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WATER RESOURCES PLANNING:

NAR GROUNDWATER UNIT
WATER RESOURCES MANAGEMENT PLAN

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Purpose and Distribution: To refine and apply the principles of both the National and Regional Water Resources Strategies at a local scale, and to provide water resource input into Catchment Management Plans.

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FOREWORD

Water Resources Management Plans are a series of studies for specific catchments/aquifer units in which water resources issues are examined. Their purpose is to refine and apply the principles of both the National and Regional Water Resources Strategies at a local scale, and provide water resources input to Catchment Management Plans.

Water Resources Management Plans are the second of a three stage programme of resource assessment:-

- **Groundwater Balances** provide a first approximation of available groundwater resources using historical information from existing reports, recent abstraction licence and discharge consents data and make a provisional assessment of environmental requirements.

- **Water Resources Management Plans** build on, and refine the groundwater balance work. They update historical information, where relevant and make additional assessments of future needs, both for abstraction and the environment.

- **Groundwater Modelling** through computer simulation aims to aid understanding and quantify estimates of recharge into aquifers; the subsequent storage and movement of water within aquifers; eventual discharges of water from aquifers, given various abstraction scenarios. These models enable more accurate assessment of aquifer yield and evaluation of options for water resources management.

This Water Resources Management Plan examines both the water resources and demands of the Nar Groundwater Unit and sets out a plan to achieve the twin objectives of water resources;

secure water supplies <u>and</u> a better water environment.

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1 SUMMARY

The River Nar is a Chalk fed river in Norfolk, to the East of King's Lynn. In 1992 it was designated a Site of Special Scientific Interest (SSSI) as it is "an outstanding river system of its type." Water use in the Nar Groundwater Unit is mainly for public supply and agricultural purposes, including a large degree of spray irrigation.

Current issues within the Nar Groundwater Unit include the following:-

- The provision of secure water supplies in the light of increasing demands.
- The protection and improvement of the water environment, encompassing both rivers and wetlands.
- The protection of river water quality.
- The possible future use of river support pumping.
- A suitable abstraction licensing policy.
- Appropriate river channel management.

This report identifies that the Nar Groundwater Unit has a deficit of resources in relation to demands, after taking account of both environmental requirements and the entitlements of existing abstractors. It recommends an appropriate abstraction licensing policy to take account of these findings and a series of further measures in order to conserve and enhance important wetlands and the river environment, and to help protect river water quality.

The following recommendations are made in accordance with the principles of sustainability, precaution and demand management.

- no summer surface water is reliably available for abstraction, but there may be some scope for licensing small quantities of winter surface water.

- with a few exceptions, no additional groundwater is available for licensing.

- an 'In River Needs' study should be undertaken to identify minimum flow regimes and level requirements for key indicator species. This should incorporate aspects of river channel management, and should review the hands-off flow for the public water supply abstraction at Marham.

- a separate study should identify the needs of wetland environments within the Unit.

- an enhancement of the groundwater observation network around Marham should be considered.

- an integrated approach to the management of the water resources of the Nar Unit would be aided by the medium term development and application of a groundwater simulation model. Existing models have only been applied partially to the Unit.

2 INTRODUCTION

2.1 Location

The Nar Groundwater Unit (Cambs Chalk Unit 11) is located to the east of King's Lynn (Figure 1). Its boundaries are derived from minimum groundwater heads as shown on the "Hydrogeological Map of Northern East Anglia"[1], apart from the eastern boundary which is defined by the Totternhoe Stone horizon within the Lower Chalk.

The Unit mainly corresponds with surface water catchment 6/33/58 (River Nar) but also parts of 6/33/48 (River Wissey), 6/33/49 (Stringside Drain), 6/33/56 (Cut Off Channel) and 7/34/11 (River Wensum) are included within the Unit.

2.2 Current Issues

2.2.1 Provision of Secure Water Supplies

Public Water Supply

The current public water supply forecast[2] to the 2021 planning horizon shows a much lower increase in demand than previous forecasts. This is largely due to a combination of factors such as metering programmes, leakage reduction programmes and an increase in public awareness to use water wisely. However, the forecast assumes approval from OFWAT[3], of major expenditure which may, or may not be forthcoming following the recent decision on water company K factors.

In the context of the Nar, much of the water is used for public water supply and is exported out of the catchment to the King's Lynn demand centre. The demands on the Unit may prove to be a local exception to the Regional public water supply demand forecast. Anglian Water Services have already indicated that they wish to increase the security of supply in this area.

Agriculture

National spray irrigation forecasts[4] predict, under the 'most likely' scenario, an increase of 1.7% per year for the period 1996-2001 and 1% per year for the period 2001-2021. For the Anglian Region, the forecast under the same scenario is 2% per year for the period 1996-2001 and 1.25% per year for the period 2001-2021. This may have a significant implication within the Nar Unit where spray irrigation is a major use.

Industry

Industrial forecasts show an increase of 20%[2] over the 1991-2021 period, but with little industrial abstraction in the Unit, this is only of minor consequence. If industrial demands were to arise within the unit, the most likely use would be for mineral abstraction. Almost all such abstraction is returned, after use to the river, therefore impacts are likely to be minimal.

2.2.2 Protection and Improvement of the Water Environment

Wetlands

There are 2 wetland/riverine SSSI (including the River Nar itself) and around 40 County Wildlife Sites within the groundwater unit, with several more on the periphery (Figure 2). Investigations are currently being undertaken into 'wetland catchments' so that licensing policies may more effectively protect them.

Rivers

Water levels and river flow regimes required to satisfy the ecology need to be identified in order to achieve a better water environment, and to devise an appropriate licensing policy. No study on the Nar has identified these to date, although recent investigations on the Rivers Wissey[5] and River Babingley[6] may produce methodologies which can be applied to the River Nar.

The North Norfolk Rivers Project[7] identifies that spray irrigation demand can reduce low flows by up to 25% in the River Nar.

The surface water of the River Nar is of a good quality in general. Specific problems however, are likely to be encountered in the upper reaches especially during times of low flow (Figure 3).

2.2.3 Water Resources Management Policy

River Support

The unit contains two boreholes at Broom Covert and Warren Farm (West Acre) drilled by the NRA during 1990 in order to enable emergency augmentation of the River Nar during the drought. The future operation of this scheme requires consideration.

Abstraction Licensing Policy

The Nar Groundwater Unit is currently designated as having 'no water available'. This is largely due to both the demands of the Marham abstractions at the bottom of the catchment and allocations to the environment.

Other Management Policies

Consideration of other activities such river channel maintenance need to be addressed in order to operate in harmony with both existing and future management activities.

3 DESCRIPTION

3.1 Geology and Hydrogeology

The Nar Groundwater Unit is dominated by Upper Cretaceous Chalk which gently dips from west to east. The western part of the Unit has outcrops of Lower Cretaceous Chalk, notably near Marham, with Middle and Upper Chalk between Narborough and Castle Acre. Alluvium covers Chalk outcrop in the valley sides. The east of the Unit is characterised by thick Boulder Clay deposits which partially confine the Upper Chalk, but absent on the valley sides where alluvium, glacial sands and gravels overlie the chalk.

The River Nar flows within a buried glacial channel up to 80m deep filled with a mixture of alluvium, glacial sands and gravels.

Figure 4 shows the surface geology of the Nar Groundwater Unit.

A more detailed description of the geology and hydrogeology can be found in Appendix A.

Observation borehole data within the chalk were used to identify how the groundwater unit responded to different groundwater levels. Figures 5 & 6 show the groundwater contours derived from the high April 1988 levels, and the low September 1991 levels. The general shape of the contours shows that the overall shape of the groundwater catchment remains constant, but within it, differences of up to 10m in levels appear throughout.

3.2 Hydrology

The River Nar drains the area to the south east of King's Lynn, where it then flows into the River Great Ouse. The Nar can be divided into two distinct sections; downstream of Marham Gauging Station, the river flows through flat, heavily drained fen areas; upstream a predominantly Chalk catchment area of 153.3 km^2 contributes to the flow. It is the area upstream of the gauging station which is of most interest both in terms of water resources and the environment and therefore provides the main focus of the study.

The stream length from the source at Mileham to the gauging station is about 32 km with a drop in elevation of some 80m. [8]. Baseflow indices of 0.91 [9], and 0.87 [3] indicate that the river has a major baseflow (groundwater) component which is also reflected in the flat nature of the flow duration curves (Figure 7), and the relative non-peakiness of the hydrographs (Figures 8 to 11).

The catchment has one permanent gauging station at Marham (Table 1, Figure 12 and Plate 1) and several sites are current metered on a monthly basis (Table 2 & Figure 12).

Current metering data has been used to produce accretion profiles (Figure 13) which indicate that the flows upstream of West Lexham and Newton Mill only form a minor component of total flow. This is largely due to the Boulder Clay capping of the headwaters which restrict the interaction between the river and Chalk groundwater, resulting in very low natural flows during dry periods.

3.3 River Support Facilities

Concern arose during 1989/90 over the low flows being experienced in the River Nar, which threatened the security of the Marham surface intake and the river's quality and ecology. A feasibility study was undertaken by Mott MacDonald in 1990[3] into the construction of emergency river support boreholes. The scheme was predominantly to support the public water supply intake at Marham and other surface abstractions, but a spin off was to support the natural habitats which provide considerable conservation and recreational value. Design and construction of boreholes at Broom Covert and Warren Farm (West Acre) took place between June and October 1990 [10].

Three target flows were investigated as stated below, and were examined in relation to the 1976 recession curve (applied to 1990 flows) to indicate when operation of the scheme would require implementation.

0.219 cumecs (18.9 tcmd)	The lowest gauged flow on record plus the legal abstraction rate.
0.243 cumecs (21.0 tcmd)	The lowest naturalised flow on record.
0.300 cumecs (25.9 tcmd)	The flow that is equalled or exceeded for 99 percent of the time during the month of August.

It was estimated that a combined borehole output of 10 tcmd to be provided by two boreholes would be sufficient to meet requirements from August to mid October.

In practice, the Broom Covert scheme produced an inadequate yield and was abandoned prior to a public hearing in August 1990, which approved the more productive Warren Farm site. The river support scheme was operated from 8 October 1990 to 22 November 1990 and provided an average output of 4.9 tcmd. No estimation of net gain has been calculated.

The effects of the abstraction on the surrounding Chalk aquifer were seen as a 0.4 m to 0.1 m drawdown in groundwater levels within a 1.4 km to 2.6 km radius. Maximum drawdown was 6.35 m at steady state, and there was no indication of an effect to the south of the river.

From macroinvertebrate sampling just before the augmentation period, there was no evidence of derogation to aquatic communities due to low flows. Where derogation had occurred, it was considered more likely to be as the result of a deterioration in water quality due to sewage treatment work effluent, or a lack of suitable habitat due to unsympathetic river bank management. However, it was noted that it is highly desirable to maintain flows for dilution of effluent given the SSSI status of the river and its high conservation value.

Plate 1: Marha
Gauging Statioı

Plate 2: Marham PWS
river Intake

Mott McDonald consultants stated that it was difficult to assess the efficiency of the operation of the emergency river support scheme for several reasons:-

- The recovery of flows, although slow had already started by the time the scheme was in operation.
- The quantity of augmentation water was small in relation to the natural flows.
- There was uncertainty over the natural river flows after correction to account for public water supply abstraction.

Ideally it may be necessary to operate and test the scheme for several months with effective groundwater monitoring and current metering to better assess the effectiveness of the scheme.

These abstractions were never licensed and the plant installed to operate these boreholes was temporary and has since been removed. The future operation of this scheme requires further consideration.

Longer term requirements of river support for the Nar should be considered to augment the locations where low flows are most critical. Support should be considered for the headwaters of the catchment where Litcham sewage treatment effluent is discharged and flows are important for dilution to maintain water quality. However, such consideration should compare the costs and benefits of river support with those of improved effluent treatment. Adequate flows are also required in the Fenland reaches of the river downstream of Marham gauging station where the fauna is less rich due to natural conditions, and where maintenance of flows would prevent ponding and degradation of the environment. However, it is probable that flow requirements in the fenland section of the river would differ greatly from those of the fluvial section of the Nar.

It is recommended that a review of river support requirements should relate to river flow objectives and should be considered in conjunction with sympathetic river channel management practices.

3.4 Existing Models

3.4.1 Great Ouse Resource Model

The Great Ouse Resource Model (GORM) was developed by the Anglian Water Authority (later NRA) and the Water Research Centre between 1987 and 1990 and models surface water flows. The whole of the Great Ouse river basin has been divided into reaches defined by nodes at the end of each reach. The model calculates flow at every node at weekly time intervals using information about recharge and aquifer characteristics as well as abstractions and discharges.

The inflow to a reach is given as:

runoff + baseflow + effluent returns - surface water abstractions

The inflow is then added to the flow from the upstream node, progressively adding the flows downstream. Account is taken of aquifer storage and transmissivity values as well as groundwater abstractions when the model calculates the baseflow element.

The model has been calibrated with abstraction estimates for the period 1970-1986. Abstractions are allowed to vary through the year, for example the spray irrigation quantity is taken through the summer only. Effluent returns to the river have been calculated for the historical record (using consented flows multiplied by a factor derived from metering trials). The effluent returns vary seasonally and increase from year to year similar to abstractions. The 2011 effluents have been estimated. The model can be used to produce the flow record, given different abstraction regimes e.g. abstraction at full licensed quantity or predicted abstractions at the year 2011.

GORM was first used to predict historic flows for the period 1971-1986. After calibration to provide the best fit to these flows, it was run without abstractions for the same period to estimate natural flows for the catchment.

GORM underestimates the gauged flows of the Nar at Marham. It was found possible to improve the modelled flow duration curves by changing catchment areas and some model parameters. After calibration, modelled flows resemble gauged flows reasonably well (Figure 14).

Natural flows are calculated by setting abstractions and discharges to zero. The modelled natural flows over the period 1971-1986 are very similar to the modelled historic flows in the Nar (Q95's = 52.7 tcmd and 51.0 tcmd respectively). However, while the calibrated flow duration curve fits the real flow duration curve reasonably well (Figure 14), the differences at Q95 are greater than the differences between the modelled historic and natural flows. Therefore it is not appropriate to use the natural 95 percentile from this simulation in any policy decisions.

3.4.2 FLOWPATH Modelling

FLOWPATH is a two dimensional numerical groundwater modelling package which enables calculations of the following:

Steady state hydraulic head and drawdown distributions
Groundwater velocities
Pathlines
Travel times
Capture zones
Wellhead protection areas
Water balances

To date, two FLOWPATH models have been applied to parts of the Nar Groundwater Unit. Aspinwall & Co. developed a FLOWPATH model for the Wissey Groundwater Unit[11], which extended northwards to incorporate the Marham area and some southern parts of the Nar Groundwater Unit.

A further FLOWPATH model used the Aspinwall work as a foundation to build a model to be applied to the Marham sourceworks to determine a groundwater protection zone (GPZ)[12].

In order to try and identify the impact of Marham groundwater abstractions on the River Nar at Marham, results of previous modelling work were examined. Conclusions would contribute to the method of naturalisation chosen and indicate which data to incorporate.

Modelling in the Wissey Unit[11 & 12] produced uncertain results in terms of the groundwater catchment associated with the Nar:-

However in the north west part of the catchment [Wissey].... the modelled heads are substantially higher than the observed heads. This area is affected by the Marham abstraction and the River Nar. This area is very close to the base of the chalk and there is relatively little field data. Data that do exist [sic] around Marham suggest low transmissivity values (around 200 m^2/day) yet the large yield from Marham suggests that major fissure flow may be present providing very high permeability zones not included in the model.

The precise nature of the Nar-Wissey boundary and the influence of Marham groundwater abstraction requires further clarification.

The GPZ work[12] also failed to identify the effect of Marham groundwater abstractions on the River Nar, but indicated that :-

The inclusion of a significant contribution to the total abstraction of the Marham source from the Nar significantly reduces the total catchment zone and increases the defensibility of the model.

The modelling used in conjunction with particle tracking concluded that the Marham sources draw a small amount of water from the River Nar but also stated that the river and gravels have a significant contribution to the Marham groundwater source.

However, the two FLOWPATH modelling exercises fail to provide an integrated approach to the whole Unit and it is recommended that further work should be undertaken to either extend the Wissey model to incorporate the Nar Unit, or to create a model for the Nar Unit in isolation.

3.4.3 Micro Low Flows

Micro Low Flows is a computer software package which enables rapid estimation of flow statistics from catchment characteristics at both gauged and ungauged sites.

National methods for the estimation of the mean flow, the mean annual minimum flow and the 95 percentile exceedance flow at ungauged sites are calibrated using values of catchment area, standard annual average rainfall, potential evaporation and the fractions of hydrological response (HOST) classes for each catchment.

Based on a river network database, synthetic catchment boundaries are generated, which are then superimposed upon gridded databases of Q95(1) (derived from HOST classes), standard annual average rainfall and potential evaporation to derive mean catchment values of these characteristics above each river stretch. These catchment characteristic values are used for estimating the flow statistics associated with each stretch.

When applied to the Nar at Marham, Micro Low Flows estimates the natural 95 percentile flow as 29.4 tcmd. Due to the net effect of effluents and abstractions on the River Nar (and many other catchments where major abstraction occurs), one would expect the natural flows to be higher than the gauged. With the Nar this is not the case using Micro Low Flows. Therefore, when using the method outlined in "The Application of Micro Low Flows in Water Resources Planning"[13] where the natural 95 percentile is calibrated to the gauged mean flow, a value of 34.6 tcmd is calculated. However, this is still considerably less than the gauged 95 percentile at Marham (42.8 tcmd for 1966-93 or 47.5 tcmd for 1966-1986). For this reason, the Micro Low Flows results have not been used.

3.4.4 HYSIM

HYSIM is a rainfall/runoff model which uses precipitation and climate data to simulate the movement of moisture both above and below ground. Internally, the model simulates interception storage, runoff from impermeable areas, overland flow, interflow from the upper and lower soil horizons, rapid and slow response from groundwater and the hydraulics of flow in river channels.

The application of HYSIM to the River Nar is described more fully in "HYSIM Model: Modelling the Flows of the River Nar"[14].

In summary, modelling using HYSIM led to an estimate of 45.4 tcmd for the natural 95 percentile flow for the period 1961-1990. **This value represents the best current estimate of the natural 95 percentile flow**, although some reservations about the model and data used have been expressed.

The modelling process also provided statistical evidence to support the theory that groundwater abstractions at Marham have little influence on the flows of the Nar at Marham gauging station. Simulations were undertaken with the Marham component of groundwater abstraction set at 100%, 30% and 0% of actual abstraction respectively*. All of the runs were calibrated to the 1970-1973 period where little or no groundwater abstraction from Marham took place. The 0% simulation runs resulted in the best statistical fit when applied to the full data set, and matched the gauged record particularly well at low flows (see Figure 14.1). However, this is only indicative that Marham groundwater abstraction is minimal and it is acknowledged that some interaction will occur, possibly at say the 5 or 10% scenarios.

3.4.5 Conclusions on Existing Models

Groundwater

Previous work has not provided an integrated model of the Nar Groundwater Unit.

Surface Water

Both GORM and Micro Low Flows fail to produce convincing calibration. However, calibration using HYSIM in conjunction with improved data collection is more convincing and output can be used to:-

- provide an indication of the degree of interaction between the public water supply groundwater abstraction at Marham and the flows of the River Nar at Marham.
- quantify the effects of abstractions and effluents on the flows of the River Nar.
- provide a naturalised 95 percentile flow value to enable a minimum allocation of groundwater to river flows to be identified.

* The 100%, 30% and 0% scenarios relate to the percentage of Marham PWS groundwater actual abstraction assumed to affect the flows at or above Marham Gauging Station.

4 WATER RESOURCES

4.1 Surface Water Resources

The Nar receives a high contribution of its flow from groundwater, rather than surface runoff. Only 10 % of the total annual volume is direct from surface runoff. This 10 % is highly variable but mainly occurs in winter months.

4.2 Groundwater Resources

The groundwater resources are the reliable source of water and contribute 90 % of the total river volume.

"Wright's method[15]", adopted in the Cambridge Water Plan[16 & 17] has been used to estimate the gross groundwater resource.

Wright looked at the relationship of infiltration and rainfall. He did this by using known factors of geology, rainfall and river flows to produce the relationships by multiple regression analysis. He gave different equations depending upon the type of geology.

The infiltration through Chalk: $I = (0.810 \times R) - 308$ (mm/a)
The infiltration through Jurassic Boulder Clay over Chalk: $I = (0.202 \times R) - 77$ (mm/a)

where R = average annual rainfall (mm/a)

This gives the 'gross resource' (average recharge). The available resource however, is lower to reflect unavailability through space and unreliability through time. The available resource is then allocated between net abstractions and environmental requirements.

4.2.1 Cambridge Water Plan (1985) Assessment of Resources

The following assessment was made in the Cambridge Water Plan[7] using Wright's method with 1915 to 1950 rainfall records:

Table 3: Nar Groundwater Unit: 1985 Gross Resource Calculations.

Sub Catchment	Chalk Area (km^2)	I (mm/a)	Boulder Clay Area	I (mm/a)	Recharge (tcma)
6/33/58	99.0	239	75.0	72	29,060
6/33/48	4.5	217	11.5	68	1,760
Unit 11	103.5		86.5		30,820 (84.4 tcmd)

N.B. Minor sub-catchment areas are lumped into the two main catchments given above.

4.2.2 Water Resources Strategy - Consultation Draft (1993)[18] Assessment of Resources

For the purposes of the above report, a review of groundwater resources[19] within the Anglian Region was undertaken. Water resources management studies within the Lark[20] and the Little Ouse[21] groundwater units identified an average 2 % reduction in rainfall from the Standard Average Annual Rainfall (SAAR) periods 1915-1950 to 1961-1990. This resulted in an estimated 5 % reduction in recharge for the Cambridge Chalk Groundwater Units. As 1985 assessments within the Cambridge Water Plan used the 1915-1950 period, all other resource estimates within the hydrometric area were reduced by 5 % and used within the Water Resources Strategy - Consultation Draft. The Nar Unit's recharge was therefore recalculated as 79.8 tcmd.

The gross resource calculated as above is then reduced by 20 % to reflect the inadequacy of the Chalk storage to fully even out the year to year fluctuation in recharge (drought years to wet years) and becomes the 'effective resource'. The 20 % is unreliable for abstraction but instead contributes to river flow in the wetter years. Separate allocations are made for the river.

4.2.3 Current Assessment of Resources

The following calculations update the Cambridge Water Plan method of analysis using the standard rainfall period 1961 to 1990, and Wright's equations. The relationships identified in these equations may not hold true for the 1961 to 1990 conditions, but they represent the best method in the time available.

Rainfall figures from individual records have been weighted by the fraction of the area represented by the gauges and then summed. These areas were determined by the technique of Theissen polygons. In summary:-

Table 4: Nar Groundwater Unit: 1961-90 Rainfall & Recharge Calculations

Raingauge	Met Office Number	Polygon Area km²	Proportion of Groundwater Unit	1961-1990 Rainfall (mm)	1961-1990 multiplied by proportion (mm)
Castle Acre	198866	94.27	0.497	741	368
Mileham	207185	14.69	0.077	665	51
Wendling Ash	206950	19.57	0.103	666	69
Swaffham STW	193213	18.85	0.099	648	64
Marham Pumping Station	199425	29.05	0.153	626	96
Gayton	199654	13.34	0.070	677	47
TOTALS		189.77	0.999		695

Sub Catchment	Chalk		Boulder Clay		Total	
	Area (km^2)	Recharge (tcmd)	Area (km^2)	Recharge (tcmd)	Area (km^2)	Recharge (tcmd)
6/33/58	92.9	64.97	65.0	11.30	157.9	76.28
6/33/48	2.2	1.54	11.3	1.96	13.5	3.50
6/33/49	4.5	3.15	-	-	4.5	3.15
6/33/56	2.8	1.96	-	-	2.8	1.96
7/34/11	0.7	0.49	14.6	2.54	15.3	3.03
Unit 11	103.1	72.11	90.9	15.80	194.0	87.92

N.B. Areas re-assessed using planimeter.

The rainfall of 695 mm was used in Wright's equations (see Section 4.2) to produce a gross resource value of 87.9 tcmd.

4.3 Transfers into & out of the Catchment

The public water supply abstractions from Marham are largely exported from the groundwater unit, and provide supplies to the Wisbech District (CM 29) of the King's Lynn Supply Zone.

4.4 Summary

The best estimate of gross groundwater resource (ie. long term average recharge) is 87.4 tcmd.

5 WATER QUALITY

This study assumes that water quality will continue to be successfully managed in the future.

This chapter provides a brief description of the current water quality of the Unit given. It indicates that in general quality is good and there are no major problems, other than concern over the lack of dilution of effluent in the headwaters during periods of low flow. However, it is not usually water resources policy to allocate water specifically to the dilution of effluents. The NRA's approach is to continue to set discharge consent conditions according to the anticipated regime of dilution flows.

