided by the N. R. A. that the licence be issued for a limited period only. The choice of a period of ten years was to enable more information on groundwater discharge, river flows and the ecology of the Babingley river to be collected. A ten year period was considered long enough to measure the effects of hydrological extremes of floods and low flows yet not so long that the ecology of the Babingley could be damaged beyond recovery.

Proposed Investigations into the Impact of Abstraction from the Hillington Borehole

20. I have listed below the particular uncertainties that have made the assessment of the Hillington Greensand licence difficult together with the additional investigations that the N. R. A. proposes to carry out :

(a) Groundwater Flows. The current groundwater level network listed in document NRA 27 provides insufficient data to characterise the groundwater flow between :

- beds within the Greensand aquifer
- the aquifer outcrop and the confined area at the Hillington borehole
- the aquifer outcrop and the Babingley River
- the aquifer and the pre-glacial valley

To remedy this lack of knowledge, the N. R. A proposes to extend the groundwater monitoring network to regularly observe water levels at additional existing wells and to construct two or three extra observation boreholes. These would be in addition to the observation borehole to be constructed by Anglian Water Services and which is a condition within clause 8 of the Hillington licence.

(b)Possible Reduction in River Flows. River flows will continue to be monitored at the N. R. A.'s gauging station at Castle Rising. In addition other points along the river will be gauged during periods of extended low flow. These data will be used to compare river flows before and after the Hillington abstraction.

(c) River Flows Required to Mainatin the Fishery. The ecological performance of the Babingley River will continue to be monitored by means of detailed surveys carried out by the

N. R. A.'s Biologists and Fisheries staff. The results will be used with empirical relationships between the flow, physical characteristics and biological indices to set the flow required to maintain the current status of the River. Loughborough University has been contracted to investigate such relationships as part of the N. R. A.'s Research and Development programme.

Conclusion

21. The effects of the Anglian Water Sevices abstraction from the Greensand aquifer at Hillington are difficult to predict. The abstraction could be at the expense of river flows in the Babingley River which supports an important fishery. Equally, there could be enough groundwater resource available to both support the abstraction and maintain sufficient flow in the Babingley River. It was, therefore, in my view correct to time limit the Anglian Water Services licence in order to allow a period during which the effects of the abstraction could be monitored and the Greensand resource evaluated.

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Documents within the Evidence of D. B. Burgess

Document NRA 21	Map of Babingley Catchment Showing the Location of Hillington P.S., Abstraction Licences, Observation Boreholes and Castle Rising Gauging Station.
Document NRA 22	Hillington Greensand Borehole : Construction and Geological Details.
Document NRA 23	Stratigraphic Table for the Hillington Area.
Document NRA 24	Geological Map of the Hillington Area.
Document NRA 25	Geological Cross-Sections through the Hillington Site.
Document NRA 26	Hillington P.S. : History of Chalk Abstraction.
Document NRA 27	Table of Greensand Observation Boreholes within the Hillington Area.
Document NRA 28	Original Diagram of 1965 Pumping Test at Hillington Greensand Borehole.
Document NRA 29	Table of Licensed Abstractions within the Babingley Catchment.
Document NRA 30	Castle Rising Gauging Station : Flow Duration Curve