5.1 Surface Water Quality

River water quality is assessed against four main criteria:

5.1.1 E.C. Fishery Directive

Two reaches of the River Nar have been designated as Fisheries:-

Salmonid:	Lexham Hall (TF 8675 1690) to Marham Surface Water Intake (TF 7240 1200)
Cyprinid:	Marham Surface Water Intake (TF 7240 1200) to Tail Sluice, King's Lynn (TF 6210 1830)

These stretches therefore have to meet quality criteria for Dissolved Oxygen, Ph, Ammonia, Zinc, Biological Oxygen Demand and Copper.

5.1.2 River Quality Objectives

The River Nar is classified according to the River Quality Objectives (1986). The river has been divided into a series of stretches and uses listed in Appendix B. These have been used to determine the quality that should be safeguarded.

5.1.3 National Water Council Classification

The NWC Classification provides an indication of the chemical quality of rivers. The results of the 1992 River Quality Survey are provided in Appendix B. Upstream of TF 6700 1350, there are 21.2 km of 'good quality' river, 3.7 km of 'fair quality' river and 5.0 km of 'poor quality' river. Table 5 provides a detailed description of the criteria for each classification.

5.1.4 Biological Standards

5 sites are biologically sampled routinely between Mileham and Narborough. They are identified below. The summary data for samples collected in 1992 is shown in Appendix B.

River Nar	Litcham Road Bridge	TF 888 174
River Nar	West Lexham Road Bridge	TF 838 169
River Nar	Castle Acre Road Bridge	TF 819 148
River Nar	West Acre Road Bridge	TF 779 147
River Nar	Narborough Road Bridge	TF 747 132

Samples provide an indication of the actual biological quality and are then compared to the predicted quality of the same stretch as modelled by RIVPAC. RIVPAC uses details about the physical features of the river channel (width, depth and type of substrate) to predict the types of invertebrate that should be in evidence. This comparison enables compliances to be set and the biological quality to be monitored through time. The most recent samples for the above sites show that 3 out of 5 comply.

These reaches are of satisfactory biological quality:-

Litcham Road Bridge
West Acre Road Bridge
Narborough Road Bridge

These reaches fall short in respect of the target compliance:-

West Lexham Road Bridge
Castle Acre Road Bridge

5.2 Groundwater Quality

In general, the quality of the Chalk groundwater is suitable for abstraction and environmental demands.

The NRA has recently produced "Policy and Practice for the Protection of Groundwater"[22] in which policy is established for the future protection of the aquifer and potable sources. Groundwater Protection Zones exist around two abstraction sites in the study area, namely Marham and West Lexham. Draft protection zones (Figure 15) have been produced but these are strictly provisional and will not be finalised until mid 1994.

There are no Nitrate Sensitive Areas (NSA'S), and no known solvent contamination exists within the study area. The site at West Lexham is a Nitrate Vulnerable Zone (NVZ) and therefore has a Groundwater Protection Zone. However, this is a disused PWS site and therefore no further refinement of its GPZ will take place.

6 WATER USE IN THE GROUNDWATER UNIT

There is a relatively high degree of groundwater abstraction in the Nar Unit; 41 % of the net resource (33 % of the gross resource) being allocated by abstraction licences.

Surface water licensed abstractions are less in quantity, but can be just as significant when spatial and seasonal distributions are taken into account. Figures 16 to 20 and Tables 6 & 7 illustrate the components of use through time.

The public water supply surface intake which forms a major component of abstraction is located at the bottom end of the Unit, several metres upstream of the gauging station and therefore has little or no environmental impact in the area of study.

6.1 Public Water Supply

Currently the only PWS abstraction within the Unit is from Marham. This is a major source, but has little impact on the Unit as a whole due to its location at the bottom of the catchment. Marham has a surface intake just upstream of Marham Gauging station at TF 723 119. There are also ten boreholes at Marham (of which 4 are disused).

The surface water intake at Marham (Plate 2) operates with the constraint of a hands-off flow originating from the Wisbech Water Order 1948. It prohibits abstraction from the River Nar when the flow is less than 40,000 gallons per day (0.18 tcmd).

Two licences relate to the surface abstraction, and another two licences relate to the boreholes. The sum of the individual entitlements is 14,519 tcma. However, the licences are 'grouped', and an aggregate of 9542 tcma applies to these 4 licences, and a further aggregate of 12,624 tcma applies with the inclusion of the borehole at Beachamwell, which is in Unit 10 (Wissey). Figure 20.1 shows how the aggregates relate to one another.

Because of the nature of the grouped licence it is impossible to know what quantities will be taken from what sourceworks; Table 8 shows how the PWS quantities used for planning purposes are derived. Licensed quantities are reduced so that their total does not exceed any group aggregate, although individual licensed quantities may be higher.

Table 8: Derivation of PWS Quantities used for Planning Purposes from Aggregates.

Source	Licence No.	Licensed Quantity	Allowing for Group Aggregate
Beachamwell	6/33/49/*g/051	13.64 tcmd	11.86 tcmd
Marham Surface	6/33/58/*s/040	6.82 tcmd	5.93 tcmd
Marham Surface	6/33/58/*s/102	6.82 tcmd	5.93 tcmd
Marham Groundwater	6/33/56/*g/040	} Abstraction up to }	
Marham Groundwater	6/33/56/*g/071	} Marham Aggregate }	10.87 tcmd

N.B. **'Marham Aggregate'** = 6/33/58/*s/040 & 102
6/33/56/*g/040 & 071 = 26.14 tcmd ave.

'Group Aggregate' = 'Marham Aggregate'
plus 6/33/49/*g/051 = 34.59 tcmd ave.

All quantities expressed as tcmd (annual average)

10.87 tcmd is therefore assumed for water resources planning purposes for the Marham groundwater abstraction licence. However, Marham surface and groundwater sources are used conjunctively, and the licence permits groundwater abstraction up to 22.7 tcmd (annual average) provided that no surface abstraction takes place. **Therefore in terms of groundwater balance calculations, the precautionary principle is adopted and 22.7 tcmd is used.**

6.1.1 Licensed Quantities and S.R.O's of PWS Sourceworks

Prior to the PWS development at Marham, several other PWS abstractions were licensed. Table 9 lists the details of all PWS licences - both current and historic. Figure 21 shows their location.

Table 9: History of PWS Licensed Abstractions

Licence	Most Recent Annual Quantity (tcma)	S.R.O. (tcma)	Issue Date	Expiry Date
6/33/58/*s/040 Marham (Surface)	2489.0	2920.0 includes 58/*s/102	March 66	-
6/33/58/*s/102 Marham (Surface)	2489.0	see above	April 67	-
6/33/56/*g/040 Marham (Ground)	9542.0 including 58/40 & 58/102	4843.6 includes 56/*g/071	April 67	-
6/33/56/*g/071 Marham (Ground)	no additional water than 6/33/56/*g/040	see above	July 75	-
6/33/58/*g/079 Castle Acre	11.82	-	July 68	Jan 87
6/33/58/*g/082 Castle Acre	29.32	-	July 68	Jan 87
6/33/58/*g/078 West Acre	9.27	-	July 68	Jan 87
6/33/58/*g/026 Narborough	96.38	-	July 68	May 72
6/33/58/*g/069 Litcham	22.40	-	July 68	May 77
7/34/11/*g/336 Weasenham Hall	31.80	-	Feb 67	Feb 78
6/33/58/*g/066 Beeston	62.40	-	July 68	Feb 73
6/33/58/*g/067 Rougham	10.27	-	July 68	Dec 76

The sourceworks reliable output (SRO) figures associated with each licensed abstraction provide an indication of the amount of water that can reliably be abstracted in a 1 in 50 year drought.[23]

6.2 General Agriculture & Spray Irrigation

A relatively high proportion (approximately 20%) of total licensed abstraction within the Nar Groundwater Unit is licensed for agricultural use. About 90 % of this quantity is used for spray irrigation.

Spray irrigation abstractions can have a disproportionate impact on the water environment because water is taken at relatively high peak rates, usually during summer low flow conditions and their use is consumptive.

Direct surface abstractions for spray irrigation have the greatest impact. The peak impact of seasonal groundwater abstraction is less, but depends on local aquifer characteristics and may still be severe where water is taken from shallow sand and gravel aquifers close to the river system.

The University of East Anglia study, 1994 "The Effects of Water Resources Management on the Rivers Bure, Wensum and Nar in North Norfolk" looked at the effects of water resources management since the 1930's. It concluded that:

Losses to flows due to spray irrigation during the lowest average weekly flows of the 1989 to 1992 drought were 24% in the Nar and about 15% in both the Wensum and Bure.

The 24% figure was calculated by using the GORM model described in Section 3.4.1. This however, is not directly comparable with the 63% impact (Figure 14.2) on the lowest flow as calculated from the HYSIM modelling for the following reasons:

- HYSIM looked at the lowest flows for the period 1961-1990, whereas GORM looked at the lowest flows for the 1989-1992 period.
- GORM reflects the impact of spray irrigation in isolation, HYSIM takes account of all uses.
- GORM uses average weekly flows, HYSIM uses a daily timestep.
- The University of East Anglia when using GORM used only the abstraction returns that were on record, the HYSIM modelling exercise included generated data for returns not on record. Therefore more abstraction has been accounted for in HYSIM.

The NRA value was re-assessed as 40% impact on the lowest natural flow when PWS surface abstractions at Marham are excluded from the data. This enables an indicative comparison to be made with the UEA value, but the two values cannot be compared too directly due to the reasons stated above.

Abstractions for general agriculture are less consumptive (assessed to be around 10%) and returns are assumed to be close to the point of abstraction.

6.3 Industry

There is little industrial use of water within the Unit, less than 1 % of total licensed abstraction.

Mineral washing particularly between Castle Acre and West Acre (Plate 3), in the Nar valley accounts for another 1.5%, but 90% of this is assumed as being recycled.

6.4 Environmental

Environmental needs have to be met from our water resources. River flows have to be maintained at adequate levels, saline water has to be prevented from entering aquifers and rivers, and wetland sites require protection from over abstraction.

6.4.1 Wetland Conservation Sites

There are currently 3 Sites of Special Scientific Interest (SSSI) within the Unit. Of these, 2 are considered to be water dependant sites (Plates 4 & 5) including the River Nar itself (designated in 1992). Appendix C provides details of their notification.

Around 40 water dependant County Wildlife Sites exist within the Unit. Little information other than NGR and a brief description is available and is given in Appendix C.

6.4.2 River Needs

The current minimum allocation of groundwater resources to a river is based on the natural 95 percentile flow (Q95) of that river (ie. that flow which is exceeded for 95% of the time under 'natural' conditions). This value is somewhat arbitrary as there is currently little scientific evidence as to whether, or to what extent the environment would suffer if a lower minimum value was allocated (eg 97-98 percentile flow). For the meantime, until Minimum Acceptable Flows (MAF's) are set for individual rivers, the natural 95 percentile flow will be the basis for allocation of resources to rivers. It is assumed that these low flows will be met from the groundwater resource, perhaps using river augmentation schemes to maintain minimum flows when necessary.

It has been suggested that in some cases the natural Q95 may be unnecessarily high in relation to the 'gross resource' (Section 4.2). Therefore the use of an alternative environmental allocation which is restricted to 50% of the gross resource is under consideration. This alternative is under debate at present and is not used presently in any policy decisions. In relation to the Nar Groundwater Unit, this would 'release' a further 1.13 tcmd, but the Unit would still remain in deficit.

Several computer models have been used to assess the natural 95 percentile flow of the Nar at Marham, but with a lack of confidence in the results produced from both Micro Low Flows and GORM, alternative methods were considered:-

- Replacing the GORM estimated data (1970-86) with actual abstraction data (1970-1993).
- Using alternative computer simulation models (eg HYSIM) to calculate naturalised flows.
- By 'recomposition' from the gauged record.

Confidence in the results obtained from the HYSIM rainfall runoff simulation model proved to be greatest (Section 3.4.4), therefore a natural Q95 value of 45.4 tcmd is currently used in the resource balance assessment.

6.5 Navigation

The River Nar is non navigable within the Unit, although previously (1751 Act of Parliament) it was a waterway for commercial navigation from King's Lynn to Narborough.

6.6 Fisheries

The River Nar has been routinely surveyed on 4 occasions, in 1982, 1985, 1990 & 1993. The 1993 survey recorded a total of 17 species with roach being dominant in terms of weight and number.

Growth rates were calculated for the two most numerous cyprinid species, roach and dace, and both were found to be close to standard. Roach growth was 99% of standard growth and dace growth was 106% of standard growth.

The roach year class structure was dominated by fish from the 1989 and 1991 year classes, with the 1989 year class being particularly strong. Every year class was represented between 1983 and 1992.

The dace population was dominated by the 1991 year class with the 1990 year class also relatively strong. All year classes between 1988 and 1992 were represented except 1992.

The brown trout population was dominated by the 1991 and 1992 year classes indicating the presence of a breeding population and confirming the F1 status of the river. The 1990 year class was well represented and a few fish from 1989 were also recorded.

Plate 3: Sand & Gravel Abstraction - West Acre

Plate 4: Castle Acre Common SSSI

Eels continue to be the only species recorded at all twelve sites, and with its close proximity to the Tidal River Great Ouse and suitable benthic habitat the River Nar continues to support an important population of eels. Eel biomass and density estimates have fallen by approximately half since the 1989/90 survey although this decline is restricted mainly to the section of river below Narborough. This could be due to the differing seasonal patterns of distribution, reduced recruitment to the population during the drought or possibly the effects of the parasite Anguillicola crassa.

The results of the 1993 survey indicate a good biomass class 'A' fishery at 27.4 gm^{-2}, this is an increase of over 5 gm^{-2} since the 1990 survey. The density estimate of 0.43 fish m^2 is the highest recorded for the River Nar since the river was first surveyed in 1982. This increase in biomass may not necessarily be wholly related to recovery from the 1989-1992 drought.

6.7 Effluents

Figure 22 shows the location of existing effluent discharges within the catchment. Effluent discharges have an important role to play with regard to water resources. Reliable effluent discharges effectively support the flows of river systems, and where of a suitable quality increase the reliability of surface abstractions with hands-off flows, and help sustain a healthy environment. The effluent discharges should not be relied upon as future available water resource because their locations and suitability in terms of quality may vary dramatically through time.

The standard required of effluent discharged to watercourses is determined by the range of flows that provide dilution. However, in the headwaters, the geology is such that there is only a minor component of flow from groundwater. In dry periods, this means that low flows will result naturally (Figure 13). Data suggests[7 & 10] that biological changes have resulted here from the discharge of Litcham effluent. However, in the majority of cases it is almost always more economical to improve effluent treatment rather than increase dilution flows. It is therefore not normally water resources policy to increase flows purely for dilution purposes:

We will not, usually, allocate water specifically to the dilution of effluents; but rather we will set effluent consent conditions according to the anticipated regime of dilution flows. (Water Resources in Anglia, 1994)

It is as a result of this policy that Anglian Water Services installed phosphorous stripping plant at Litcham in 1992 in order to protect the water quality of the headwaters of the Nar.

The current quantity of effluent within the catchment has been estimated using two approaches:

'Reliable Effluent' estimation

Estimates have been based on a combination of dry weather flow values from water quality discharge consents for public water supply and industrial use (excluding direct industrial abstractions) and percentages of **licensed abstraction** for other uses. These estimates are then applied to assess the sustainability of abstractions within the catchment (see Section 7.2).

Based on 1993 data, the reliable effluent estimated for the River Nar is 2.12 tcmd.

'Actual Effluent' estimation

The quantity of effluent actually discharged through time is required for river flow naturalisation calculations and surface water modelling.

This is again estimated by a combination of methods. The public water supply component is derived from populations of parishes contributing effluent to the River Nar. This is then multiplied by domestic per capita consumption values (the industrial component has been excluded as it is not seen as relevant to the Nar Unit, and the leakage component has been excluded as it does not go directly to the River).

Effluent derived from other components of use are determined by proportions of **actual abstraction**. This will provide a more accurate reflection of actual discharges through time.

Based on 1994 best estimates of per capita consumption for 1991 and actual abstraction data for 1991, the actual effluent discharged to the River Nar was 0.92 tcmd.

6.8 Other Water Use

There are two major fish farms within the unit, one at West Acre (Plate 6) and the other at Narborough. West Acre fish farm mainly abstracts groundwater from a seepage reservoir but is licensed to take additional quantities from the River Nar (Plate 7). Narborough fish farm can abstract water from the Mill Leat, which is in turn fed by the River Nar, Narborough Lake, several drains and springs. The requirement for abstraction licences for fish farms arose in 1989, with existing abstractors granted licences of entitlement. The abstraction at Narborough is currently of 'entitlement' status, but due to the complicated nature of the site, an abstraction licence has not yet been issued. This will be considered in the near future, but is not considered a major issue, as the majority of the water is returned to the river after use.

Plate 5: River Nar at Castle Acre Priory

Plate 6: West Acre Fish Farm

Plate 7: Abstraction at W.Acre Fish Farm

7 BALANCE OF RESOURCES AND DEMANDS

7.1 Surface Water

Current policy regarding the availability of surface water in the Anglian Region[24] states that:

> *use and storage of winter flows should be encouraged.*
>
> *all surface licences should be subject to cessation flows or levels sufficient to protect all downstream interests, abstractive and environmental.*
>
> *summer surface water should generally not be licensed except from augmented rivers.*

In relation to the River Nar, the current licensing situation is as follows:-

- no new summer surface water abstractions

- due to the SSSI status of the Nar, there is a general presumption to refuse new licences, unless the effect on the ecology of the Nar is proven to be insignificant or can be mitigated by works or conditions agreed by the NRA and English Nature. Applicants would therefore be required to produce an Environmental Assessment in support of an application.

- cessation conditions are incorporated into any new licences.

The approach used to assess the current potential availability of surface water resources within the Unit was to compare the minimum recorded flows at Marham gauging station with licensed quantities of Marham PWS surface intake, unconstrained summer surface abstractions, and the hands-off flow condition within the PWS licence.

Available surface water = MIN - (PF + PWS + SURF)

MIN = Minimum Recorded Flow - 27 Aug 1976, with 10.2 tcmd added to account for Marham surface abstraction on that day = 0.26 cumecs (22.3 tcmd)
PF = Hands-off Flow - Wisbech Water Order 1948 = 40,000 g/d (0.18 tcmd)
PWS = Licensed Surface Water (Marham) = 13.6 tcmd
SURF = Other Unconstrained Summer Surface Abstractions = 7.5 tcmd

Therefore nominally available surface water resource upstream of Marham gauging station

= 22.3 - (0.18 + 13.6 + 7.5) = 1.02 tcmd

The hands-off flow given in the Wisbech Water Order 1948 was derived for the purposes of securing supplies, and had much less consideration for environmental requirements than would be given if derived today (the minimum recorded flow is 7.86 tcmd greater than the hands-off flow). In this context, and given that the river is now SSSI status we must question the current validity of the hands-off flow.

This reinforces the view that further licensing of summer surface water is unacceptable, use and storage of winter flows should be encouraged, and any new surface water licences should contain cessation clauses to protect downstream abstractions and environmental requirements.

It is recommended that a more realistic hands-off flow for PWS abstraction at Marham should be examined as part of an in river needs study for the River Nar.

7.2 Groundwater

Groundwater resources are assessed by the method outlined in the Groundwater Balances Review 1992.

The gross resource (long average recharge) is calculated from Wright's equation and 1961-90 standard annual average rainfall (SAAR) (see Section 4.2) and factored by 0.8 to account for the following:-

> *"The total groundwater resource will rarely be fully exploitable, the non uniform availability of the resource within the groundwater unit may be a limitation affected by factors such as geology, pattern of development, avoidance of sensitive areas, storativity and transmissibility of the aquifer. Some allowance must also be made for uncertainties in estimation of resource, the degree to which storage can be used to overcome seasonal fluctuations, and imperfect manipulation of baseflow by river support schemes."*
>
> (1992 Groundwater Balance Review, 1994 Edition)

This leaves an effective resource from which quantities are allocated for licensed abstraction and the environment.

The environmental requirement for groundwater is assessed. This is primarily the minimum required river flow. Ideally this might involve detailed ecological studies, but no satisfactory objective method is available yet, and no specific study has been undertaken for the River Nar. In its absence, current practice is to use the natural 95 percentile flow (ie. the flow which, in the absence of any abstractions or discharges, would be equalled or exceeded 95% of the time).

As an interim suggestion, the effect of limiting the 'reliable' river allocation to 50% of the gross resource is shown. In the case of the River Nar, this would 'release' additional water for abstraction, but the environment would still get the reliable 50% plus the unreliable 20% previously deducted when calculating the effective resource.

In practice, river flows are sustained by treated sewage effluents, and reduced by surface abstractions. These are quantified and the allocation to the river from groundwater is adjusted accordingly. Abstractions are taken as the annual average licensed quantity; and reliable effluents are taken as 75% of their normal dry weather flow, to account for reduced water usage in drought conditions.

The quantity allowable for abstraction is the effective resource minus the allocation of groundwater to the river.

The quantities thus allocated to the river are the natural 95 percentile flow plus the remaining 20% of the unreliable recharge, plus all surface runoff. This leaves a river with naturally varying flow characteristics.

Table 10 shows the components of the groundwater resource balance calculation

Table 10: Nar Unit - Groundwater Resource Balance

Catchment Characteristics

Recharge Area (km^2)	194.0
Gross Resource (tcmd)	87.9
Availability Factor	0.8
Available Resource - Net	69.9

Licensed Demands (tcmd average.)	Groundwater Licensed	Surface Water Licensed	Effluent Returns
Public Water Supply	22.70	*	1.10
Private Water Undertaking	0.01	*	0.01
General Industry	0.16	*	0.20
Industry- Mineral & Non Consumptive Cooling	0.33	*	0.31
General Agriculture	0.56	*	0.50
Spray Irrigation	5.15	1.60	0.00
Miscellaneous	0.00	*	0.00
Totals	**28.91**	**1.60**	**2.12**
Net Abstraction (-) or return (+)	**-28.91**	**0.52**	

Environmental Allocation

Gross Allocation (natural 95 percentile flow)	45.36
Net Allocation (allowing for net surface abstraction)	**44.84**
If allocation restricted to 50% of gross resource	*43.70*

Resource Surplus/Deficit

(Net resource - total GW licensed - net environmental allocation.)	**- 3.79**
If allocation restricted to 50% of gross resource	*- 2.66*

* Most large surface abstractions are controlled by hands-off flows as are more recently issued spray irrigation licences. In terms of the impact on the groundwater resource balance, the average annual licensed abstraction for summer spray irrigation has been used. This represents the maximum potential average depletion of flows by such abstractions that might have to be ameliorated using an equivalent volume of river augmentation.

7.3 Summary of Water Resources and Demands

In summary, the Nar Groundwater Unit has a small deficit of 3.8 tcmd. This is accounted for in Table 11:

Table 11: Groundwater Balance Summary

	Component	tcmd (ave)
1	Gross resource	87.4
2	Net resource (80% of 1)	69.9
3	Total groundwater abstraction licensed	28.9
4	Net environmental allocation	44.8
5	Surplus/ Deficit (2-3-4)	-3.8

8 ISSUES AND OPTIONS

This section investigates the options available for each issue previously raised in Section 2.2.

8.1 Increasing Demand for Water Abstraction, & Licensing Policy

When forecast increases in the demand for water for spray irrigation and for industry, and possible local increases in public water supply are considered in the context of a fully committed resource for the Unit, the following options are available.

Options

i) The current "no water available" status of the Nar groundwater unit is maintained, and no new water should be licensed. However, possible exceptions as noted in the regional abstraction licensing guidelines[2 & 24] may be considered.

ii) Time limited licences might be granted until such time that the resource assessment and/or in river needs requirements are refined in the hope of meeting future needs.

iii) Revocation of licences might be considered, especially those where compensation would not have to be paid. (ie. for sources which have had no abstraction for 7 years).

iv) Encourage the use of winter surface water, with reservoir storage to meet future summer demands.

v) Import water from adjacent catchments to meet future demands.

Option i) would follow the precautionary principle, given the sensitive nature and SSSI status of the River Nar. In the longer term, availability might increase as licences expire (if they are not re-issued).

Option ii) would enable increased demands to be met in the interim. However, this report provides the best current view on resource availability and its findings should be used accordingly.

Option iii) would 'release' water currently secured by licences. This would initially reduce the nominal deficit of the Nar and, provided the quantities involved are sufficient, might result in a resource surplus.

Option iv) would enable some additional summer demands to be met in the future, provided that appropriate hands-off flows conditions are contained in new licences. Current national R&D[25] will provide guidance on the use of hands-off flow conditions. Given the SSSI status of the river, liaison with English Nature is recommended.

Option v) may be restricted by both cost and the availability of resources in other catchments.

Recommendations

For the above reasons, it is recommended that options i) and iii) are adopted in order to address the groundwater resource deficit, and option iv) should be considered in relation to new applications for use of water in the summer.

8.2 Environmental Needs for Water

The main concern is to improve understanding of the levels and flows of both ground and surface water that are critical to maintaining the in-river environment, SSSI's and other sites of conservation importance in the Nar Groundwater Unit.

Options

i) NRA to commission special studies to identify in-river and wetland water needs.

ii) Require applicants for further abstraction to carry out relevant studies.

iii) Review and possibly change physical river channel management to enhance the river environment.

iv) Provide river support in the headwaters of the Nar. (The current river augmentation facility exists in the middle of the catchment)..

Option i) is already partly in progress for wetland SSSI, with East Walton covered as part of a current R&D project[26]. If the R&D proves successful it could be applied to other sites in the Unit.

This option would provide the most comprehensive base for managing water resources for the environment most effectively, and is recommended in the longer term. It would need to address the differing needs of the fen river downstream of Marham and the fluvial reaches upstream. A possible outcome of such a study might be to re-address the hands-off flow for the Marham surface abstraction. However, the results of current R&D on both wetland and in-river needs are needed if the NRA is to obtain the best value from further such studies.

Option ii) is attractive in passing the onus onto the applicant. However, it may lead to fragmented studies that do not cover the integrated needs of the environment, and would still require significant input from the NRA in order to specify the requirements of such investigations. This option would only apply to groundwater licences which are 'exceptions' to the "no groundwater water available" policy, and to applications to utilise winter water. All other applications would be refused at an earlier stage.

Although option iii) is outside the immediate scope of the water resources function, river channel management can have major effects on environmental needs. The scope to enhance the river environment, but at the same time perhaps to reduce the in-river flow needs through changes to drainage and channel morphology (eg two stage channels, riffles and pools) could be explored.

Option iv) should be addressed with the evaluation of the efficiency of the current river support facility in conjunction with river flow objectives, resulting from an 'In River Needs Study'.

Recommendations

It is recommended that an 'in-river needs study' (option i)), based on the comparable work in the Wissey and Babingley and upon current National R&D should be commissioned, and consideration of option iv) should be based upon its findings.

It is recommended that option ii) is done as far as possible, but is not regarded on its own as an adequate policy for protecting the environment.

It is recommended that option iii) is included within any in-river needs study undertaken in the future.

8.3 Protection of River Quality

Although they are also largely outside the immediate remit of the water resources function, water quality issues are important.

There are some minor problems in the headwaters parts of the catchment, although they are not a major issue at present. The maintenance of quality if abstraction increases will become more important.

Options

i) Higher effluent treatment standards.

ii) Tighter control of diffuse agricultural pollutants.

iii) Limit further licensed abstraction in the headwaters areas of the catchment unless for local low consumption use.

iv) Restrict any further abstraction throughout the catchment.

Recommendations

Of these options, i) and ii) are water quality related policies that should be encouraged. Indeed, option i) is actively being implemented in the Nar. In 1992, Anglian Water Services installed phosphorous stripping plant at Litcham sewage treatment works in the headwaters.

Options iii) and iv) are already recommended. However exceptions to them might be used as opportunities to include river augmentation as part of the licence conditions.

8.4 Future Operation of Nar Emergency River Support Scheme

The future use of the Nar Emergency River Support Scheme requires consideration.

Options

i) Obtain a permanent abstraction licence and install a permanent river support facility.

ii) Further evaluate the scheme's efficiency of operation during 1990 and determine future river support requirements.

iii) Do nothing.

If permanent facilities are installed (option i)), further implications regarding the abstraction charging scheme require consideration. It may mean that the status of the river would change to 'supported' and existing and future abstractions would be charged at a higher rate.

If option ii) is undertaken, it is recommended that a review of river support requirements in the middle and lower reaches should relate to identified river flow objectives. It should be considered in conjunction with sympathetic river channel management practises and should relate to any need to support Marham surface intake on reliability grounds.

With option iii), the borehole could remain as emergency standby and temporary plant could be used in extreme drought conditions such as those experienced during 1990.

Recommendations

It is recommended that option ii) is adopted.

9 CONCLUSIONS

9.1 Water Resources

The best estimate of the gross groundwater resource (long term average recharge) is 87.4 tcmd.

9.2 Water Abstraction Demands

The main abstractive demand for water is for public supply (69% of abstractive use). Spray irrigation and general agriculture account for the majority of remaining use (22%).

Demands for spray irrigation are expected to rise, and an application to increase the security of the public water supply groundwater abstraction at Marham is currently in hand.

A study by the University of East Anglia (UEA) for the NRA indicates that up to 24% of lowest natural flows are lost due to spray irrigation abstraction. NRA modelling studies confirm this, but suggest that the UEA results may be rather conservative, and up to 40% impact may occur. However, the two figures are not directly comparable due to the reasons stated in Section 6.2.

9.3 Environmental Water Demands

The current minimum flow requirement of the fluvial River Nar above Marham is based on the natural 95 percentile flow as modelled by HYSIM, and is estimated as 45.4 tcmd. With consideration of the impact of effluents, a net environmental allocation of 44.8 tcmd has been calculated.

Downstream of Marham the River Nar flows through fens and the environmental requirements are likely to be lower. An 'In River Needs' study is recommended to further assess these requirements along with application of current wetland water needs R&D to all major sites within the Unit.

9.4 Balance of Resources and Demands

No reliable summer surface water is available. There may however, be some scope for further abstraction of winter water subject to appropriate licence controls and consideration of both the environment and existing entitlements.

Groundwater resources are currently allocated as follows:

Gross resource	87.4 tcmd
Unreliable resource	17.5 tcmd
Licensed abstraction	28.9 tcmd
Net environmental allocation	44.8 tcmd
Nominal Deficit	**3.8 tcmd**

The Nar Groundwater Unit therefore has a 'no water available' abstraction licensing policy.

10 RECOMMENDATIONS

10.1 Licensing Policy

Surface Water

This analysis confirms the existing abstraction licensing policy:-

- there is no reliable summer surface water available for abstraction
- there may be some scope for using winter surface water
- storage of winter water should be encouraged for summer use
- new licences should incorporate cessation clauses.

Groundwater

There is no additional water available for licensing and the current status of the catchment should remain as 'no water available'. However exceptions as noted in the regional abstraction licensing guidelines may be considered where appropriate.

10.2 Actions & Investigations

- An 'In River Needs Study' should be undertaken for the River Nar with the focus on minimum acceptable flow regime and level requirements for key indicator species, and should also incorporate aspects of river channel management.
- The 'In River Needs Study' should address a more appropriate hands-off flow condition for the Marham surface water abstraction. This may identify separate requirements for the fenland reaches of the river downstream of Marham, and the fluvial reaches upstream.
- Following the 'In River Needs Study', there should be a review of the efficiency of the emergency river support facility and identification of future requirements to meet river flow objectives and secure water supplies.
- A 'Wetland Needs' study should also identify the requirements to conserve and enhance the wetland environment of the Nar Unit.

- Consideration of an improvement in the groundwater observation network around the

Marham area is required. This would assist in the identification of the interaction between the River Nar and the groundwater in the Chalk. Better knowledge of the degree of interaction would provide a higher level of confidence in the modelling process and therefore the naturalised 95 percentile value, which forms the basis of the current river allocation. In turn, the resulting licensing policies would have a firmer foundation.

- An integrated approach to the management of the water resources of the Nar Unit would be aided by the medium term development (5yrs) and application of a groundwater simulation model. Existing groundwater models have only been applied partially to the Unit.