LIST OF UNITS AND ABBREVIATIONS

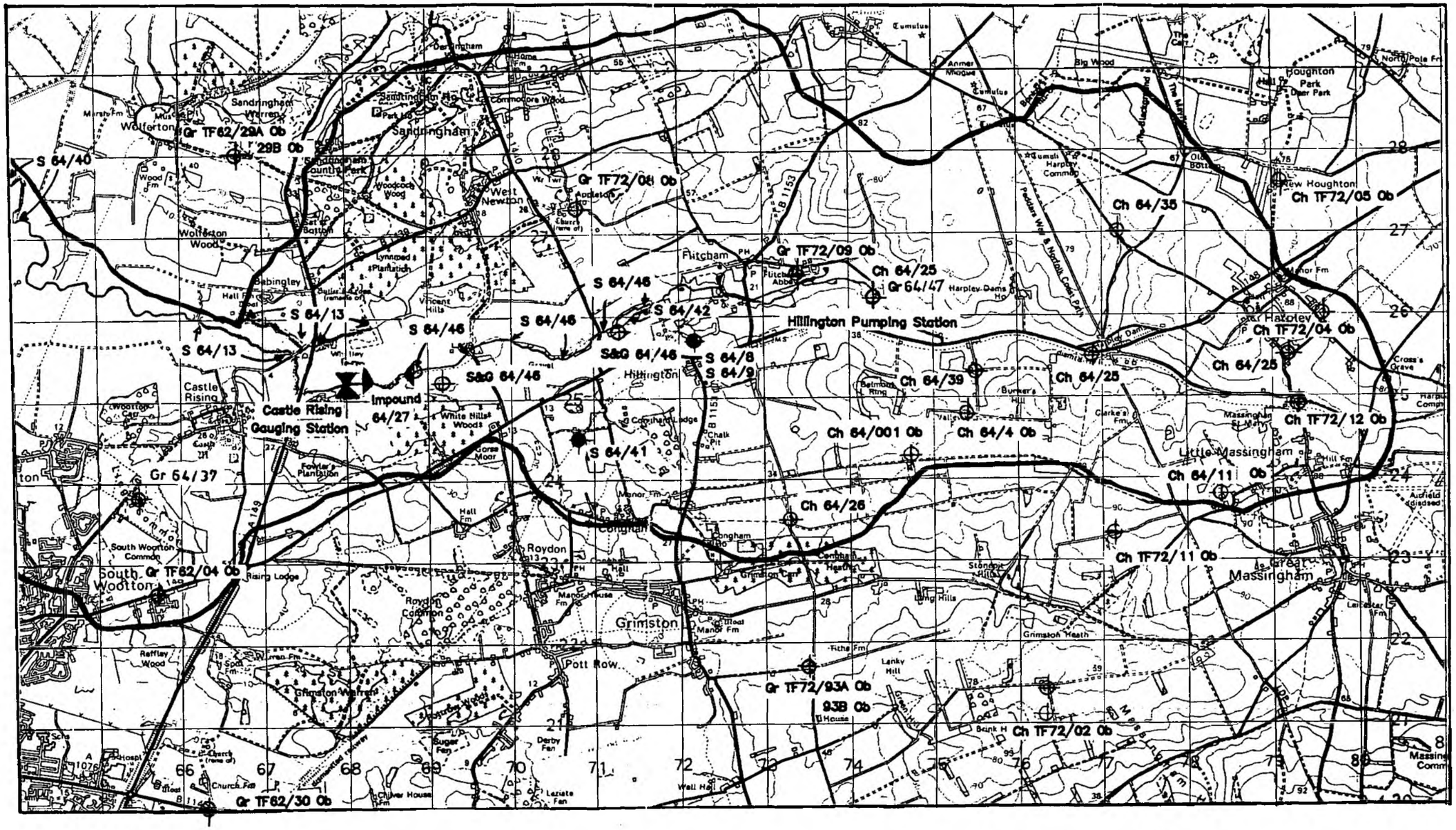
t.c.m.a = thousand cubic metres per annum

t.c.m.d = thousand cubic metres per day

l/s = litres per second

95% = river flow equalled or exceeded for 95 per cen of the time.

m^2/d = metres squared per day. Units of transmissivity. Transmissivity is an index of aquifer permeability. It is the product of aquifer thickness and hydraulic conductivity.



LOCATION MAP FOR THE BABINGLEY CATCHMENT TO CASTLE RISING

Legend

- Ch — Chalk
- S — Surface
- Gr — Greensand
- S&G — Sand & Gravel
- 64/.. — Licensed Abstraction
- TF72/.. TF62/.. — Unlicensed site
- Ob — Site regularly monitored
- Site of impounding