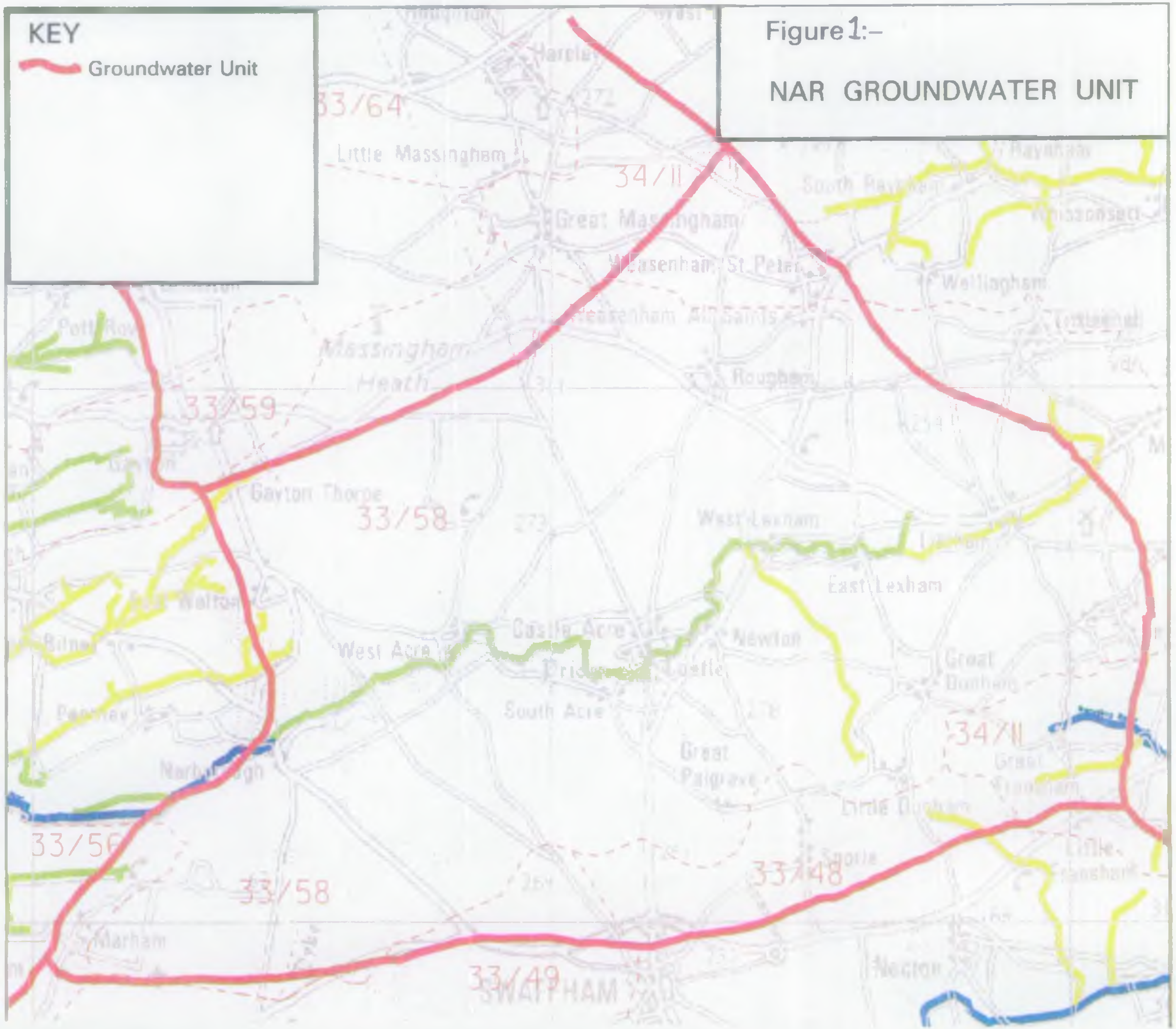


Figure 1:-

NAR GROUNDWATER UNIT

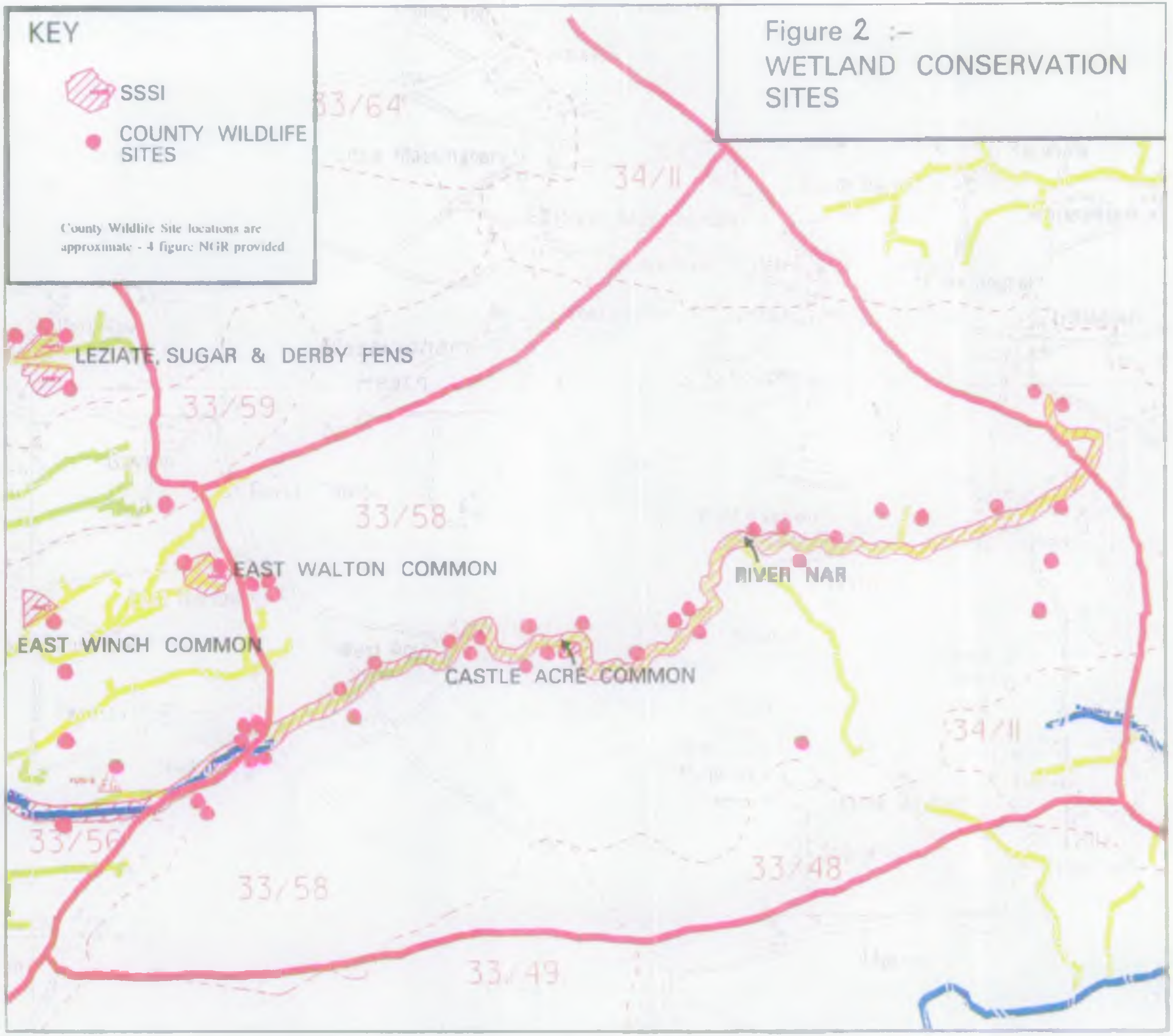


Figure 2 :- WETLAND CONSERVATION SITES

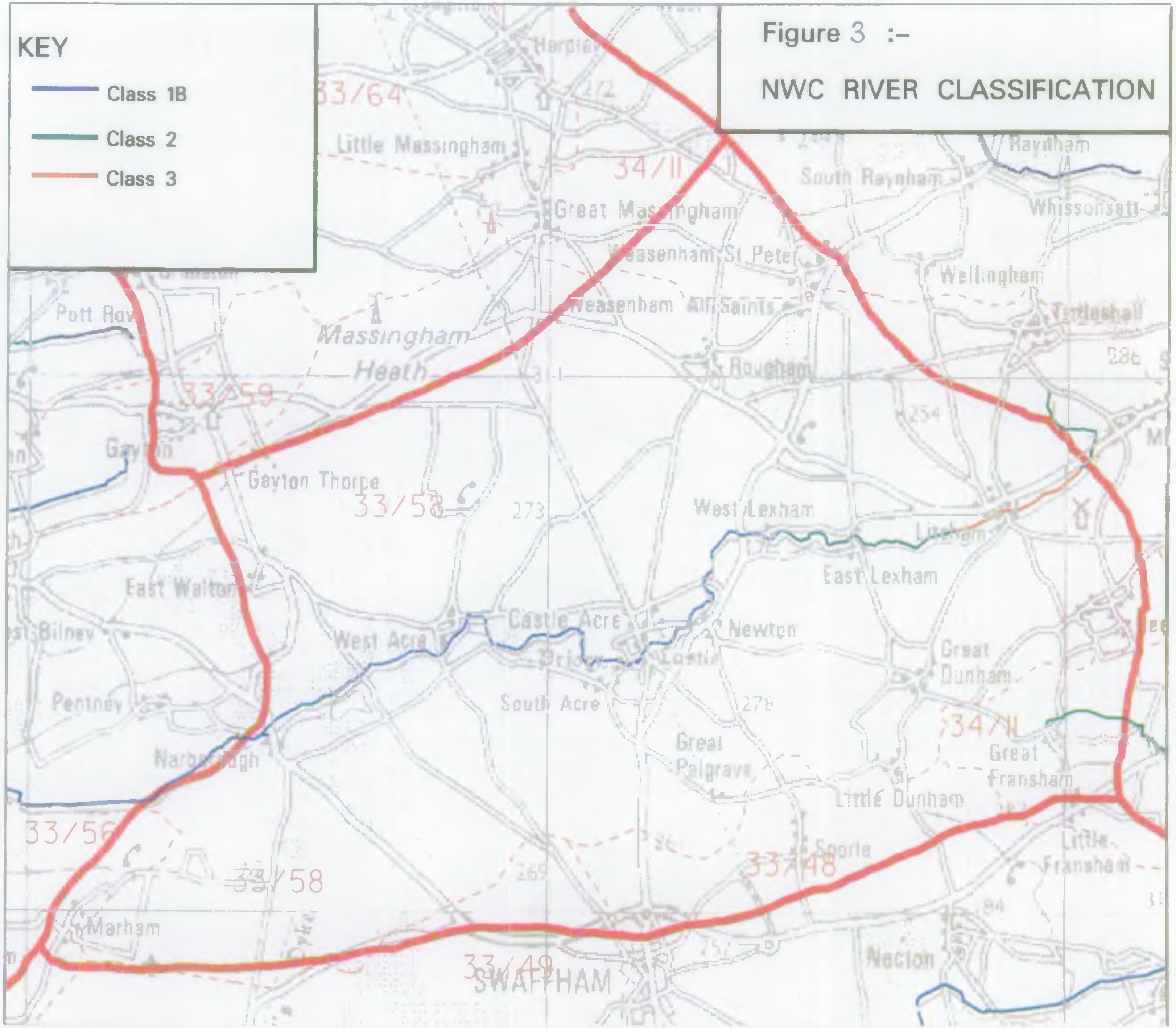


Figure 3 :-

NWC RIVER CLASSIFICATION

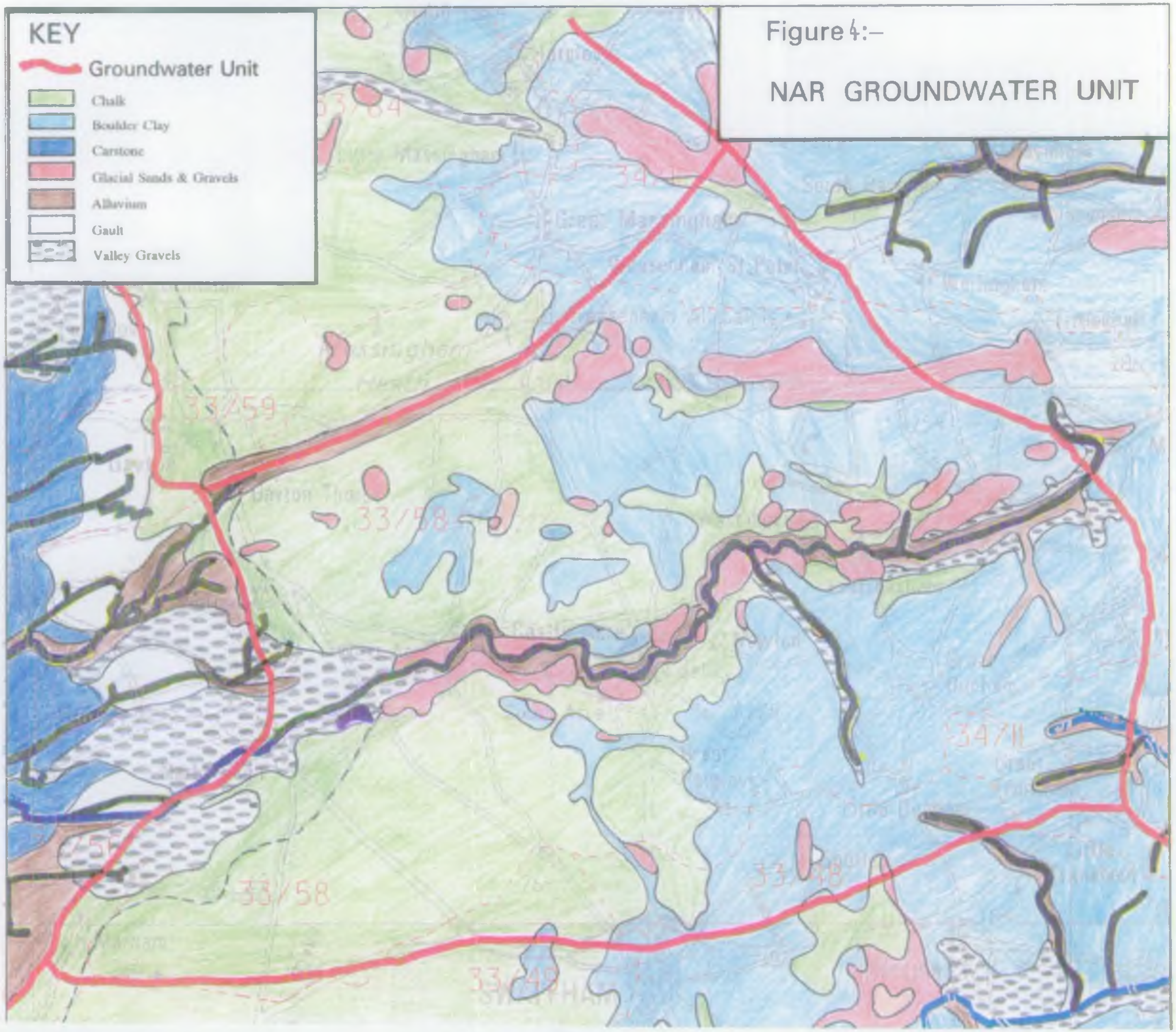


Figure 4:-

NAR GROUNDWATER UNIT

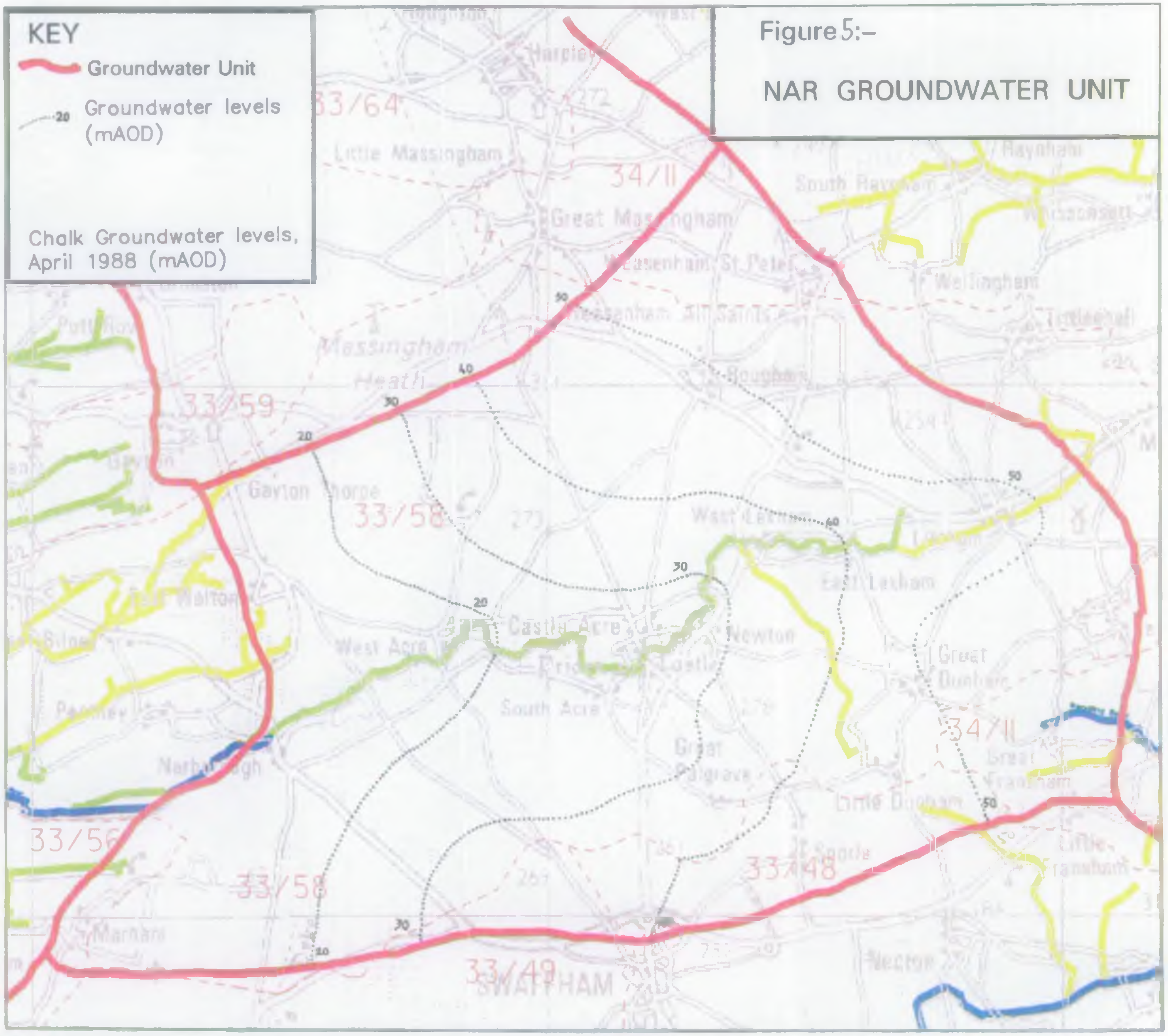


Figure 5:-

NAR GROUNDWATER UNIT

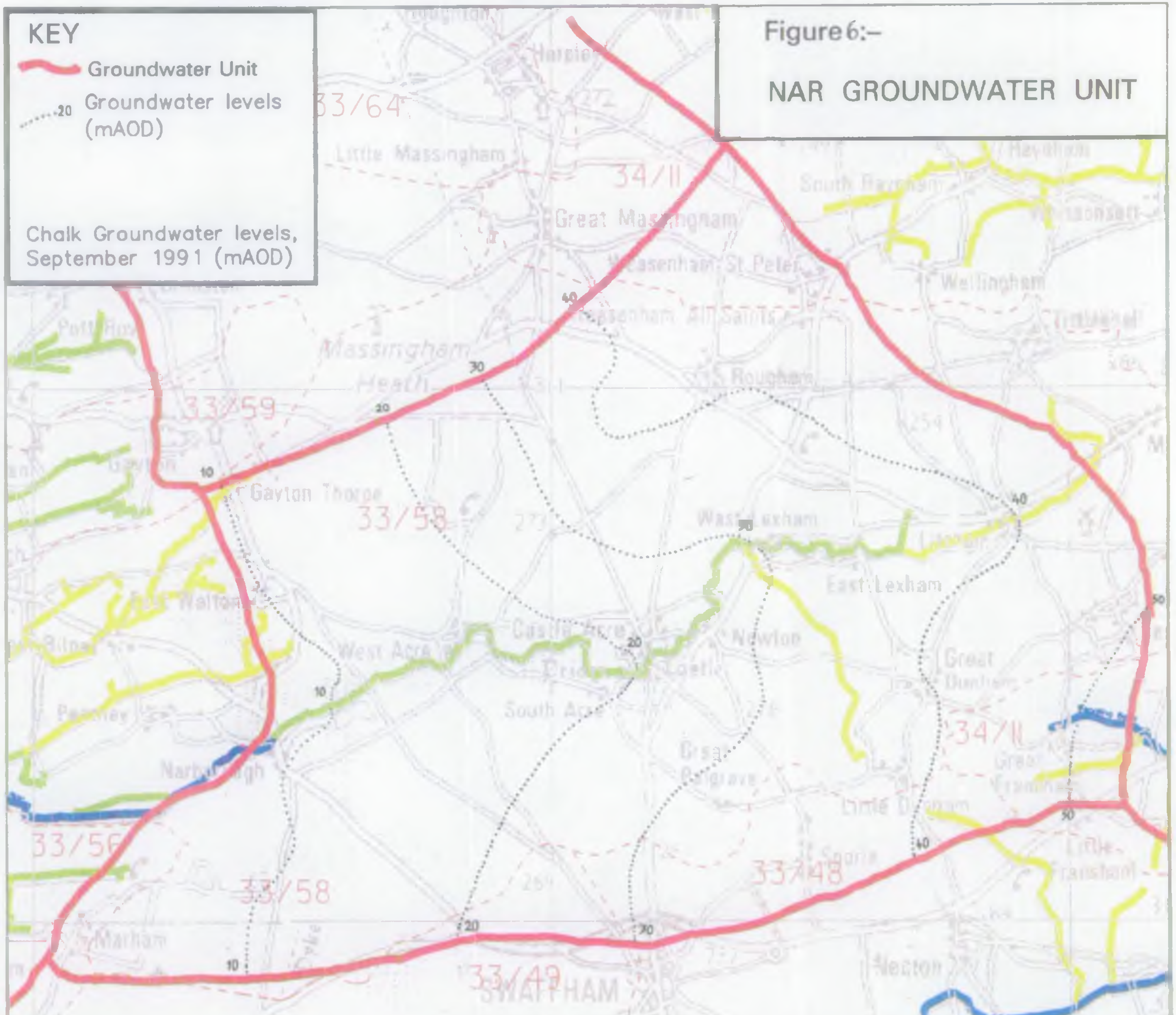
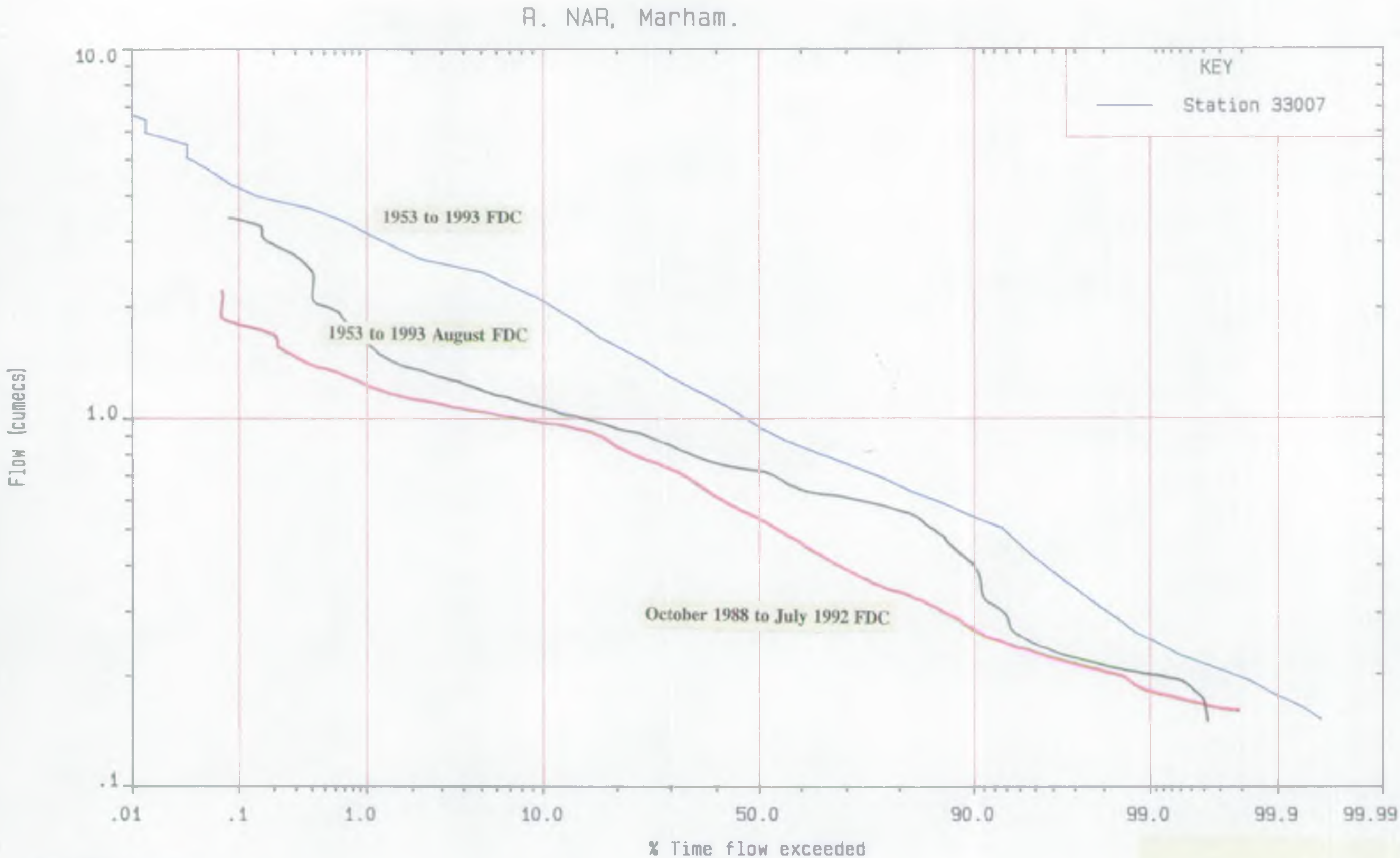


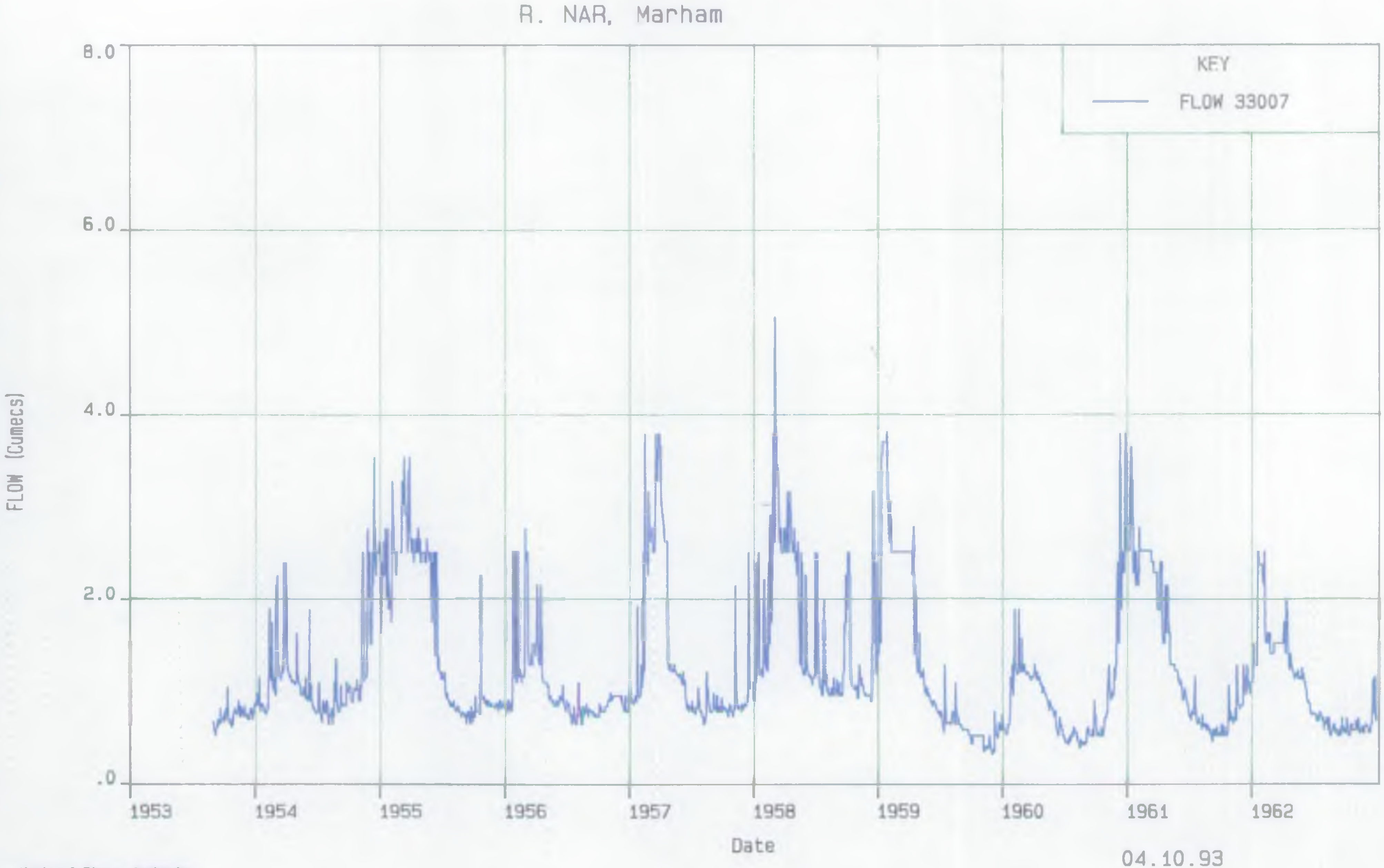
Figure 6:-

NAR GROUNDWATER UNIT



National Rivers Authority

FIGURE 7



National Rivers Authority

FIGURE 8

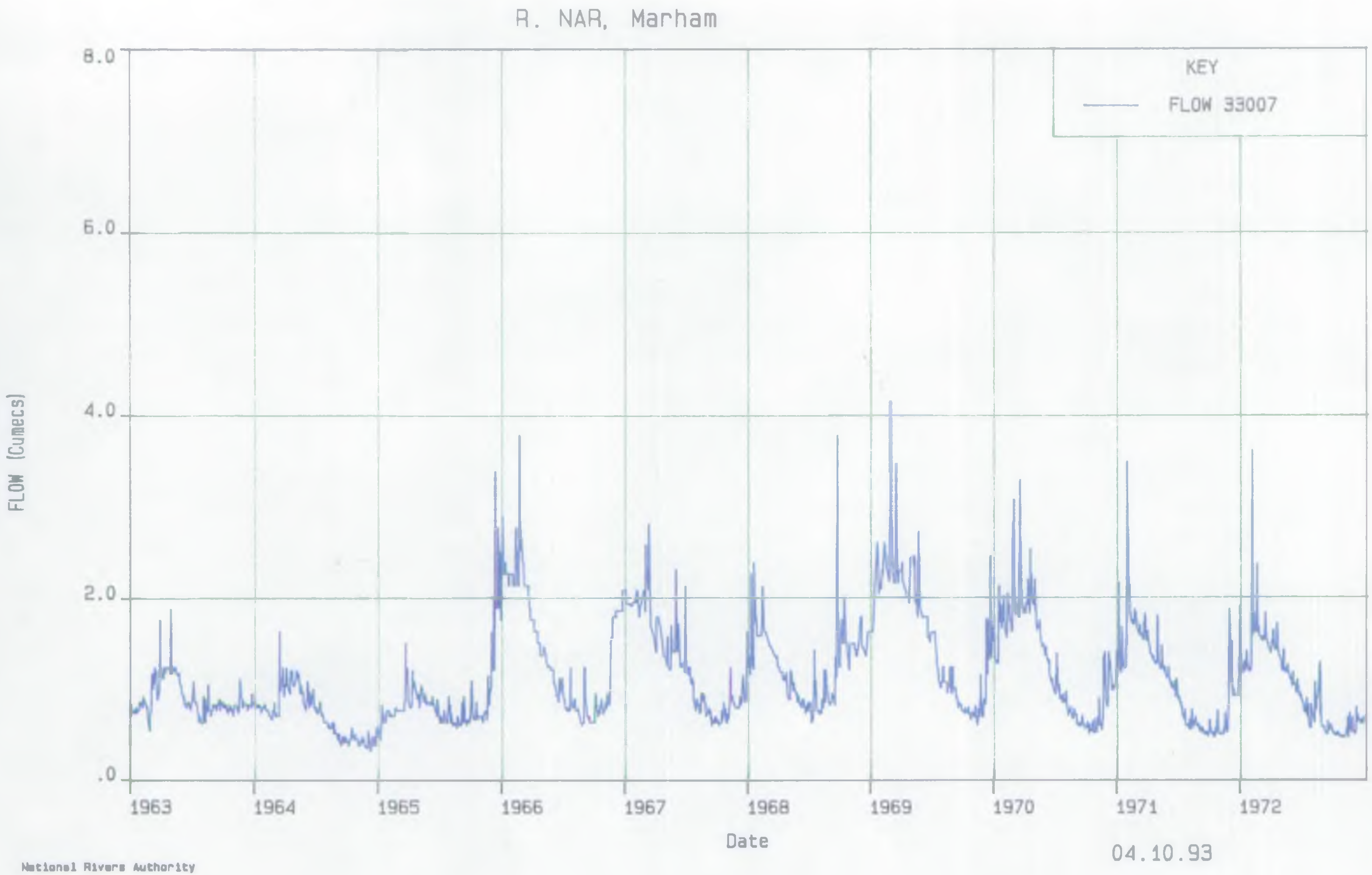
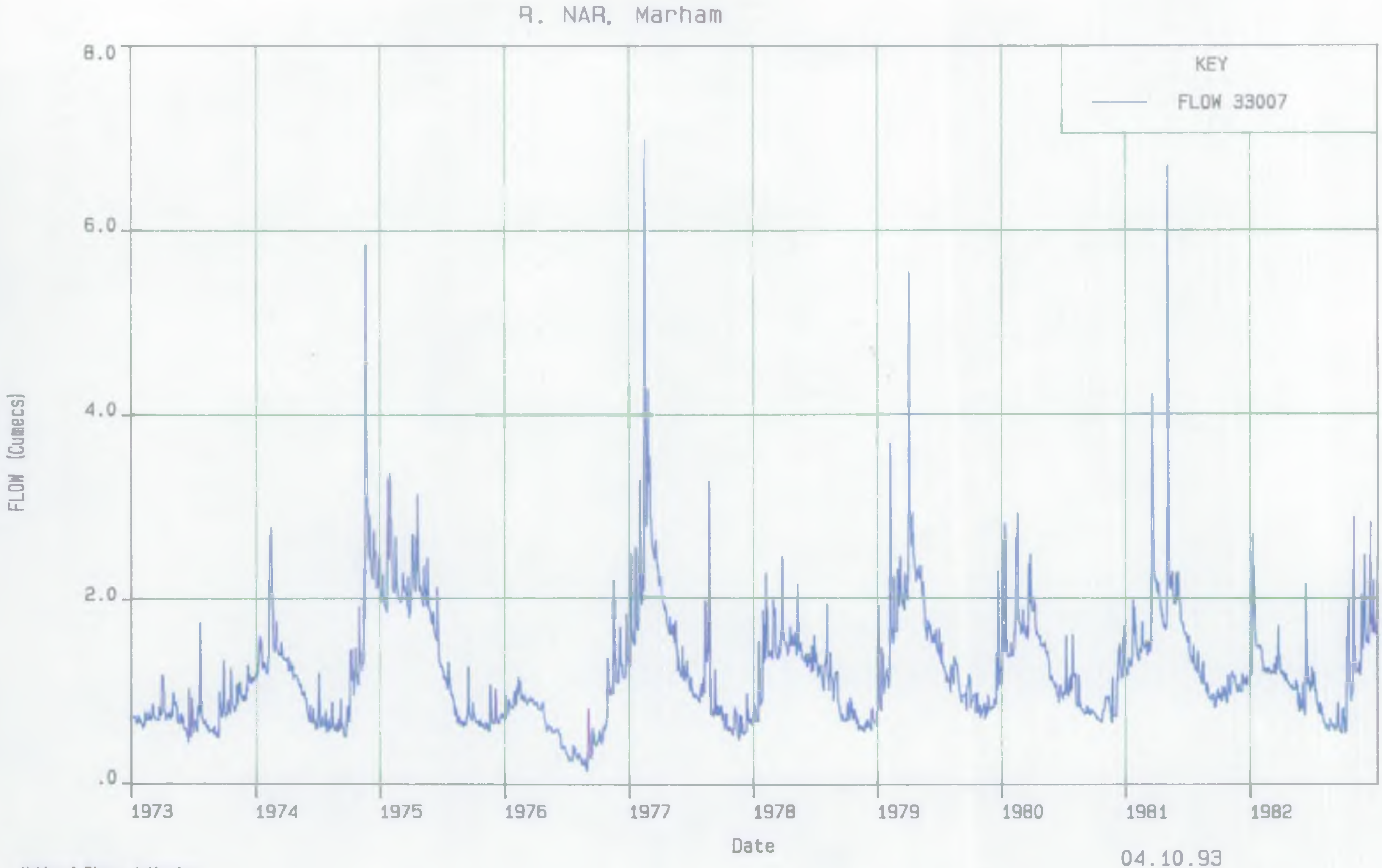
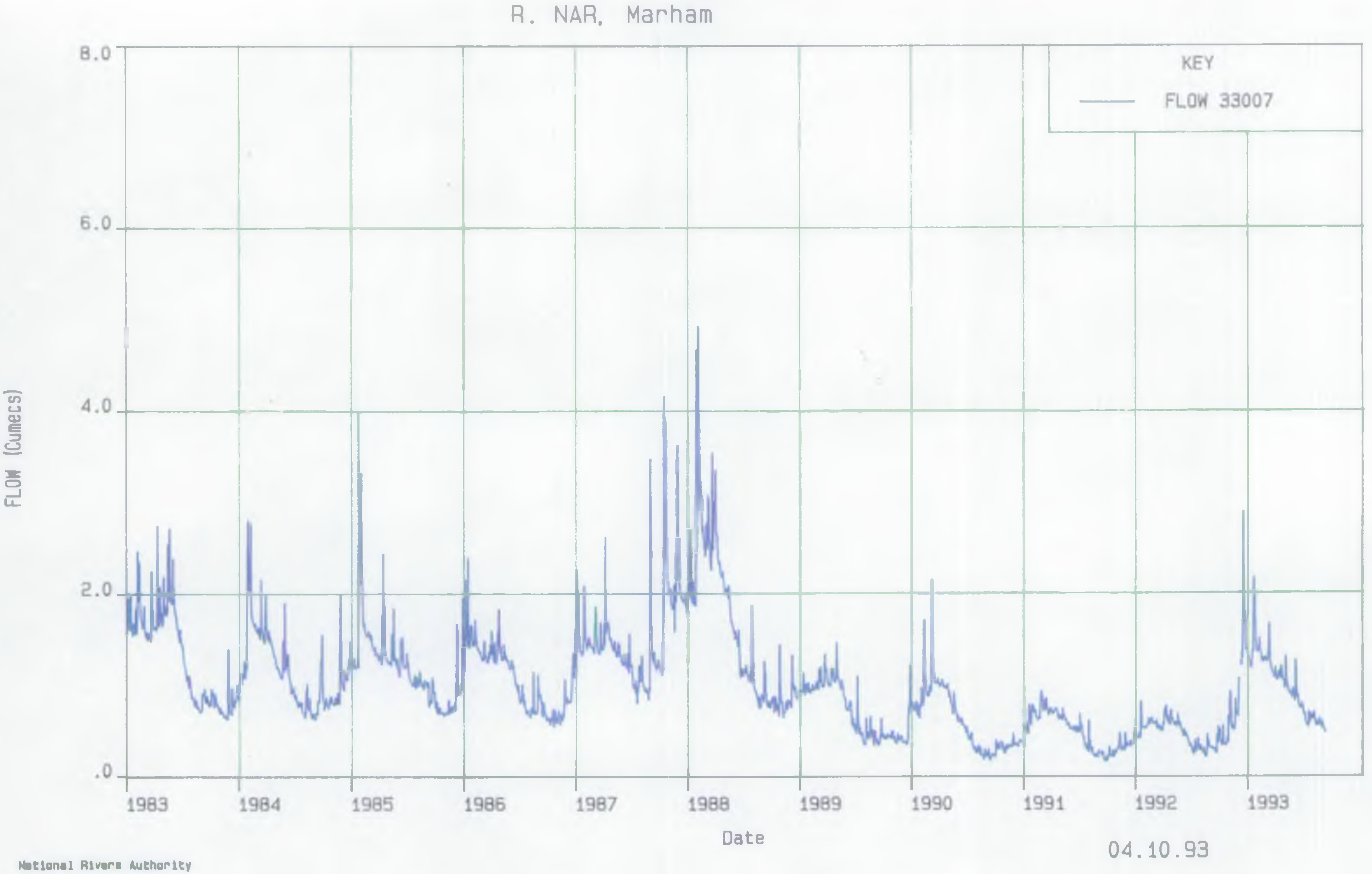

R. NAR, Marham
KEY
FLOW 33007
FLOW (Cumecs)
8.0
6.0
4.0
2.0
.0
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
Date
04.10.93
National Rivers Authority

FIGURE 9



National Rivers Authority

FIGURE 10



R. NAR, Marham
KEY
FLOW 33007
8.0
6.0
4.0
2.0
.0
FLOW (Cumecs)
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
Date
04.10.93
National Rivers Authority

FIGURE 11

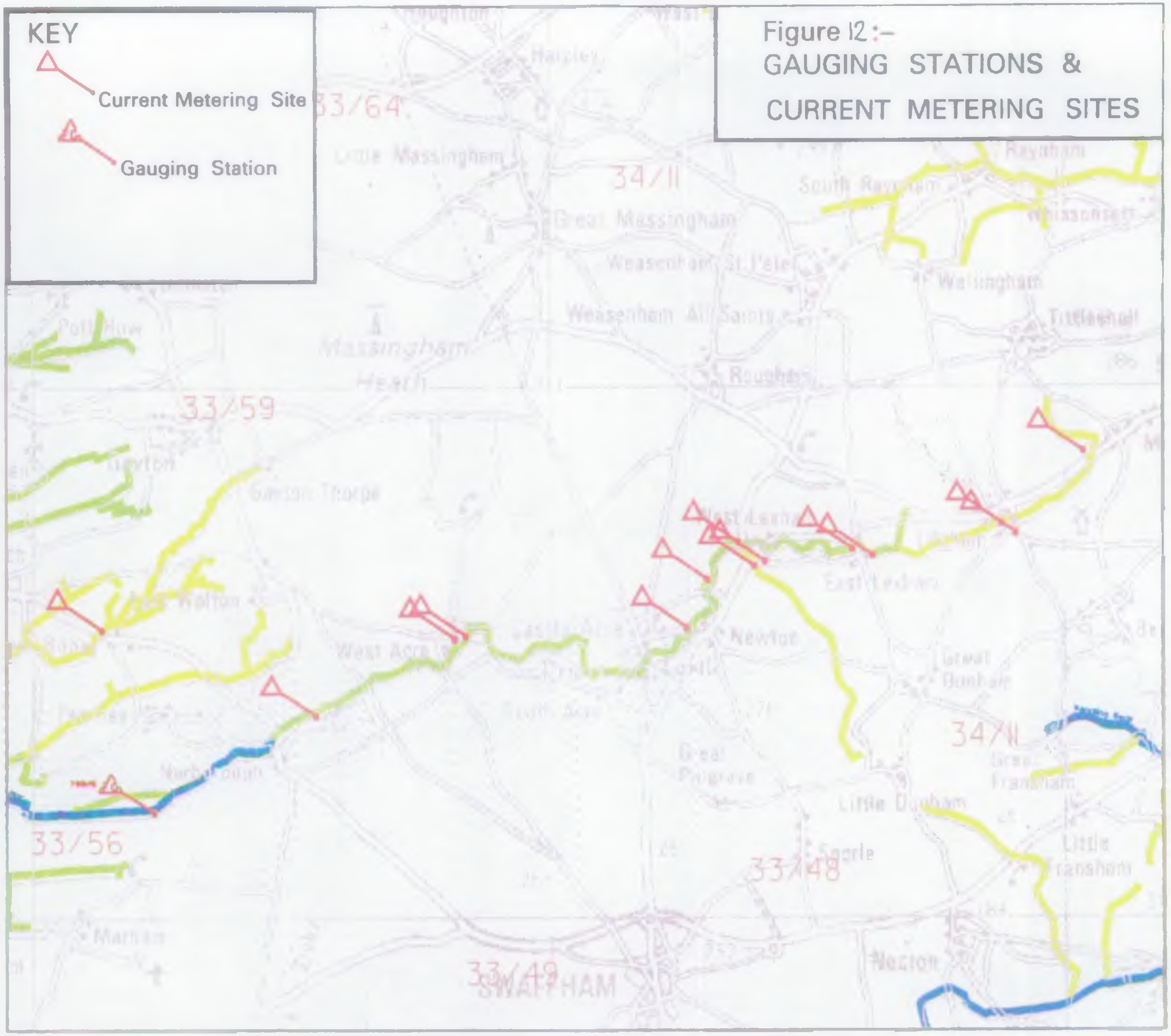


Figure 12 :–
GAUGING STATIONS & CURRENT METERING SITES

River Nar: Flow Accretion Profiles

Figure 13

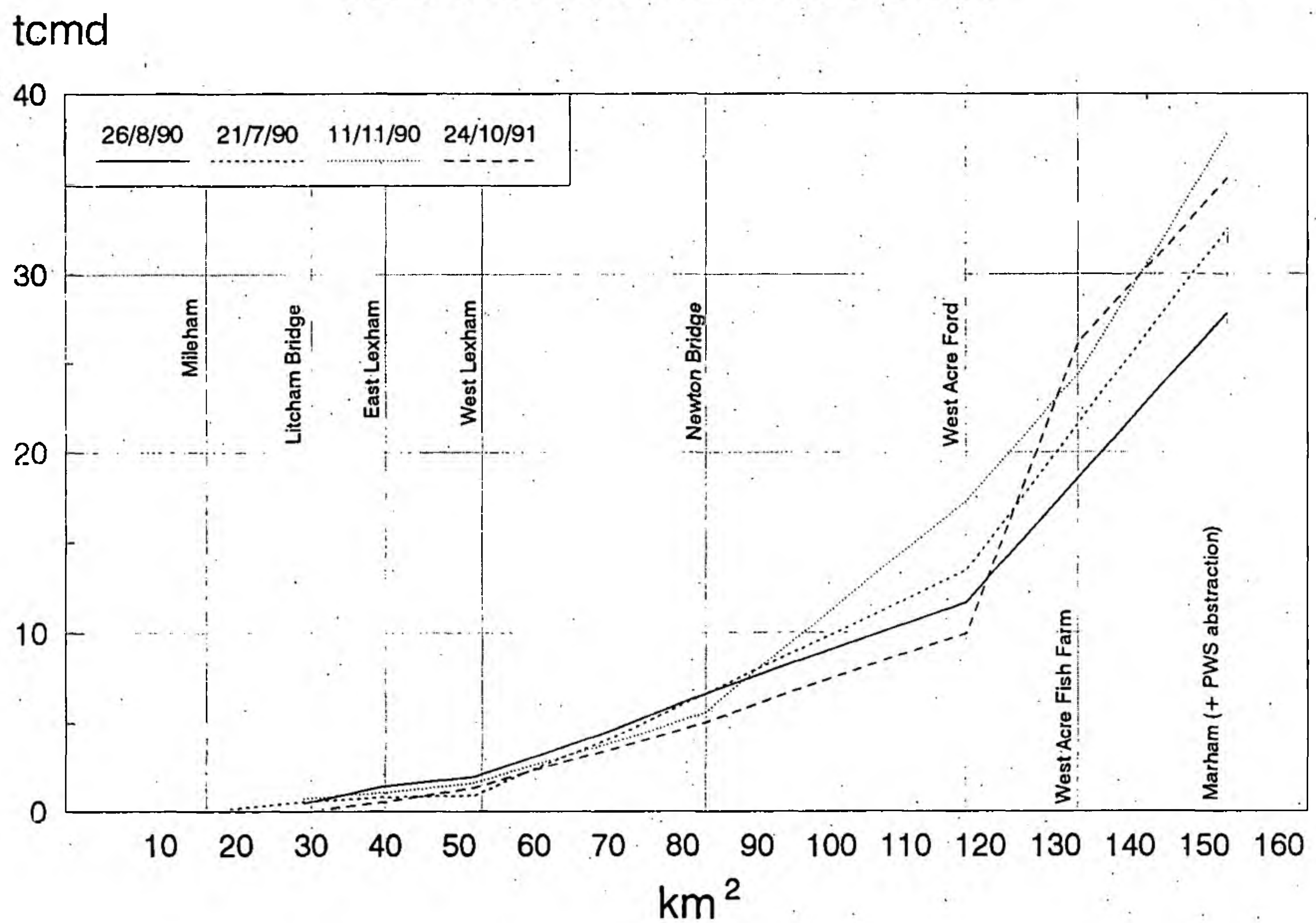
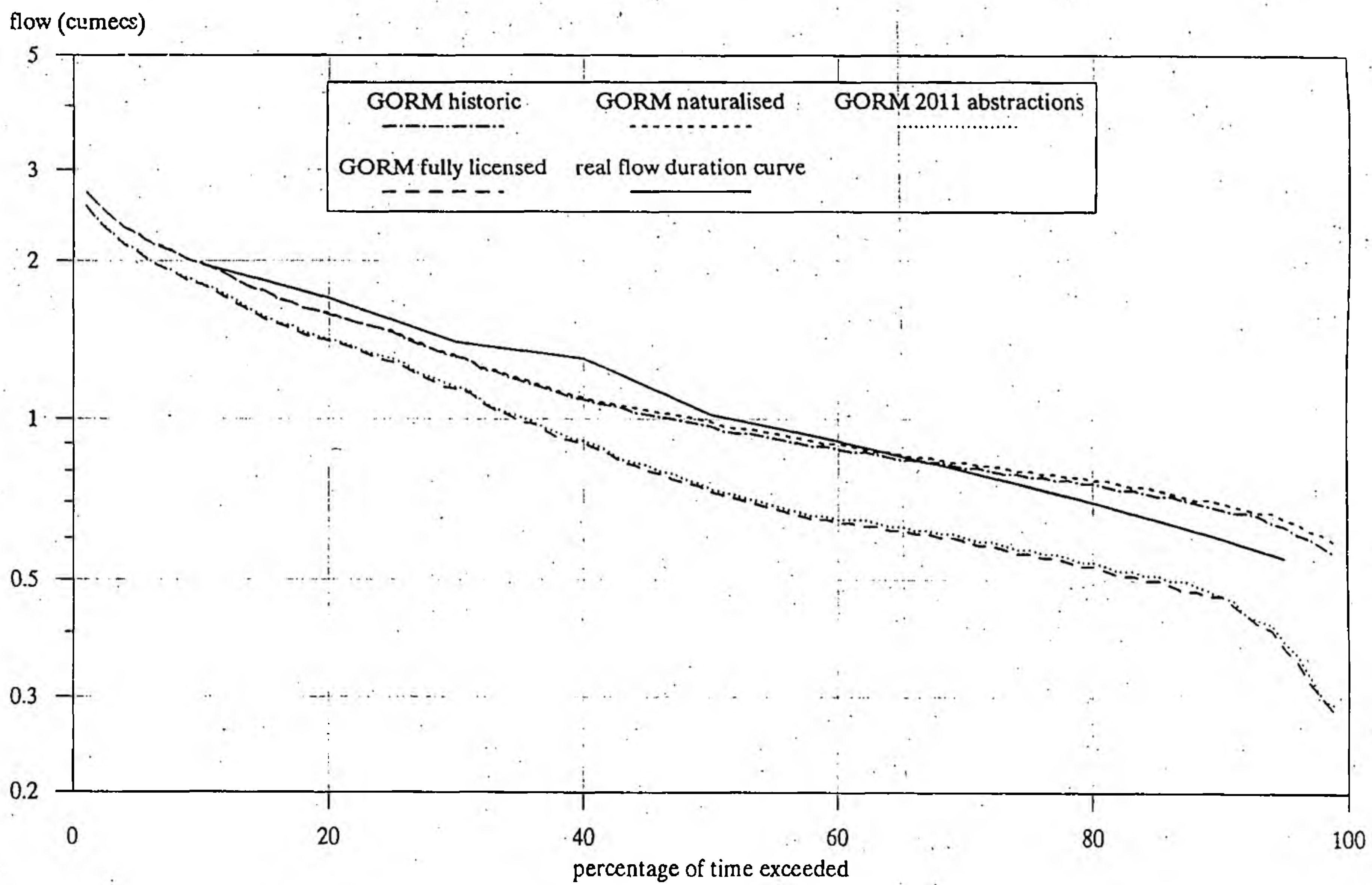


Figure 14



River Nar at Marham

Figure 14.1: Calibration of HYSIM Against Assumptions of Impact of Marham Groundwater Abstraction

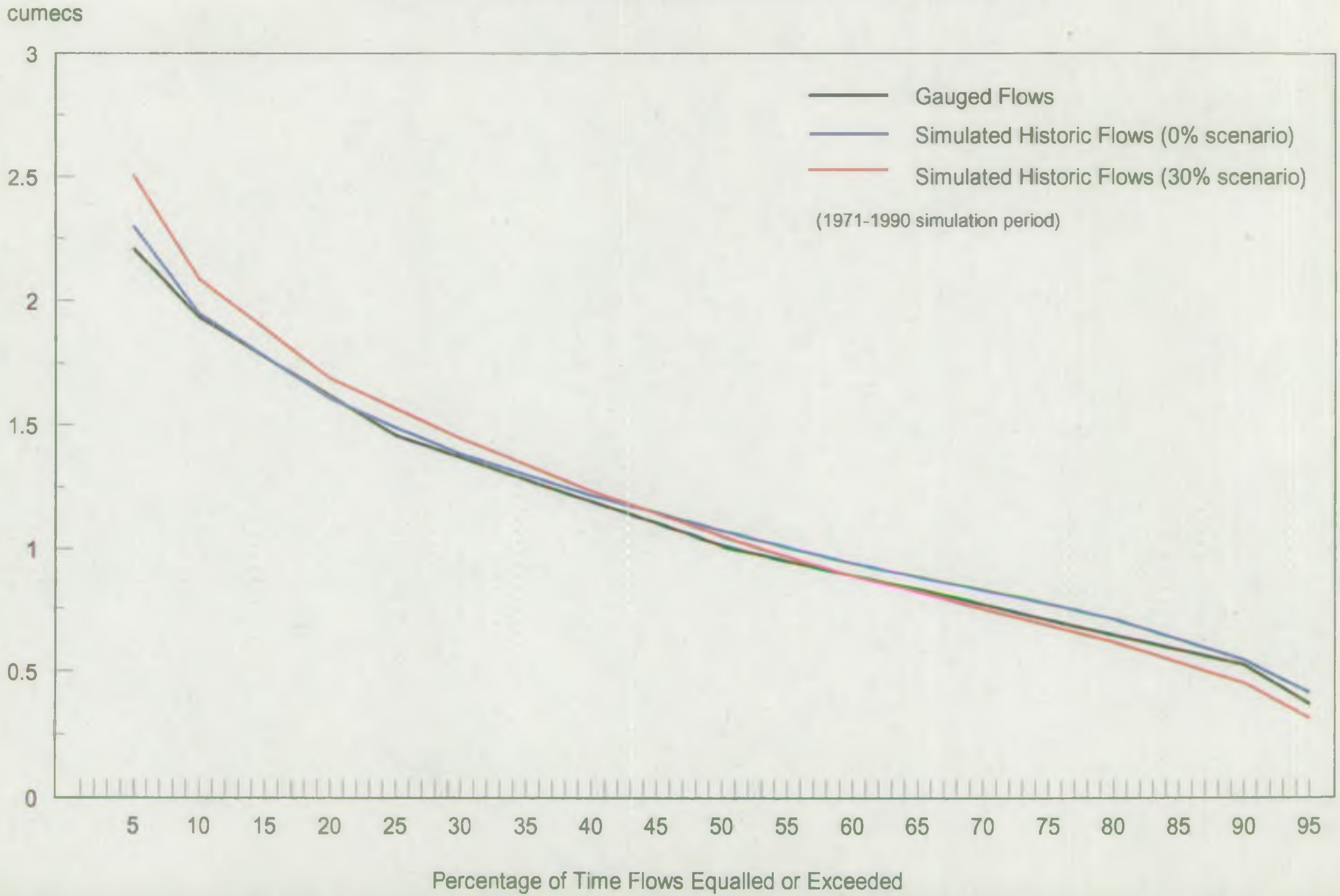
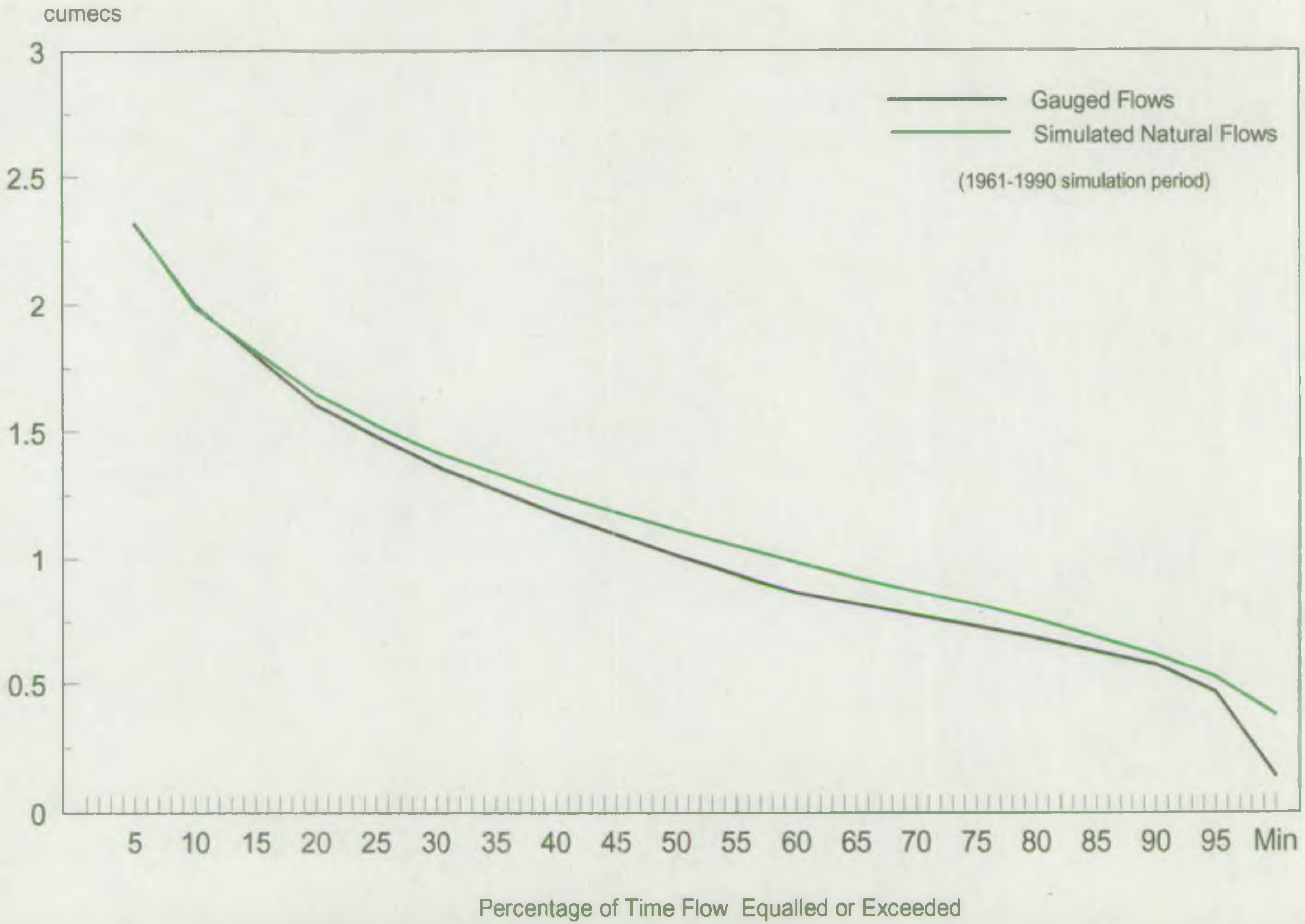
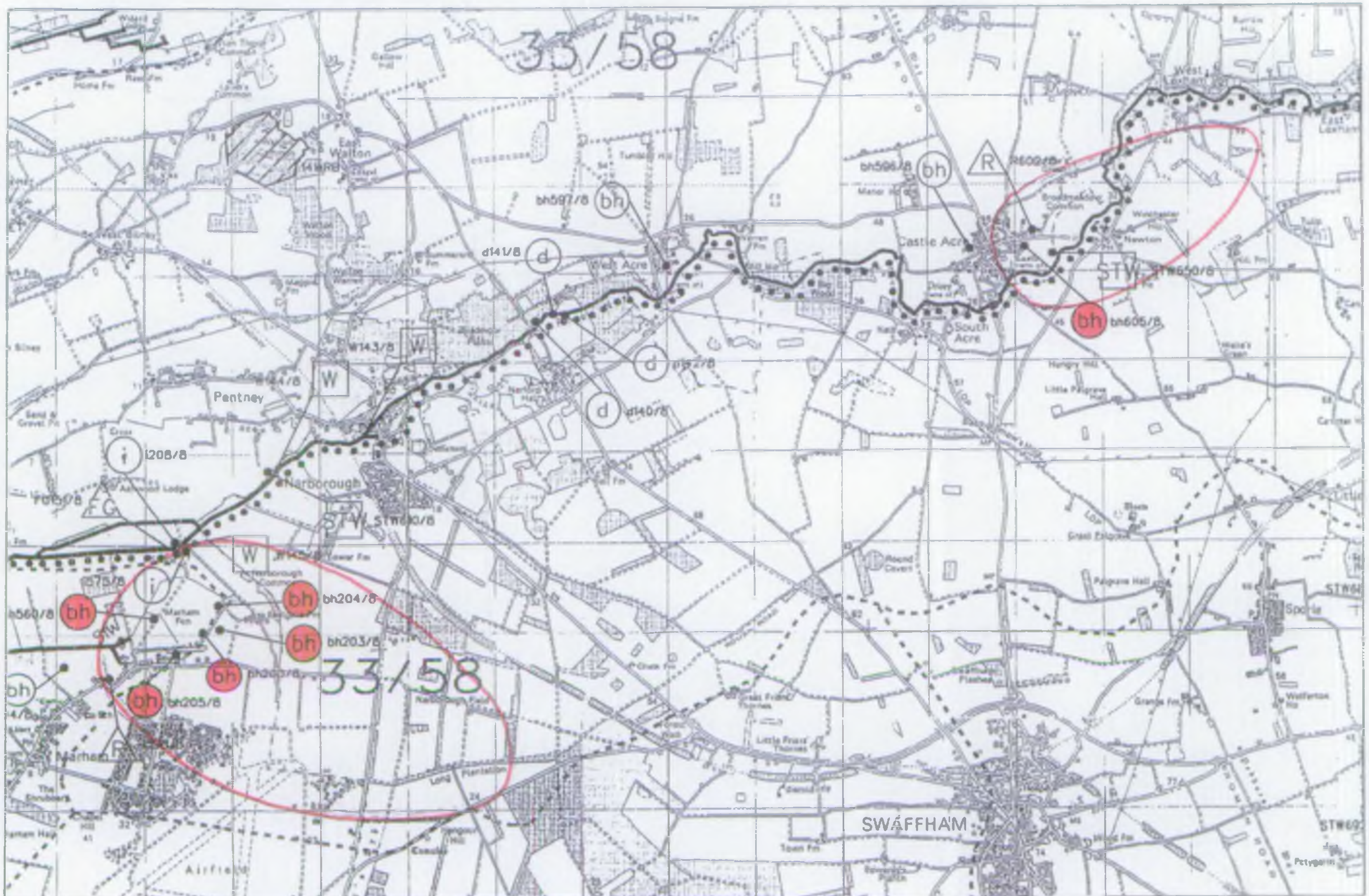