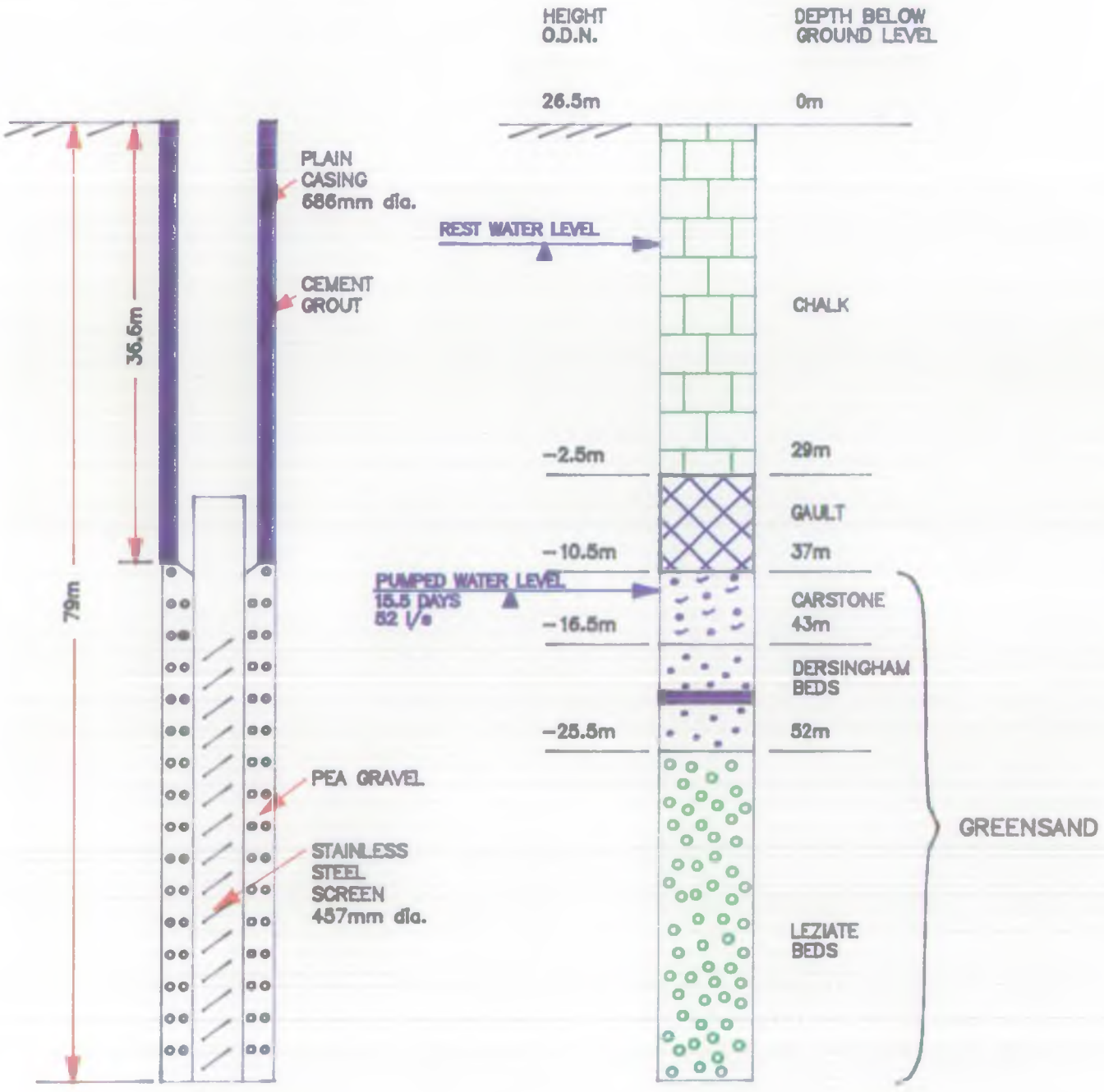
Scale 1:50 000

NRA Document 22

HILLINGTON P.S. (N.G.R. TF743 262)
GREENSAND BOREHOLE DETAILS

CONSTRUCTION DETAILS

GEOLOGICAL LOG

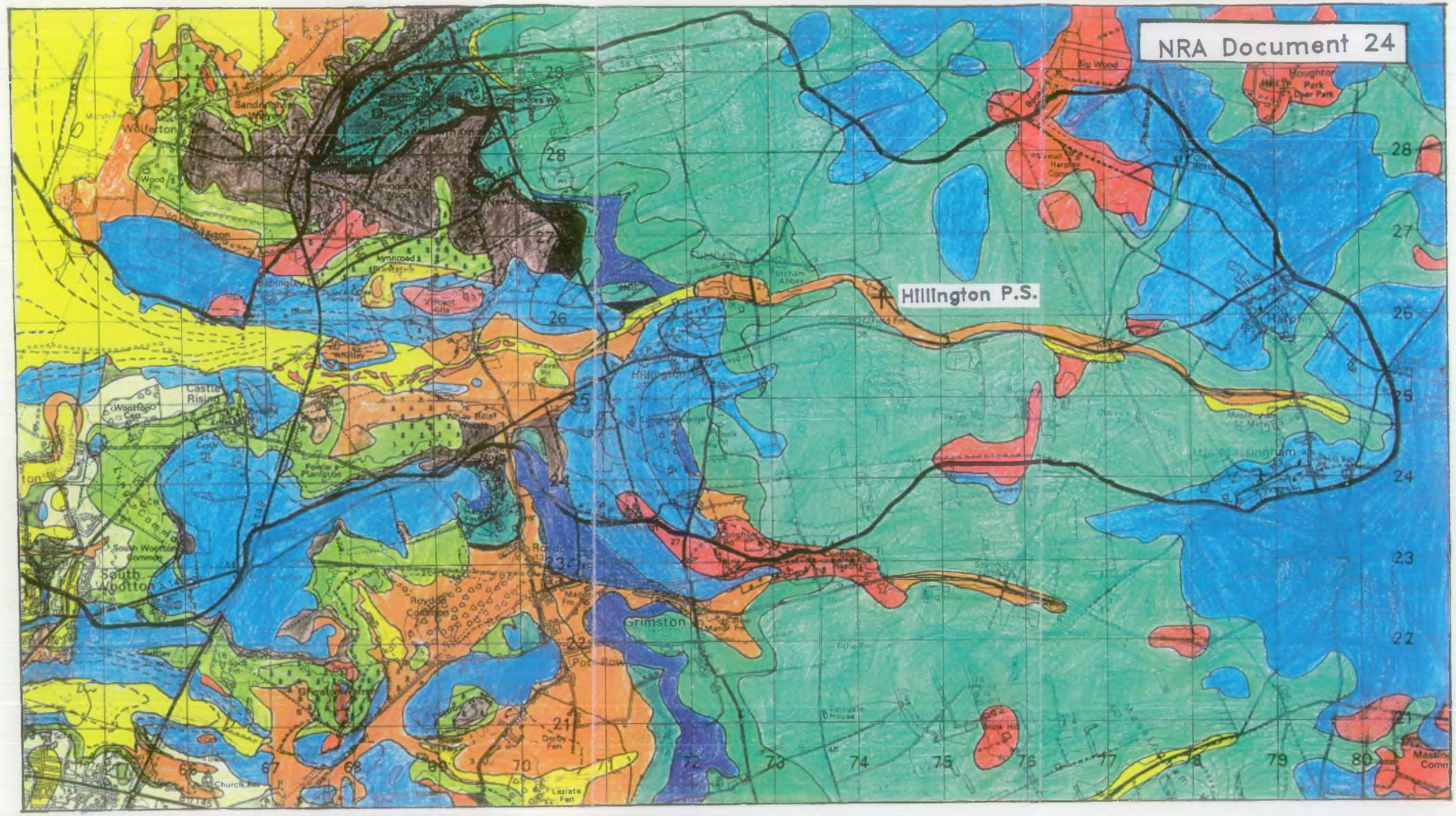


CONSTRUCTED JULY 1965
by LE GRAND, SUTCLIFF & GELL

Document NRA 23

Stratigraphic Table for the Hillington Area

Age	Formation	Thickness up to:	Description	Hydrogeo. Class.
RECENT	Peat	5 m		
	Alluvium	2 m		
PLEISTOCENE	Chalk-Jurassic Till	50 m	Grey boulder clay, rich in local rock fragments.	
	Glacial Sands & Gravels		Within above.	
CRETACEOUS	Chalk (Upper, Middle, Lower)	120 m	Soft, fine-grained limestone	CHALK AQUIFER
	Gault	8 m	Brown & grey clays	AQUITARD
	Carstone	16 m	Dark green oolitic sandstone	GREENSAND AQUIFER
	Dersingham Beds	30 m	Ferruginous, fine-grained sand+clay band.	
	Sandringham Sands (Leziate Beds)	30 m	Loose, clean quartz sands.	
	Sandringham Sands (Mintlyn & North Runcton Beds)	25 m	Green, sandy clay/ clayey sand. Silty clays	
JURASSIC	Kimmeridge Clay	70 m	Grey clay with cementstone bands	AQUITARD