Figure 14.2: Comparison of Actual and Natural Flow Characteristics from HYSIM



Nar Groundwater Unit: Groundwater Protection Zones (50 day travel time) - Draft

FIGURE 15



Scale 2km

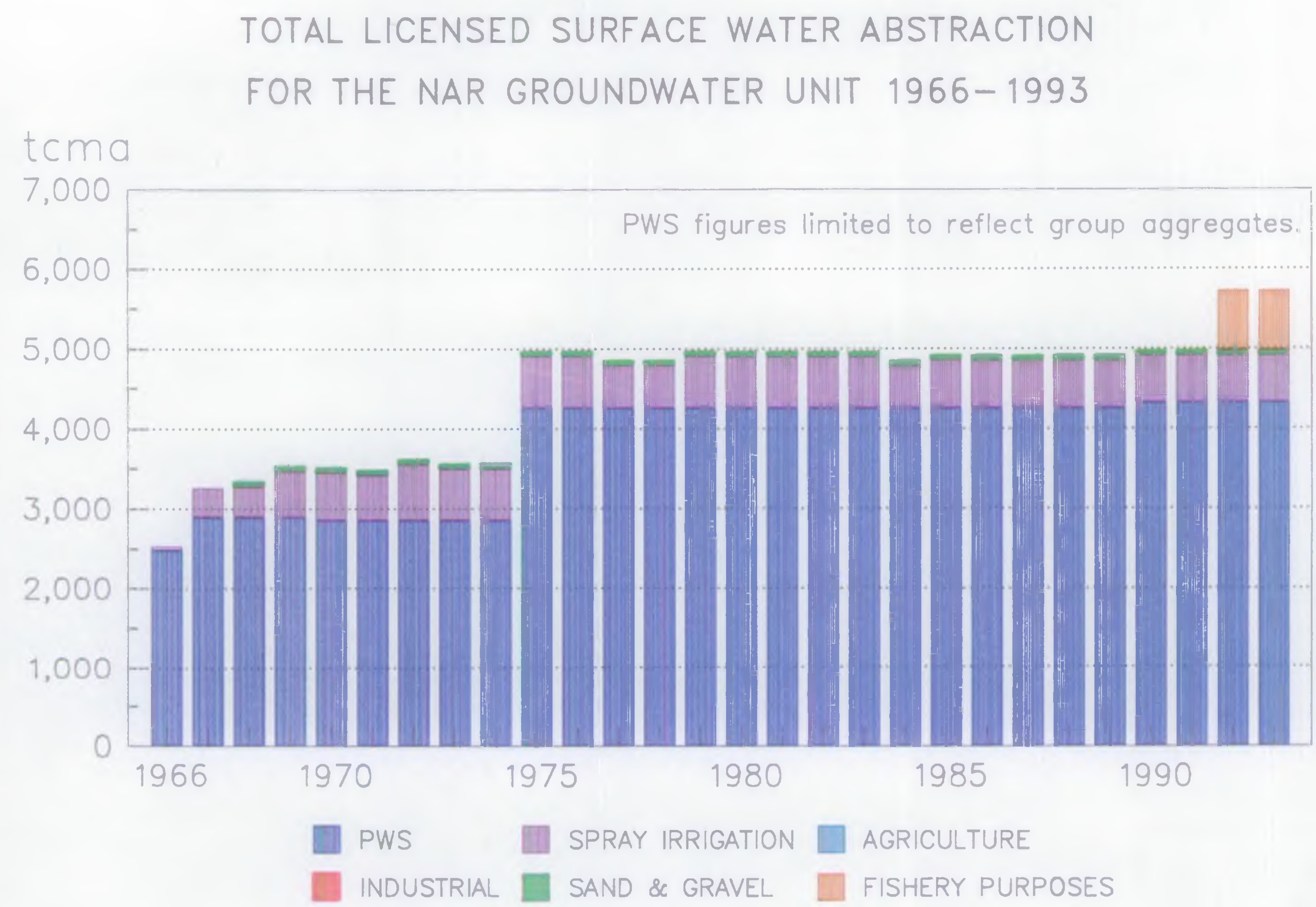
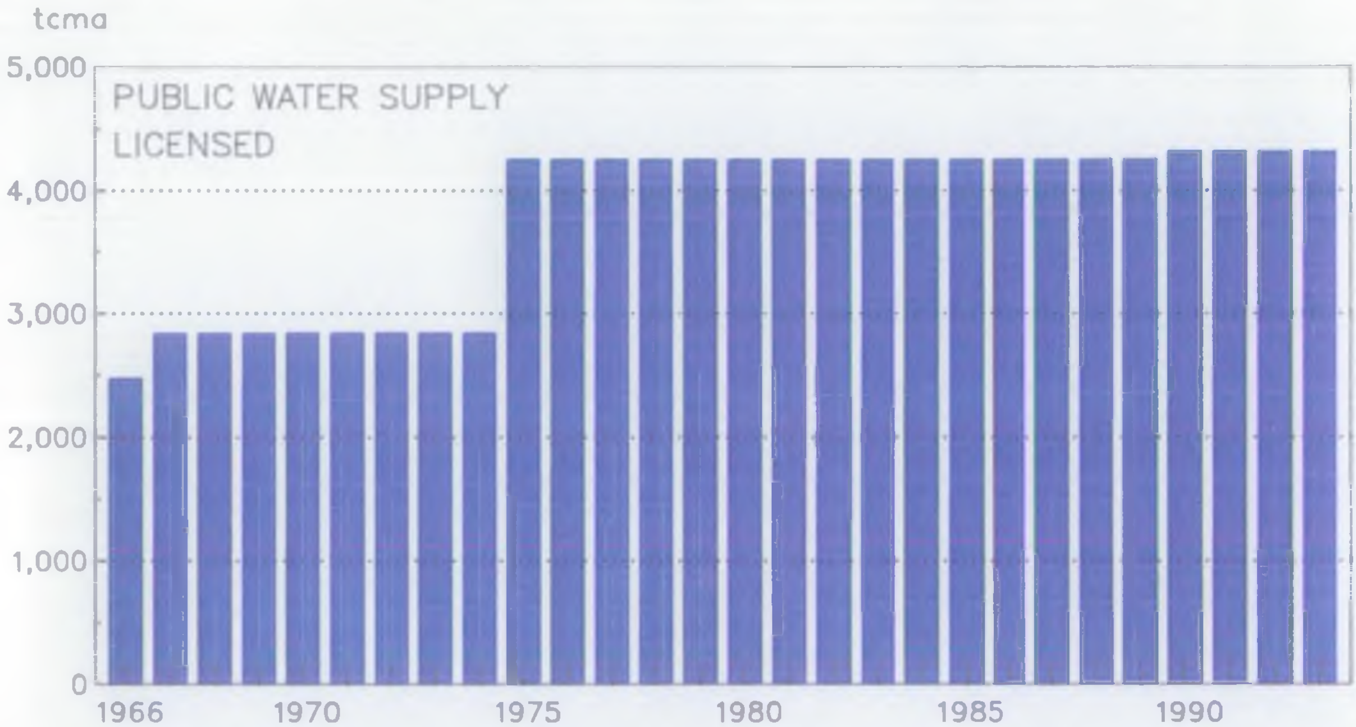
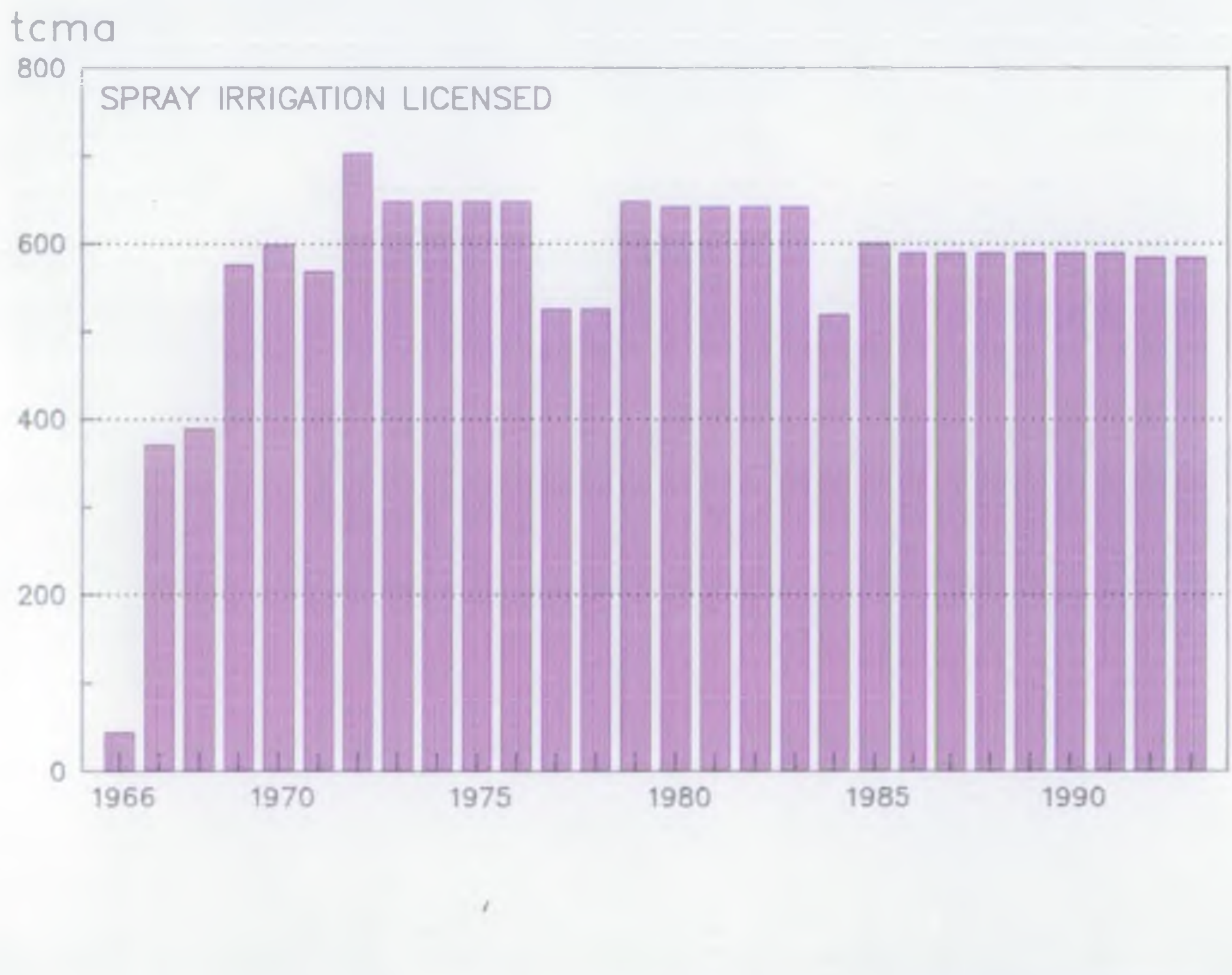

TOTAL LICENSED SURFACE WATER ABSTRACTION
FOR THE NAR GROUNDWATER UNIT 1966-1993
tcma
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
PWS figures limited to reflect group aggregates.
1966
1970
1975
1980
1985
1990
PWS
SPRAY IRRIGATION
AGRICULTURE
INDUSTRIAL
SAND & GRAVEL
FISHERY PURPOSES

FIGURE 16

LICENSED SURFACE WATER ABSTRACTION FOR THE NAR GROUNDWATER UNIT





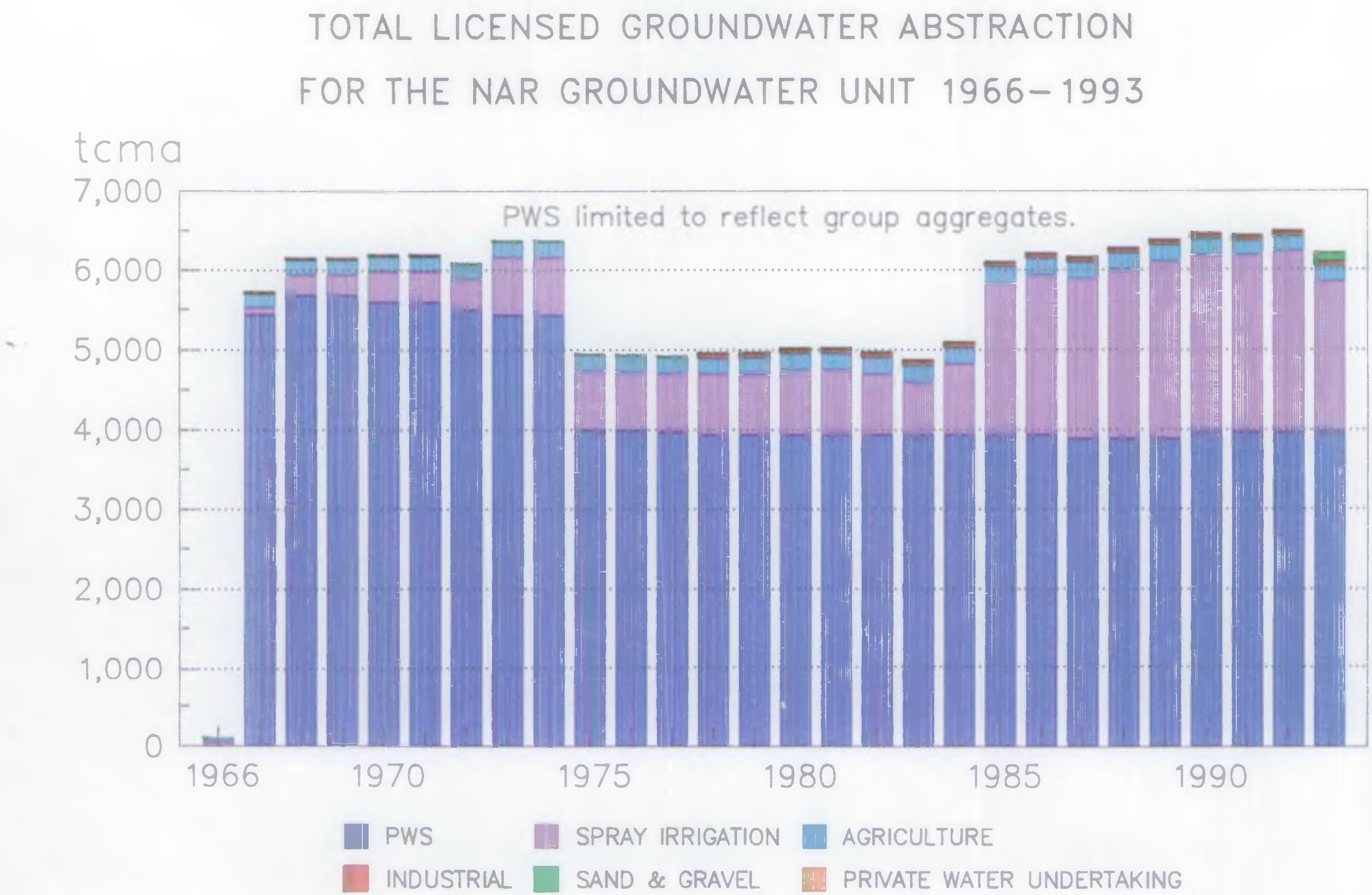
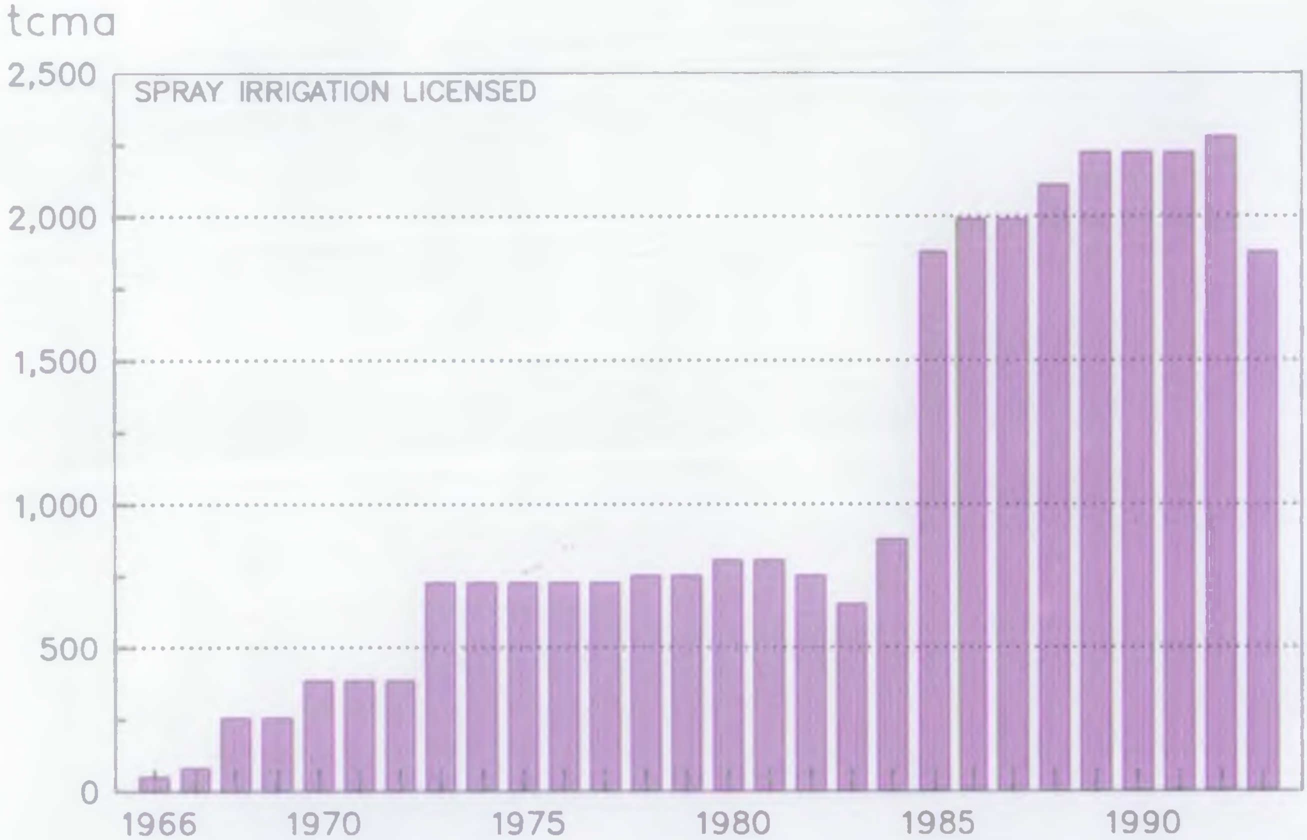
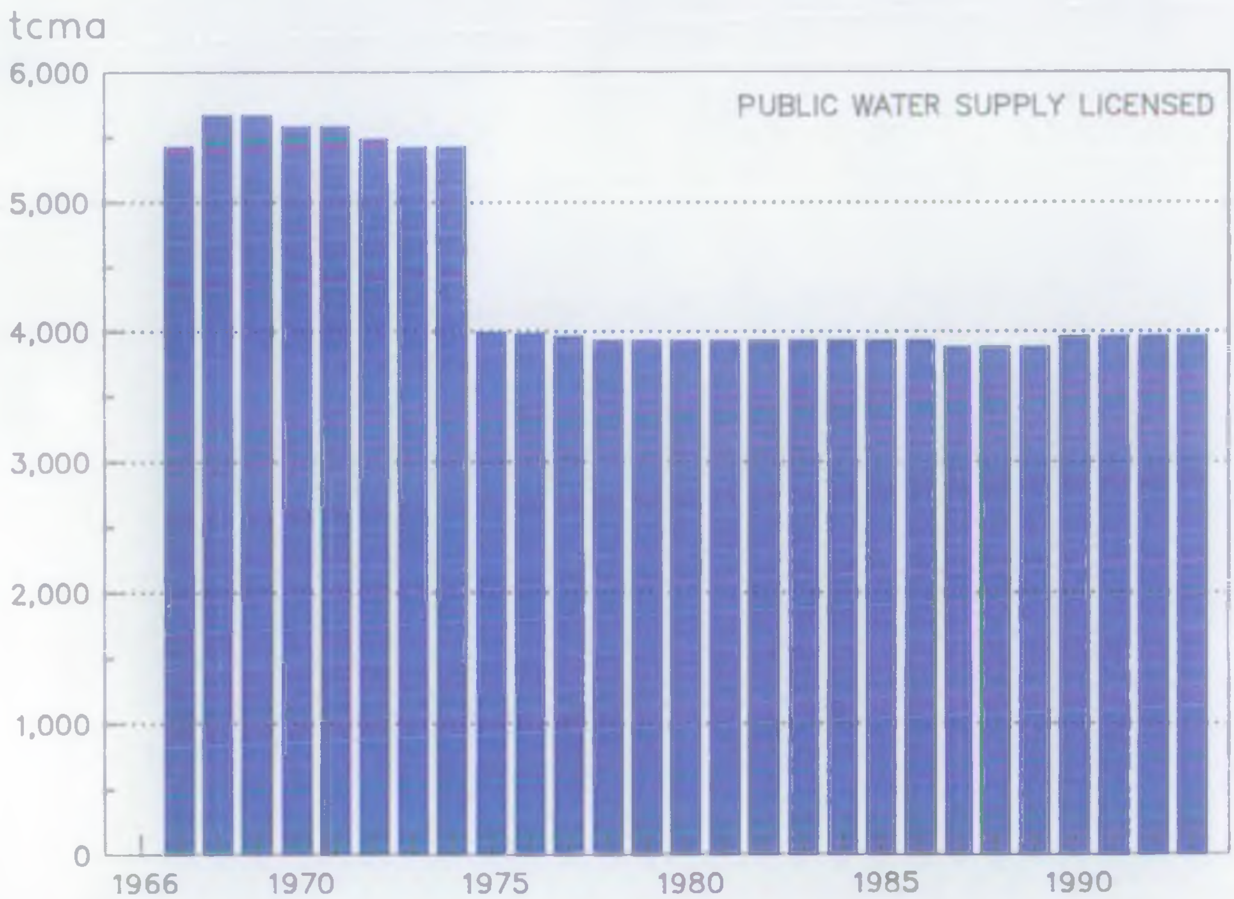

TOTAL LICENSED GROUNDWATER ABSTRACTION
FOR THE NAR GROUNDWATER UNIT 1966-1993
tcma
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
PWS limited to reflect group aggregates.
1966
1970
1975
1980
1985
1990
PWS
SPRAY IRRIGATION
AGRICULTURE
INDUSTRIAL
SAND & GRAVEL
PRIVATE WATER UNDERTAKING