PEAT

ALLUVIUM

HEAD

BOULDER CLAY

GLACIAL SAND AND GRAVEL

UPPER & MIDDLE CHALK

LOWER CHALK

RED CHALK/GAULT

CARSTONE

SNETTISHAM CLAY — DERSINGHAM BEDS

LEZIATE BEDS — SANDRINGHAM SANDS

MINTLYN BEDS

RUNCTON BEDS

ROXHAM BEDS

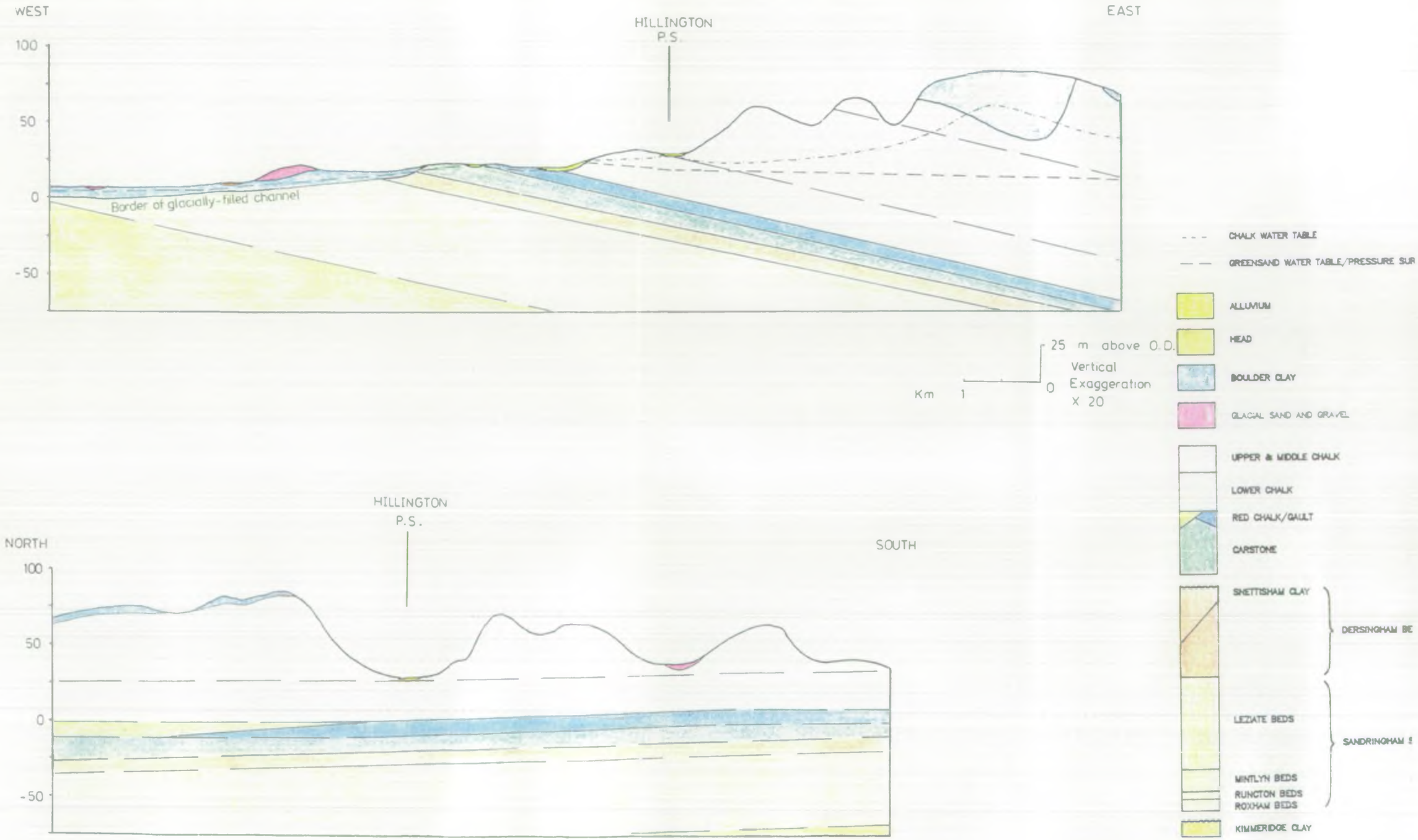
KIMMERIDGE CLAY

GEOLOGY MAP OF THE BABINGLEY CATCHMENT TO CASTLE RISING

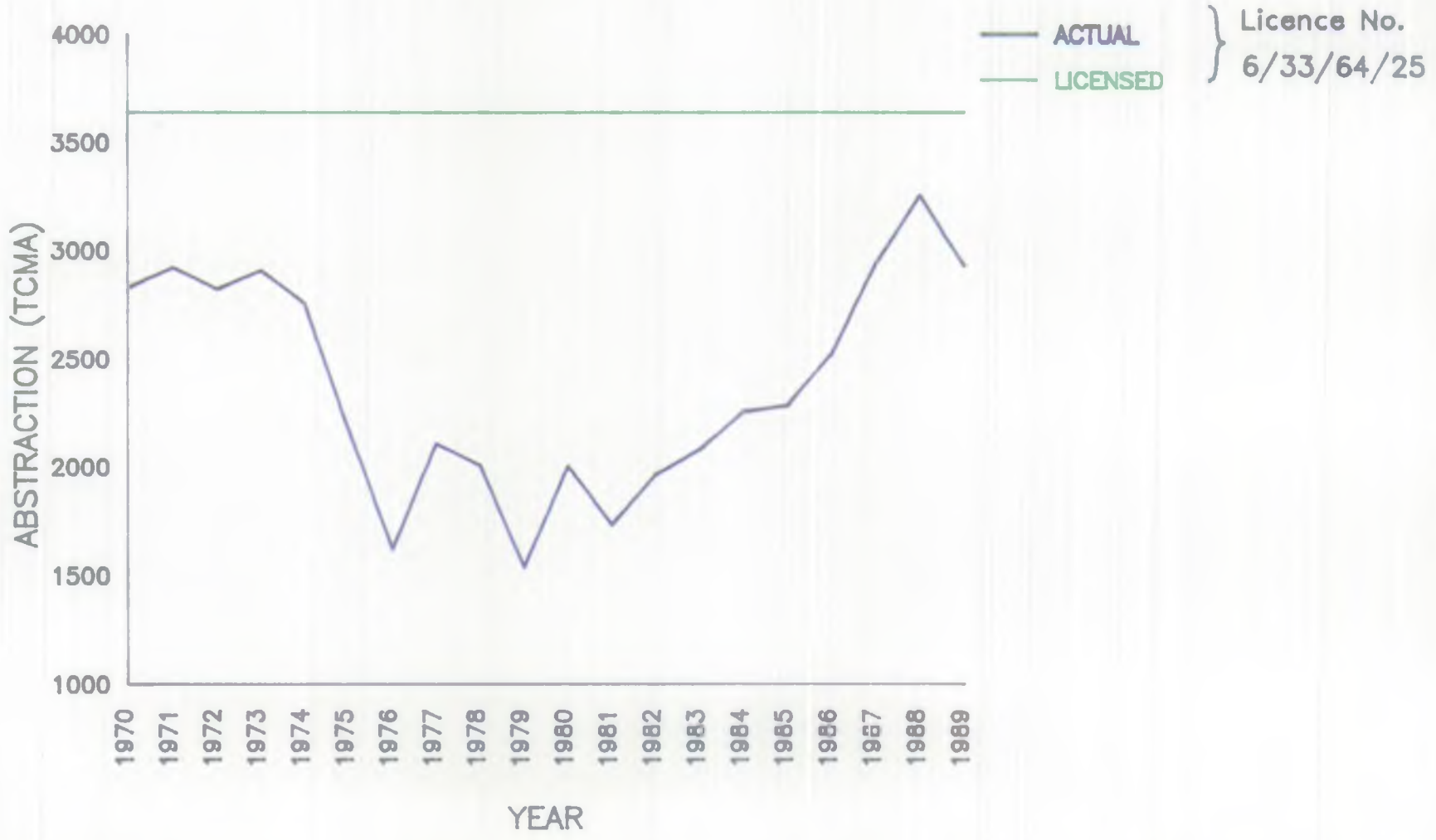
Scale 1:50 000

GEOLOGICAL CROSS SECTION THROUGH HILLINGTON P.S. GREENSAND BOREHOLE
N.G.R. TF743 262

NRA Document 25



HILLINGTON P.S.: History of Chalk Abstraction



Document NRA 27

Water Levels at Greensand Observation Wells & Boreholes in the Hillington Area

Name	National Grid Reference	N.R.A No.	Ground Level metres ODN	Period of Record (see note)	Range of Water Levels (m.ODN)
Hillington P.S.	TF 743262	72/10	25.18	1972-89 (Leziate)	15.7 - 23.2
Grimston Tithe Cot.	TF 735217	72/93b	39.47	1984-90 (Carstone)	12.4 - 17.1
Sandringham Warren	TF 667280	62/29a	32.50	1986-90 (Leziate)	13.2 - 18.5
Flitcham Abbey Fm.	TF 734265	72/09	25.83	1975-89 (Carstone)	21.1 - 25.7
Appleton Ho. Sandringham	TF 708273	72/08	26.93	1973-90 (Leziate)	11.7 - 20.6

note

The term Leziate or Carstone in brackets indicates the deepest formation sampled

WELL LEVELS

1 INCH TO 10 FEET VERTICAL

MAY | JUNE | JULY | AUG | SEPT

135' O.D.N

133' O.D.N.

114' O.D.N

82' O.D.N

83' O.D.N

73' O.D.N.

55' O.D.N.

HARDLEY DAMS (TF769254)

ANMER FARM (TF743294)

MIDDLE FARM (TF756275)

VALLEY FARM (TF754249)

FIELD FARM - CONGHAM

HARDLEY DAMS HOUSE (TF759263)

HILLINGTON STATION (TF722254)

53·0 O.D.N.

44' O.D.N

12' O.D.N

HILLINGTON PUMPING TEST 12–27 AUG 1965

HILLINGTON TEST BORE

RIVER: BABINGLEY - WEST NEWTON MILL (TF695256)

RIVER: BABINGLEY - TF718262

DISCHARGES

DISCHARGE (MGD)

GAYTON W.W. RAINFALL

INCHES 1·0 0·5

SPRING: MANOR FARM - CONGHAM (TF721241)

SPRING: FLITCHAM ABBEY x 10 PRELIMINARY TEST

YIELD

MINUS 45' O.D.N.

-20 O.D.N

RECOVERY TO 44' O.D.N. IN 5 HOURS

0 1 2 4 6

MAY | JUNE | JULY | AUG | SEPT

1965

ALL LICENSED ABSTRACTIONS WITHIN THE BABINGLEY CATCHMENT (6/33/64/**)