FIGURE 18

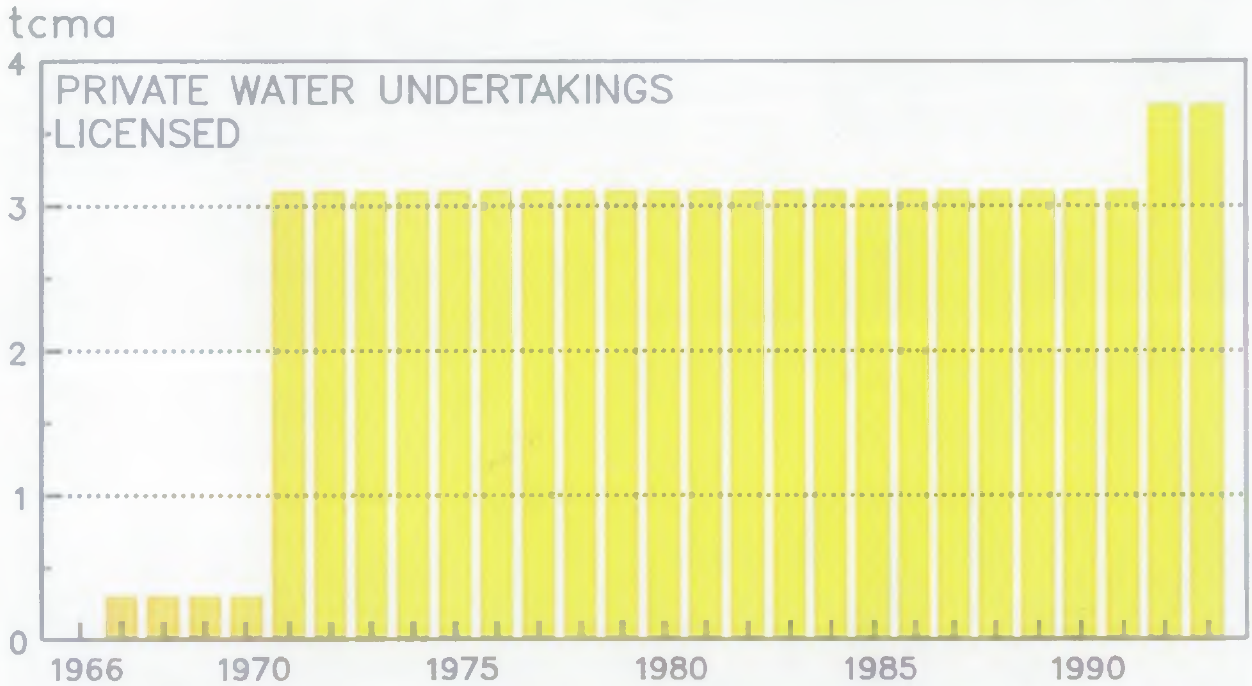
FIGURE 19

LICENSED GROUNDWATER ABSTRACTION FOR THE NAR GROUNDWATER UNIT





LICENSED GROUNDWATER ABSTRACTION FOR THE NAR GROUNDWATER UNIT



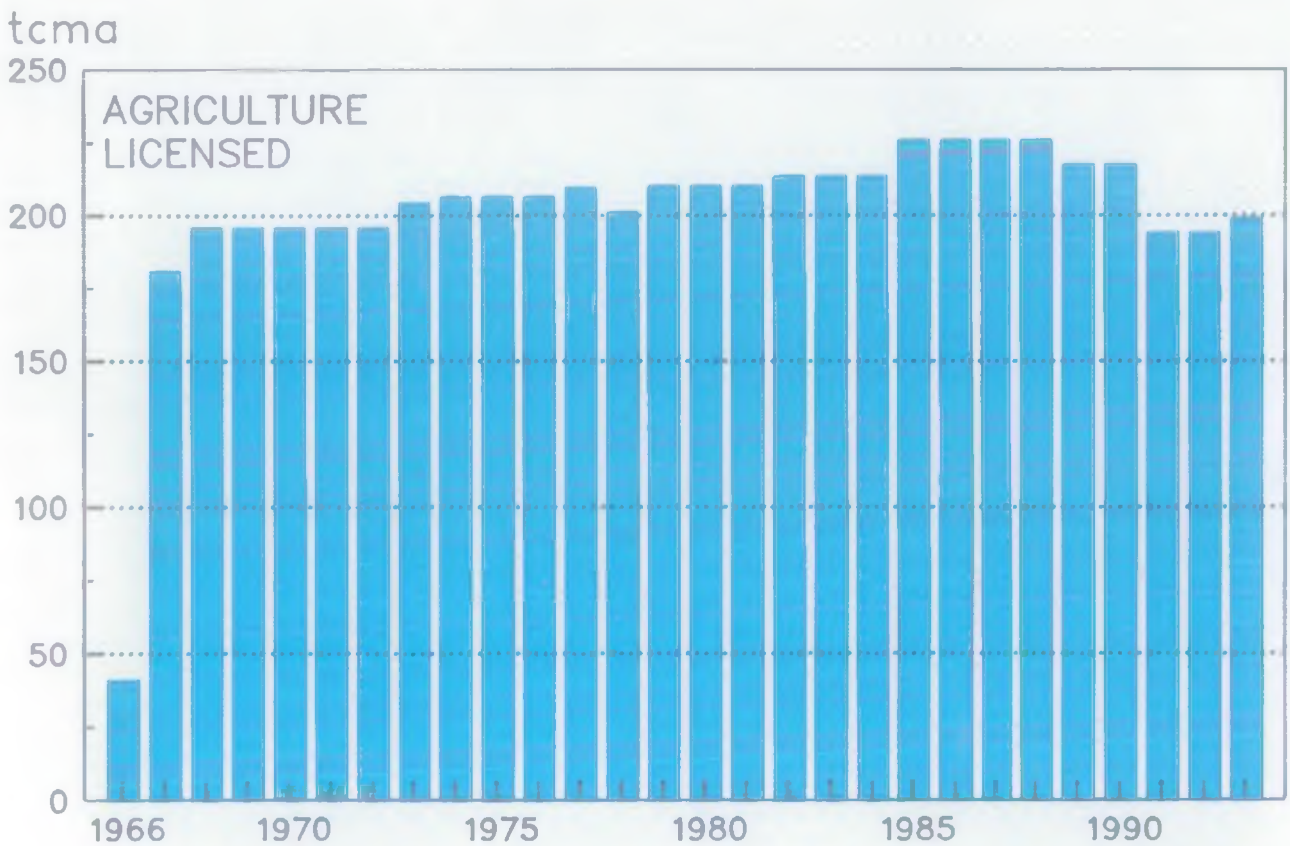
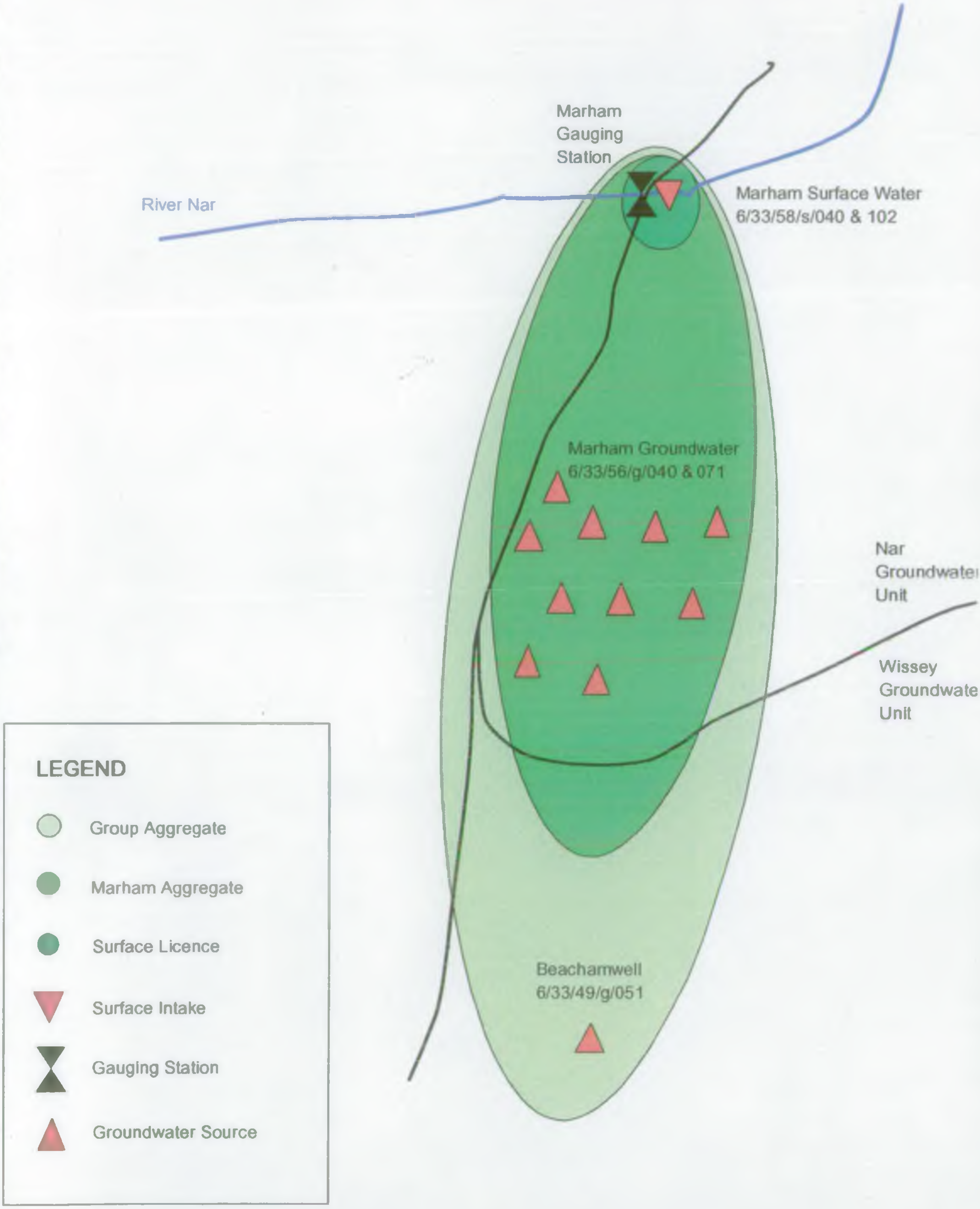


FIGURE 20.1: Schematic of Marham/Beachamwell Group Aggregate



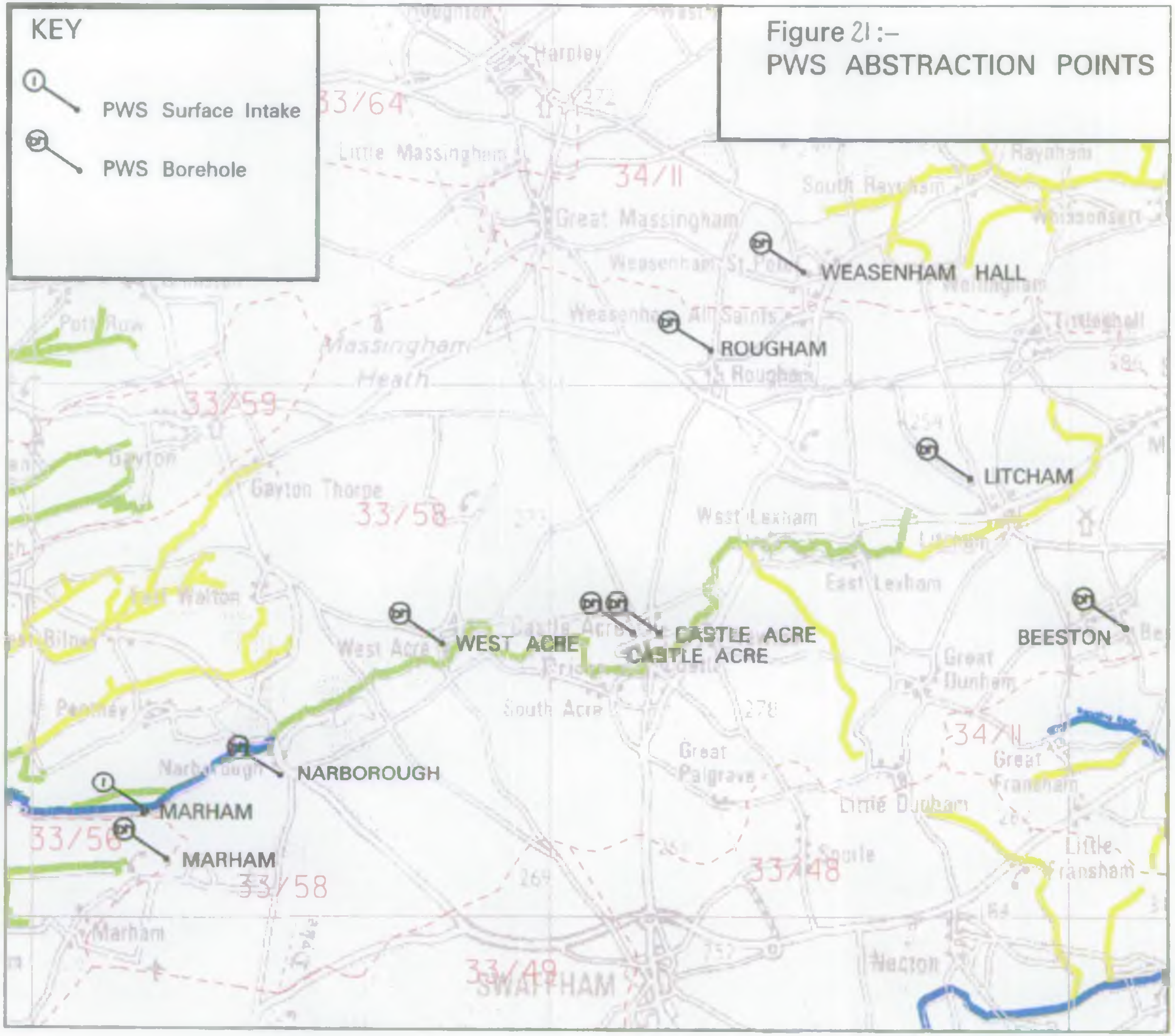


Figure 21 :-
PWS ABSTRACTION POINTS

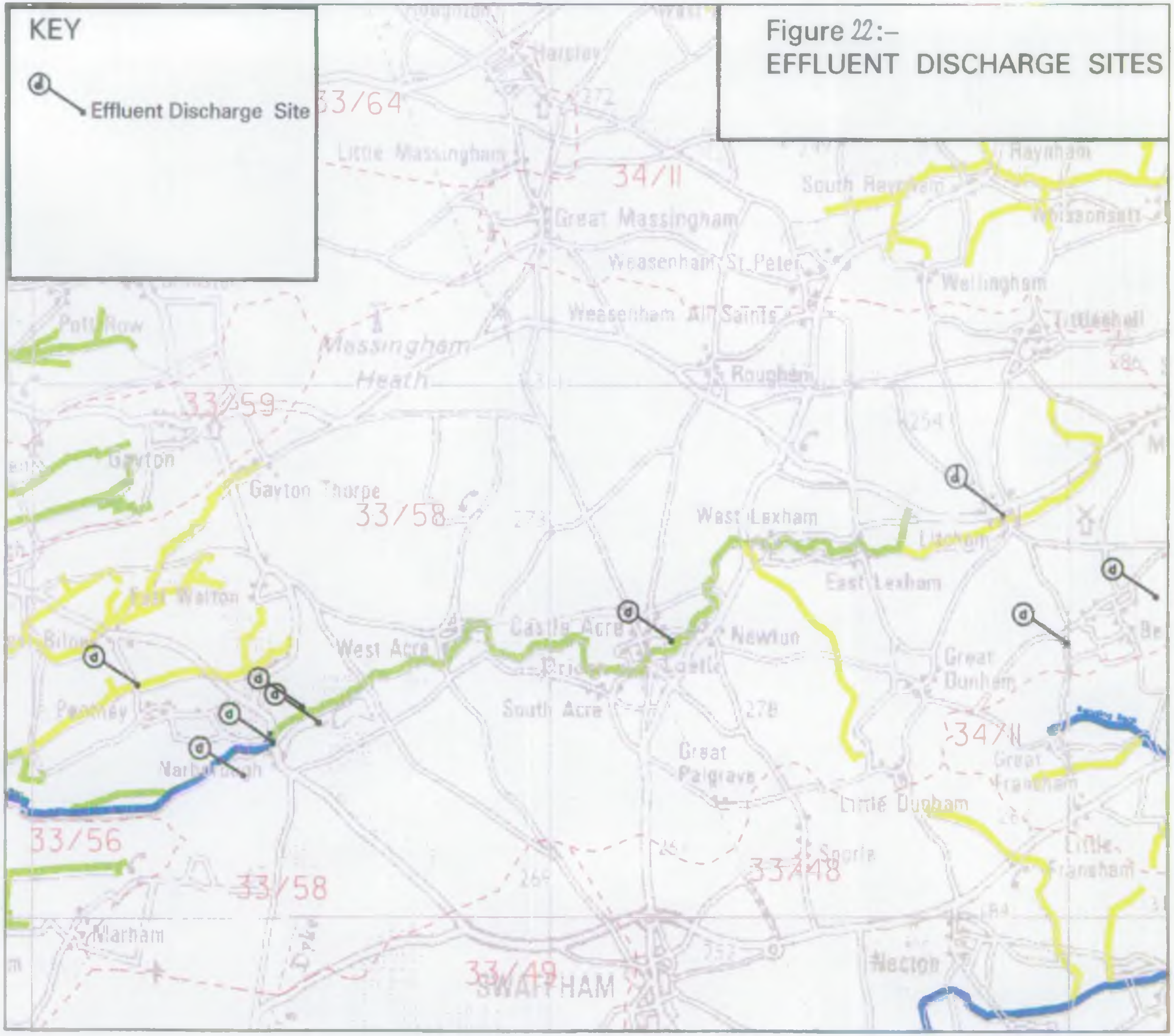


Figure 22:–
EFFLUENT DISCHARGE SITES

Table 1

Gauging Station: 033007

Nar at Marham

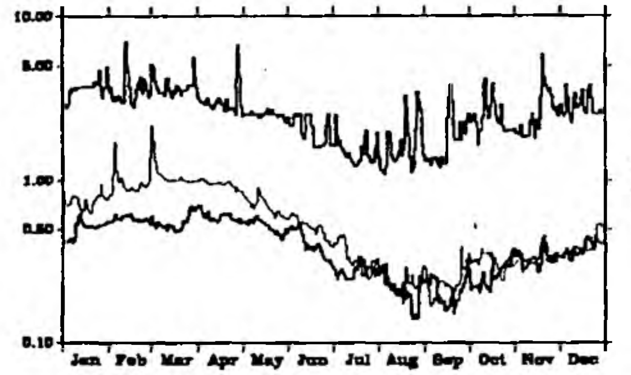
Surface Water Archive
Data Retrieval Service

Measuring Authority: NRA - Anglian
Grid Reference: 53 (TF) 723 119
Station Type: FL

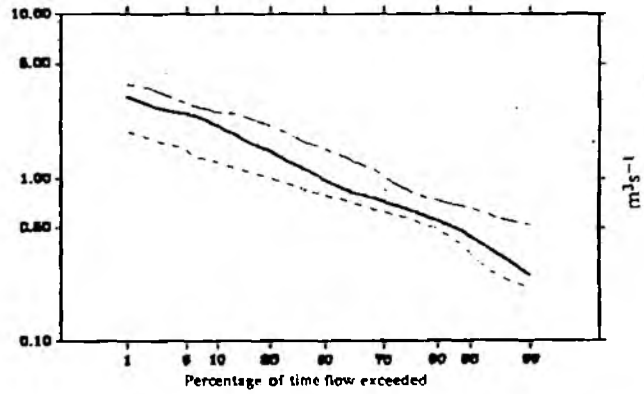
Gauged Flows and Rainfall: 1953-1992
IH Station Number: 033007
Local Number: 033007

Daily Flow Hydrograph

Max. and min. daily mean flows from 1953 to 1992 excluding those for the featured year (1990)



Flow Duration Curve



Flow Statistics

(Units: m^3s^{-1} unless otherwise stated)

Mean flow	1.15	
Mean flow (ls^{-1}/km^2)	7.52	
Mean flow ($10^6m^3/yr$)	36.4	
Peak flow / date	7.8	12 Feb 1977
Highest daily mean / date	7.0	12 Feb 1977
Lowest daily mean / date	0.140	27 Aug 1976
10 day minimum / end date	0.172	21 Sep 1991
60 day minimum / end date	0.219	8 Oct 1991
240 day minimum / end date		
10% exceedance (Q10)	2.112	
50% exceedance (Q50)	0.979	
95% exceedance (Q95)	0.439	
Mean annual flood	4.3	
Bankfull flow		
IH Baseflow index	0.91	

Rainfall and Runoff

	Rainfall (1953-1991) mm					Runoff (1953-1992) mm				
	Mean	Max/Yr		Min/Yr		Mean	Max/Yr		Min/Yr	
Jan	61	118	1988	15	1964	26	55	1959	9	1992
Feb	45	122	1977	5	1985	26	51	1977	10	1992
Mar	50	114	1981	12	1976	30	55	1957	10	1992
Apr	46	99	1981	8	1957	26	46	1958	10	1992
May	50	116	1967	10	1991	22	43	1955	9	1992
Jun	58	145	1982	9	1976	18	30	1955	7	1976
Jul	57	112	1988	8	1955	15	22	1981	5	1976
Aug	62	124	1954	3	1983	13	24	1977	4	1990
Sep	56	134	1968	3	1959	12	25	1968	4	1991
Oct	60	149	1974	6	1972	14	39	1987	5	1991
Nov	69	147	1970	28	1956	15	38	1974	6	1991
Dec	62	127	1965	23	1963	20	44	1960	7	1990
Year	676	827	1968	508	1991	237	342	1958	96	1991

Catchment Characteristics

Catchment Area	(km^2)	153.3
Level station.	(mOD)	4.60
Max altitude	(mOD)	91
FSR slope (SL1085)	(m/km)	1.89
1941-70 rainfall (SAAR)	(mm)	686
FSR stream frequency (STMFRQ)	(junctions/km^2)	
FSR percentage urban (URBAN)		

Station and Catchment Description

Critical depth flume, 7.16m wide. Prior to April 1982, flume (7.47m wide) contained low flow notch. Weed growth can be a problem during summer if not cut regularly. Surface water abstraction for PWS immediately upstream of station.

Geology - Chalk catchment overlain by clay in upper reaches.
Land use - agricultural.

Factors Affecting Runoff

- Runoff influenced by groundwater abstraction and/or recharge.
- Runoff reduced by public water supply abstraction.
- Runoff reduced by industrial and/or agricultural abstraction.
- Runoff increased by effluent returns.

Summary of Archived Data

Gauged Flows and Rainfall

Key:

	All rainfall	Some or no rainfall
All daily, all peaks	A	a
All daily, some peaks	B	b
All daily, no peaks	C	c
Some daily, all peaks	D	d
Some daily, some peaks	E	e
Some daily, no peaks	F	f
No gauged flow data	-	.

	01234	56789
1950s	---eB	CCCCC
1960s	CCCCC	BBBAB
1970s	BAAAA	ABAAA
1980s	AABBA	AAAAA
1990s	BBe	

Naturalised Flows

Key:

All daily, all monthly	A
Some daily, all monthly	B
Some daily, some monthly	C
Some daily, no monthly	D
No daily, all monthly	E
No daily, some monthly	F
No naturalised flow data	-

	01234	56789
1950s	---FE	EEEEE
1960s	EEEFE	ECCCF
1970s	EF	

Table 2

NAR CATCHMENT: CURRENT METERING SITES

TF 8590 1680
TF 8380 1700
TF 8320 1630
TF 8280 1540
TF 7830 1520
TF 9050 1870
TF 8880 1740
TF 8420 1670
TF 7140 1540
TF 8910 1720
TF 8400 1660
TF 7550 1380
TF 6770 1410
TF 7840 1530
TF 8630 1680

Table 5 : River Quality Classification

RIVER CLASS	QUALITY CRITERIA	REMARKS	CURRENT POTENTIAL USES
1a Good Quality	1) 5 percentile Dissolved Oxygen Saturation greater than 80% 2) 95 percentile Biochemical Oxygen Demand not greater than 3 mg/l 3) 95 percentile Ammonia not greater than 0.4mg/l 4) Where the water is abstracted for drinking water, it complies with requirements for A2* 5) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures are unavailable)	1) Mean Biochemical Oxygen Demand probably not greater than 1.5 mg/l 2) No visible evidence of pollution	1) Water of high quality suitable for potable supply abstractions 2) Game or other high class fisheries 3) High amenity value
1b Good Quality	1) 5 percentile Dissolved Oxygen Saturation greater than 60% 2) 95 percentile Biochemical Oxygen Demand not greater than 5 mg/l 3) 95 percentile Ammonia not greater than 0.9 mg/l 4) Where water is abstracted for drinking water it complies with the requirements for A2* 5) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures are unavailable)	1) Mean Biochemical Oxygen Demand probably not greater than 2 mg/l 2) Mean Ammonia probably not greater than 0.5 mg/l 3) No visible evidence of pollution 4) Water of high quality which cannot be placed in Class 1a because of the effect of physical factors such as canalisation, low gradient or eutrophication	Water of less high quality than Class 1a but usable for substantially the same purposes.
2 Fair Quality	1) 5 percentile Dissolved Oxygen Saturation greater than 40% 2) 95 percentile Biochemical Oxygen Demand not greater than 9 mg/l 3) Where water is abstracted for drinking water it complies with the requirements for A3* 4) Non-toxic to fish in EIFAC terms (or best estimates if EIFAC figures are unavailable)	1) Mean Biochemical Oxygen Demand probably not greater than 5 mg/l 2) Water showing no physical signs of pollution other than humic colouration and a little foaming below weirs	1) Waters suitable for potable supply after advanced treatment 2) Supporting reasonably good coarse fisheries 3) Moderate amenity value
3 Poor Quality	1) 5 percentile Dissolved Oxygen Saturation greater than 10% 2) Not likely to be anaerobic 3) 95 percentile Biochemical Oxygen Demand not greater than 17 mg/l. This may not apply if there is a high degree of re-aeration.		Waters which are polluted to an extent that fish are absent or only sporadically present. May be used for a low grade abstraction for industry. Considerable potential for further use if cleaned up.
4 Bad Quality	Waters which are inferior to Class 3 in terms of dissolved oxygen and likely to be anaerobic at times.		Water which are grossly polluted and are likely to cause nuisance.
X	DO greater than 10% saturation		Insignificant watercourses and ditches which are not usable, where the objective is simply to prevent nuisance.