A) LICENSED SURFACE ABSTRACTIONS

Licence Number	National Grid Reference	Daily Abstraction m^3/Day	Annual Abstraction TCMA
6/33/64/008	TF72202570	172.86	2.546
6/33/64/009	TF72202570	172.84	2.540
6/33/64/013	TF65072680	777.27	20.545
	TF68452586		
6/33/64/023	TF62652385	1,963.64	20.545
	TF63552360		
6/33/64/027	TF68302520		
6/33/64/038	TF61252445	182.00	9.100
	TF62802540		
6/33/64/040	TF62502445	1,636.50	45.500
	TF64082725		
6/33/64/041	TF70802450	1,927.40	20.450
6/33/64/042	TF71452615	136.26	2.000
6/33/64/046	TF68802530	900.00	75.000
	TF70002570		
	TF71102580		
TOTAL		7,868.77	198.226

B) LICENSED CHALK ABSTRACTIONS

Licence Number	National Grid Reference	Daily Abstraction m^3/Day	Annual Abstraction TCMA
6/33/64/001	TF74702430	4.55	1.659
6/33/64/004	TF75402480	12.27	2.045
6/33/64/011	TF78402380	4.55	0.236
6/33/64/025	TF74302620	11,726.10	3,745.000
	TF76902550		
	TF79202550		
6/33/64/026	TF73302350	2,272.50 *	831.918
6/33/64/035	TF77202700	47.30	5.000
6/33/64/039	TF75502530	545.50	72.600
TOTAL		14,612.77	4,658.458

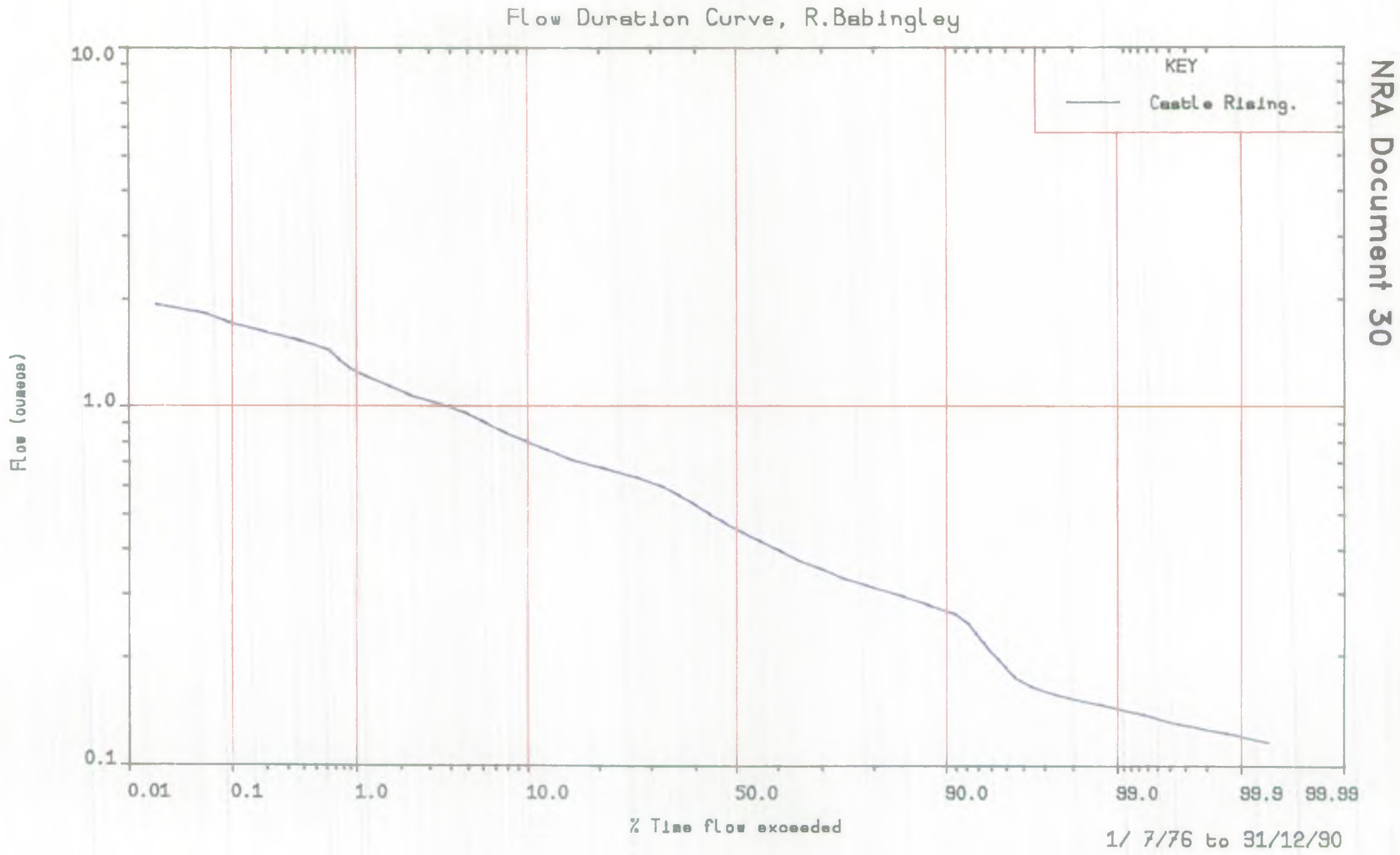
* This is the summer daily quantity.
The winter daily is 3,636 m^3/Day

C) LICENSED SANDRINGHAM SANDS ABSTRACTIONS

Licence Number	National Grid Reference	Daily Abstraction m^3/Day	Annual Abstraction TCMA
6/33/64/037	TF65502380	114	27.3
6/33/64/047	TF74302620	4,000	1,200.0
TOTAL		4,114	1,227.3

D) LICENSED SAND AND GRAVEL ABSTRACTIONS

Licence Number	National Grid Reference	Daily Abstraction m^3/Day	Annual Abstraction TCMA
6/33/64/046	TF68802530	900	75
	TF69202520		
	TF71302580		


Flow Duration Curve, R.Babingley
KEY
Castle Rising.
10.0
1.0
0.1
Flow (cumecs)
0.01
0.1
1.0
10.0
50.0
90.0
99.0
99.9
99.99
% Time flow exceeded
1/ 7/76 to 31/12/90
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