* See note (e) overleaf

Table 6

1

LICENSED SURFACE WATER ABSTRACTION 1966-1993 (tcma) FOR THE NAR GROUNDWATER UNIT

YEAR	PUBLIC WATER SUPPLY	FISHERY PURPOSES	AGRIC	SPRAY IRRIGN.	INDUST.	SAND & GRAVEL WASHING	TOTAL LICENSED ABSTRN.
1966	2489.3	.0	.0	45.5	.0	.0	2534.8
1967	2894.5	.0	.0	371.9	.0	.0	3266.4
1968	2894.5	.0	.0	390.1	.0	59.1	3343.7
1969	2894.5	.0	.0	577.1	.0	59.1	3530.7
1970	2854.3	.0	.0	600.2	.0	59.1	3513.6
1971	2854.3	.0	.0	569.7	.0	59.1	3483.1
1972	2854.3	.0	.0	703.8	.0	59.1	3617.2
1973	2854.3	.0	.0	649.2	.0	59.1	3562.6
1974	2854.3	.0	.0	649.2	.0	59.1	3562.6
1975	4263.2	.0	.0	649.2	.0	59.1	4971.5
1976	4263.2	.0	.0	649.2	.0	59.1	4971.5
1977	4263.2	.0	.0	526.5	.0	59.1	4848.8
1978	4263.2	.0	.0	526.5	.0	59.1	4848.8
1979	4263.2	.0	.0	649.2	.0	59.1	4971.5
1980	4263.2	.0	.0	642.8	.0	59.1	4965.1
1981	4263.2	.0	.0	642.8	.0	59.1	4965.1
1982	4263.2	.0	.0	642.8	.0	59.1	4965.1
1983	4263.2	.0	.0	642.8	.0	59.1	4965.1
1984	4263.2	.0	.0	520.1	.0	59.1	4842.4
1985	4263.2	.0	.0	601.9	.0	59.1	4924.2
1986	4263.2	.0	.0	590.5	.0	59.1	4912.8
1987	4263.2	.0	.0	590.5	.0	59.1	4912.8
1988	4263.2	.0	.0	590.5	.0	59.1	4912.8
1989	4263.2	.0	.0	590.5	.0	59.1	4912.8
1990	4328.9	.0	.0	590.5	.0	59.1	4978.5
1991	4328.9	.0	.0	590.5	.0	59.1	4978.5
1992	4328.9	750.0	.0	585.4	.0	59.1	5723.4
1993	4328.9	750.0	.0	585.4	.0	59.1	5723.4

Table 7

1

LICENSED GROUNDWATER ABSTRACTION 1966-1993 (tcma)
FOR THE NAR GROUNDWATER UNIT

YEAR	PUBLIC WATER SUPPLY	PWU & DOM	AGRIC.	SPRAY IRRIGN.	INDUST.	SAND & GRAVEL WASHING	TOTAL LICENSED ABSTRN.
1966	.0	.0	41.2	57.1	.0	1.4	99.7
1967	5433.8	.3	180.9	87.2	12.8	1.4	5716.4
1968	5675.6	.3	196.0	261.5	12.8	1.4	6147.6
1969	5675.6	.3	196.0	261.5	12.8	1.4	6147.6
1970	5588.1	.3	196.0	391.1	12.8	1.4	6189.7
1971	5588.1	3.1	196.0	391.1	12.8	1.4	6192.5
1972	5491.7	3.1	196.0	391.1	.0	1.4	6083.3
1973	5429.3	3.1	204.5	732.0	.0	1.4	6370.3
1974	5429.3	3.1	206.5	732.0	.0	1.4	6372.3
1975	4002.1	3.1	206.5	732.0	.0	1.4	4945.1
1976	3991.9	3.1	206.5	732.0	.0	1.4	4934.9
1977	3969.5	3.1	209.8	732.0	.0	1.4	4915.8
1978	3937.7	3.1	201.3	756.6	56.7	1.4	4956.8
1979	3937.7	3.1	210.4	756.6	56.7	1.4	4965.9
1980	3937.7	3.1	210.4	811.2	56.7	1.4	5020.5
1981	3937.7	3.1	210.4	811.2	57.0	1.4	5020.8
1982	3937.7	3.1	213.7	756.6	57.0	1.4	4969.5
1983	3937.7	3.1	213.7	656.6	57.0	1.4	4869.5
1984	3937.7	3.1	213.7	883.9	57.0	1.4	5096.8
1985	3937.7	3.1	226.2	1882.9	57.0	1.4	6108.3
1986	3937.7	3.1	226.2	1996.5	57.0	1.4	6221.9
1987	3887.3	3.1	226.2	1996.5	56.7	1.4	6171.2
1988	3887.3	3.1	226.2	2114.7	56.7	1.4	6289.4
1989	3887.3	3.1	217.6	2228.3	56.7	1.4	6394.4
1990	3967.6	3.1	217.6	2228.3	56.7	1.4	6474.7
1991	3967.6	3.1	194.2	2228.3	56.7	1.4	6451.3
1992	3967.6	3.7	194.2	2282.9	56.7	1.4	6506.5
1993	3967.6	3.7	199.2	1881.0	56.7	121.4	6229.6

APPENDIX A

Geology and Hydrogeology

A brief review of the hydrogeological information concerning the Nar and the groundwater observation network.

GEOLOGY

Boulder Clay

The Nar catchment is composed of two main geological areas. To the east of a line drawn from Massingham Common (TF800 200) to near Swaffham (TF830 090) there is an extensive area of boulder clay deposits which may be underlain by periglacially disturbed soft ("putty" or "puggy") chalk areas. The boulder clay is described as Jurassic Boulder Clay and is considered to be of low permeability when compared to the Upper Chalky Boulder Clay (Wright, 1974). As a consequence, the recharge in this area will be limited. The relatively impermeable material can be up to 81m thick associated with a buried channel feature but is generally in the order of 30m or less, thinning rapidly towards the chalk outcrop. Discontinuous sand deposits (sporadically laid as ice decayed; West and Whiteman, 1986) may lie above, within or below the boulder clay and can provide an additional store of water that can be released at a later date. Generally, in the south-east and to the north the clay overlies sands. In the boulder clay areas, the relatively impermeable nature of the drift promotes runoff into the network of dry chalk valleys.

Chalk Outcrop

The second geological area is characterised by outcropping chalk, with Upper Chalk, Middle Chalk and Lower Chalk outcropping in a westerly direction. The chalk deteriorates as Lower Chalk outcrops, becoming sandier in composition. The outcrop thins to the western margin so that borehole logs show thicknesses of two metres of chalk adjacent to Narborough. It should be noted that soft chalk within the area of exposed chalk may exceed 12m in thickness (Middle Chalk at TF790 168).

River Valley

The River Nar has cut through the boulder clay cover in the east to expose chalk along the valley. Adjacent to the river, up to 19m of sand and gravel (TF860 172) may overlie the chalk, with nearly 30m of clays and gravels lying over the chalk in the area of Litcham (TF888 176). Other sand and gravel deposits lie towards the western end of the Nar river valley, being up to 9m thick at West Acre (TF778 151). Gravels formed by a process of glacial lake sedimentation occur at the western margins (in the vicinity of TF755 145).

The river lies on a bed of alluvium. The river appears to be in direct hydraulic continuity with the chalk although thick deposits of gravel in the eastern and western margins modifies the situation.

Buried Channel

The River Nar lies within an over-deepened valley. West and Whiteman (1986) suggest that the river originated from a pre-glacial Nar which was utilised and adapted by ice during the Anglian glaciation. This is the buried channel identified by Woodland (1970). Three boreholes are sited in close proximity to the present river channel, at Castle Acre, Newton and West Lexham. At Castle Acre (TF815 152) the borehole has 81m of blue and grey clay deposits (with chalk stones in the lower half). At Newton (TF830 154) there are 75m of buried channel deposits, the upper 22m of which are clays with the remainder being composed of alternating mud, sand and clay, while below 49mbgl it appears to be composed of reworked Middle Chalk. Finally, at East Lexham (TF866 172) 77m of alternating sand, clay and silt (with some chalk material) has been proved. Boreholes logs from locations sufficiently close to the channel suggest that this channel is of extremely restricted width. If the channel is composed mainly of clays it may form a barrier to flow. However, if the channel is mainly composed of sand, the channel may create an area of preferential flow over the greater part of the thickness of the aquifer. At Newton, for example, there is 22m of clay overlying sands and clays. This would therefore restrict flow in the fissured section of the chalk although flow would be able to occur beneath it. It appears the buried channel has more permeable deposits in the east than in the west, and so flow may be removed from the river in the upstream section of the Nar. A pump test carried out at TF8737 1773 concluded that there was no clear evidence to suggest that the buried glacial valley acts as a barrier to groundwater flow although it was noted that the drawdown tended to increase towards the end of the test.

TOPOGRAPHY

The boulder clay once formed a plateau through which the Nar flows. This has been heavily dissected by the river and by dry valley features. These run into either the river or off the chalk outcrop feeding, possibly through secondary fissure systems below the level of the dry valleys, the river, its tributaries, and fens and commons at the western margin of the chalk (for example, Walton Common). The beds of the dry valleys tend to be mainly exposed chalk. The main permanent tributaries to the river, however, appear to lie not on exposed chalk but rather on beds of alluvium or river terrace gravels that lie mainly on boulder clay (the boulder clay and soft deposits are generally thicker in this area).

PUMP TEST INFORMATION

West Lexham Hall (TF833 179) emerged as being a very poor yielding borehole (despite being located in an exposed chalk area). Similar characteristics were found at TF8248 1139 where geophysical analyses indicated there was little flow in the borehole above 73.5mbgl and little flow below except for a fissure at 98.8mbgl and a larger one at 119mbgl (associated with the Melbourne Rock). The upper 23m of the borehole was composed of clayey chalk which is possibly material from elsewhere that has been glacially transported to this location. The pattern of a poorly developed aquifer continues in the area around Wicken Farm (TF812 178) where geophysical analysis within a borehole identified no fissures and no discernible flow.

A borehole at TF818 101 is located very close to the edge of the study area and in close proximity to another buried channel. At this site, transmissivity values were also very low ($T=160m^2$/day) and it is considered that layering within the chalk aquifer causes a restriction in vertical flow within the chalk.

Transmissivities are, therefore, very low throughout the Nar catchment, and storativity values indicate a dual porosity aquifer, poorly developed when distant from discrete fissure flow zones. One site is located relatively close to the present river channel (TF8399 1806) and has a high yielding borehole with a high value of storativity. (Note that there is some confusion as to the grid reference of this site. TF8737 1173 has an identical value of Transmissivity and storativity, and is situated in a similar location with regard to the river.) A second site at TF804 173 had a value of transmissivity of $1534m^2/d$ and a storativity of .003. It is located in an area of chalk outcrop approximately 2km from the river, but near dry valleys. In the extreme eastern section of the river valley, at TF907 170 transmissivity values are high ($T=1589m^2/d$) with a higher than average storativity value. This site lies upon a tributary feeding the upper portion of the river and represents a better developed zone of the aquifer. There is evidence from pumping tests adjacent to Lower Farm Narborough (TF745 103 to TF762 100) that transmissivity values in this area increase towards the Nar river valley, and eastward towards Swaffham. No continuation of this pattern is discernible, however, outside the immediate vicinity of the tests. The chalk aquifer is confined by the less permeable deposits as the drift cover thickens, with water levels falling beneath the base of the drift and soft chalk/marl as the edge of the boulder clay is approached.

Values for transmissivity and storativity at sites within the study area are given below:-

NGR	T (m^2/d)	S
TF876 113	122	.0067
TF8399 1806	2701	.1044
TF8737 1773	2701	.104
TF8248 1139	581/738	.0014- .0034
TF750 103	200	.00219
TF7645 1135	220	
TF797 093	447/281	
TF818 101	160	
TF840 093	628/1032	.00119-
TF840 093	2007/1762	.00144
TF804 173	1534	.0027
TF907 170	1589	.0166

OBSERVATION NETWORK

The observation network boreholes generally have poor geological logs. The upstream area adjacent to the river, where chalk is exposed through the boulder clay, has a relatively good coverage. The area at the edge of the drift cover also has good coverage. The remainder of the boulder clay area is poorly covered with the central portions having no cover; in particular there is a large area where there are no observation points near Great Dunham. There is also a lack of monitoring points on the chalk outcrop at the northern edge of the area as well as along the river valley. Monitoring of sites within dry valleys feeding the river is limited (one site). In summary, the coverage of the observation network in the Nar catchment is concentrated along the margins of the drift deposits and adjacent to the Upper Nar, with little coverage within the outcropping chalk area.

References:-

West, R.G. & Whiteman (eds) (1986) *The Nar Valley and North Norfolk - field guide*

Woodland, A.W. (1970) *The Buried Tunnel-valleys of East Anglia, Proc. Yorks. Geol. Soc.*, vol 37(4), no 22, pp521-578

Wright, C.E (1974) *Combined use of Surface and Groundwater in the Ely Ouse and Nar catchments* Water Resources Board

Chalk Observation Data for April 1988

Site Id	NGR	Datum Elevation (mAOD)	Water Level Elevation (mAOD)	Date
TF70/001	TF 7686 0610	21.83	15.05	22-Apr-1988
TF70/002	TF 7460 0546	11.70	9.21	22-Apr-1988
TF70/007	TF 7485 0295	9.82	7.26	21-Apr-1988
TF70/008	TF 7573 0080	11.38	6.06	21-Apr-1988
TF70/025	TF 7432 0169	10.85	6.32	21-Apr-1988
TF70/034	TF 7429 0829	21.31	16.07	13-Apr-1988
TF70/038	TF 7611 0185	17.44	9.17	21-Apr-1988
TF70/045	TF 7910 0443	35.51	23.23	21-Apr-1988
TF70/066	TF 7750 0010	13.98	12.93	21-Apr-1988
TF70/070	TF 7964 0065	36.93	20.66	21-Apr-1988
TF70/071	TF 7245 0106	8.83	5.65	21-Apr-1988
TF70/097	TF 7693 0078	10.29	9.55	21-Apr-1988
TF70/098	TF 7693 0078	10.50	9.41	21-Apr-1988
TF71/001	TF 7474 1259	14.79	11.51	06-Apr-1988
TF71/002	TF 7877 1032	67.99	39.66	19-Apr-1988
TF71/003	TF 7757 1063	48.15	28.36	19-Apr-1988
TF71/005	TF 7427 1240	10.88	9.40	06-Apr-1988
TF71/078	TF 7490 1644	24.78	17.83	08-Apr-1988
TF72/001	TF 7463 2422	66.68	27.33	08-Apr-1988
TF72/002	TF 7632 2143	84.54	32.52	08-Apr-1988
TF72/003	TF 7842 2372	91.88	65.38	06-Apr-1988
TF72/004	TF 7947 2606	75.29	55.18	27-Apr-1988
TF72/005	TF 7906 2764	76.99	56.75	27-Apr-1988
TF72/007	TF 7542 2476	53.35	27.47	27-Apr-1988
TF72/011	TF 7714 2333	81.12	39.36	06-Apr-1988
TF72/012	TF 7930 2490	60.46	55.54	27-Apr-1988
TF72/828	TF 7880 2280	92.58	50.47	06-Apr-1988
TF80/001	TF 8210 0660	57.41	34.23	22-Apr-1988
TF80/002	TF 8738 0526	73.25	37.44	18-Apr-1988
TF80/005	TF 8325 0257	49.38	29.35	20-Apr-1988
TF80/006	TF 8513 0978	59.94	45.22	18-Apr-1988
TF80/008	TF 8307 0705	44.30	38.66	13-Apr-1988
TF80/009	TF 8115 0745	60.79	37.42	22-Apr-1988
TF80/010	TF 8599 0236	37.60	30.63	20-Apr-1988
TF80/014	TF 8672 0644	38.81	37.04	18-Apr-1988
TF80/021	TF 8394 0061	36.10	23.82	20-Apr-1988
TF80/022	TF 8200 0714	60.26	37.38	19-Apr-1988
TF80/023	TF 8216 0928	64.40	42.82	18-Apr-1988
TF80/149	TF 8550 0728	52.66	40.15	18-Apr-1988
TF80/170	TF 8114 0923	70.36	40.22	08-Apr-1988

TF81/003	TF 8233 1706	64.35	37.30	22-Apr-1988
TF81/005	TF 8787 1006	52.01	48.16	18-Apr-1988
TF81/006	TF 8487 1161	68.49	45.15	22-Apr-1988
TF81/010	TF 8135 1959	80.21	49.77	06-Apr-1988
TF81/011	TF 8457 1817	69.92	43.38	22-Apr-1988
TF81/013	TF 8871 1774	56.89	49.18	22-Apr-1988
TF81/019	TF 8125 1779	72.64	39.81	22-Apr-1988
TF81/022	TF 8287 1002	70.55	43.64	18-Apr-1988
TF81/116	TF 8328 1370	85.47	32.57	22-Apr-1988
TF82/001	TF 8164 2952	70.20	52.01	06-Apr-1988
TF82/005	TF 8314 2031	72.14	49.92	22-Apr-1988
TF82/006	TF 8892 2097	63.87	56.06	22-Apr-1988
TF82/007	TF 8002 2001	90.86	48.59	22-Apr-1988
TF82/008	TF 8151 2077	69.43	49.73	22-Apr-1988
TF82/382	TF 8323 2808	49.08	48.83	06-Apr-1988
TF90/001	TF 9452 0948	80.61	59.67	18-Apr-1988
TF90/003	TF 9290 0659	73.32	54.62	18-Apr-1988
TF90/004	TF 9977 0144	52.59	51.83	18-Apr-1988
TF90/879	TF 9893 0707	67.24	58.62	06-Apr-1988
TF91/001	TF 9109 1537	69.83	52.25	18-Apr-1988
TF91/002	TF 9127 1605	67.92	57.23	18-Apr-1988
TF91/133	TF 9125 1698	65.85	52.96	18-Apr-1988
TF91/622	TF 9623 1249	53.22	50.25	18-Apr-1988
TF91/751	TF 9714 1529	40.78	36.62	18-Apr-1988
TF91/864	TF 9848 1626	45.96	39.76	19-Apr-1988
TF91/886	TF 9867 1881	30.72	24.92	18-Apr-1988
TF92/423	TF 9433 2220	58.96	56.90	18-Apr-1988
TF92/671	TF 9615 2734	32.23	30.12	18-Apr-1988
TF92/816	TF 9869 2183	46.36	27.17	18-Apr-1988

Chalk Observation Data for September 1991

Site Id	NGR	Datum Elevation (mAOD)	Water Level Elevation (mAOD)	Date
TF70/001	TF 7686 0610	21.83	10.74	12-Sep-1991
TF70/002	TF 7460 0546	11.70	6.90	12-Sep-1991
TF70/007	TF 7485 0295	9.82	6.82	12-Sep-1991
TF70/025	TF 7432 0169	10.85	5.63	12-Sep-1991
TF70/034	TF 7429 0829	21.31	10.00	11-Sep-1991
TF70/038	TF 7611 0185	17.44	7.74	12-Sep-1991
TF70/045	TF 7910 0443	35.51	20.72	12-Sep-1991
TF70/066	TF 7750 0010	13.98	10.53	19-Sep-1991
TF70/070	TF 7964 0065	36.93	15.12	19-Sep-1991
TF70/071	TF 7245 0106	8.83	3.91	12-Sep-1991
TF70/097	TF 7693 0078	10.29	8.10	19-Sep-1991
TF70/098	TF 7693 0078	10.50	8.50	19-Sep-1991
TF70/109	TF 7490 0740	18.76	9.15	15-Sep-1991
TF71/001	TF 7474 1259	14.79	9.99	02-Sep-1991
TF71/002	TF 7877 1032	67.99	22.74	20-Sep-1991
TF71/003	TF 7757 1063	48.15	15.15	20-Sep-1991
TF71/005	TF 7427 1240	10.88	7.28	20-Sep-1991
TF71/078	TF 7490 1644	24.78	15.62	03-Sep-1991
TF72/001	TF 7463 2422	66.68	21.48	24-Sep-1991
TF72/002	TF 7632 2143	84.54	21.89	24-Sep-1991
TF72/003	TF 7842 2372	91.88	58.20	02-Sep-1991
TF72/004	TF 7947 2606	75.29	47.84	24-Sep-1991
TF72/005	TF 7906 2764	76.99	45.82	24-Sep-1991
TF72/007	TF 7542 2476	53.35	20.77	24-Sep-1991
TF72/011	TF 7714 2333	81.12	25.80	24-Sep-1991
TF72/012	TF 7930 2490	60.46	44.73	24-Sep-1991
TF72/828	TF 7880 2280	92.58	39.40	09-Sep-1991
TF80/001	TF 8210 0660	57.41	27.96	26-Sep-1991
TF80/002	TF 8738 0526	73.25	32.25	25-Sep-1991
TF80/005	TF 8325 0257	49.38	23.70	25-Sep-1991
TF80/008	TF 8307 0705	44.30	29.94	26-Sep-1991
TF80/009	TF 8115 0745	60.79	27.11	12-Sep-1991
TF80/010	TF 8599 0236	37.60	27.14	26-Sep-1991
TF80/023	TF 8216 0928	64.40	31.90	12-Sep-1991
TF80/149	TF 8550 0728	52.66	31.80	25-Sep-1991
TF80/152	TF 8213 0960	63.56	31.44	26-Sep-1991
TF80/153	TF 8159 0881	74.04	29.09	26-Sep-1991
TF80/170	TF 8114 0923	70.36	29.48	02-Sep-1991
TF81/005	TF 8787 1006	52.01	41.18	25-Sep-1991
TF81/010	TF 8135 1959	80.21	41.21	03-Sep-1991

TF81/011	TF 8457 1817	69.92	36.42	24-Sep-1991
TF81/019	TF 8125 1779	72.64	33.54	24-Sep-1991
TF81/022	TF 8287 1002	70.55	35.47	20-Sep-1991
TF81/116	TF 8328 1370	85.47	28.97	20-Sep-1991
TF82/001	TF 8164 2952	70.20	45.20	25-Sep-1991
TF82/004	TF 8260 2823	69.70	62.97	25-Sep-1991
TF82/005	TF 8314 2031	72.14	41.14	24-Sep-1991
TF82/006	TF 8892 2097	63.87	49.55	24-Sep-1991
TF82/007	TF 8002 2001	90.86	38.34	24-Sep-1991
TF82/008	TF 8151 2077	69.43	40.73	23-Sep-1991
TF82/382	TF 8323 2808	49.08	44.39	09-Sep-1991
TF90/002	TF 9290 0659	52.47	40.51	26-Sep-1991
TF90/003	TF 9290 0659	73.32	51.84	26-Sep-1991
TF90/004	TF 9977 0144	52.59	50.64	18-Sep-1991
TF90/879	TF 9893 0707	67.24	56.36	18-Sep-1991
TF91/002	TF 9127 1605	67.92	50.22	25-Sep-1991
TF91/133	TF 9125 1698	65.85	47.35	25-Sep-1991
TF91/622	TF 9623 1249	53.22	48.31	18-Sep-1991
TF91/751	TF 9714 1529	40.78	34.97	18-Sep-1991
TF91/774	TF 9747 1705	41.31	34.51	18-Sep-1991
TF91/864	TF 9848 1626	45.96	37.91	18-Sep-1991
TF91/886	TF 9867 1881	30.72	22.56	18-Sep-1991
TF92/423	TF 9433 2220	58.96	51.85	09-Sep-1991
TF92/671	TF 9615 2734	32.23	29.11	09-Sep-1991
TF92/816	TF 9869 2183	46.36	24.10	09-Sep-1991

APPENDIX B

Surface Water Quality

SURFACE WATER QUALITY

EC Directives:

River:	Nar	
Stretch:	Lexham Hall...Marham WW Intake	
Start NGR:	TF86701690	End NGR: TF72401200
Length:	17km	
Type:	**SALMONID**	

River:	Nar	
Stretch:	Marham WW Intake...Tail Sluice Kings Lynn	
Start NGR:	TF72401200	End NGR: TF62101830
Length:	16km	
Type:	**CYPRINID**	

River Quality Objectives:

Key to Use Codes:

F1: Fisheries supporting a breeding population of trout/grayling
F2: Fisheries supporting a breeding population of non-salmonid fish
HA: High Amenity
LW: Livestock Watering
MA: Moderate Amenity
PD: Potable water supply (Direct to treatment)
SI: Spray Irrigation

Stretch Code:	960010.0	
River:	Nar	
Stretch:	Mileham...Lexham Hall	
Start NGR:	TF8960019800	End NGR: TF8670016900
Length:	6.0 km	
Uses:	**SI LW HA**	

Stretch Code:	960040.0	
River:	Nar	
Stretch:	Lexham Hall...Narborough	
Start NGR:	TF8670016900	End NGR: TF7480013200
Length:	14.0 km	
Uses:	**F1 SI LW HA**	

Stretch Code:	960050.0	
River:	Nar	
Stretch:	Lexham Hall...Marham WW Intake	
Start NGR:	TF7480013200	End NGR: TF7240012000
Length:	3.0 km	
Uses:	**PD F2 SI LW MA**	

Stretch Code:	960030.0	
River:	Narrowgate Stream	
Stretch:	Narrowgate Stream	
Start NGR:	TF8910015900	End NGR: TF8910017400
Length:	3.0 km	
Uses:	**LW MA**	

Stretch Code:	960020.0	
River:	Nar Tributary	
Stretch:	Beeston...Nar	
Start NGR:	TF9180015900	End NGR: TF9020018100
Length:	3.0 km	
Uses:	**MA**	

National Water Council Results: 1991 and 1992

Stretch:	County Drain...Litcham		
Total Length:	29.9 km		
County Drain NGR	TF6820012800	Litcham:	TF9020018100
Breakdown:	21.2 km...1b		
	3.7 km...2		
	5.0 km...3		

Stretch:	County Drain...Little River		
Total Length:	2.3 km		
County Drain:	TF6700013500	Little River:	TF650001350
Breakdown:	1.8 km...1b		
	0.5 km...2		

Stretch:	Middleton Stop Drain...Little River		
Total Length:	8.0 km		
Middleton Stop Drain:	TF6200019300	Little River:	TF6500013500
Breakdown:	8.0 km...1b		

Biological Standards: 1992

There are 5 sites which are biologically sampled routinely between Mileham and Narborough.

They are as follows:

Site Code	Site Name	NGR
R02BF58M03	R. NAR LITCHAM RD.BR.	TF 888 174
R02BF58M04	R.NAR WEST LEXHAM RD.BR.	TF 838 169
R02BF58M05	R.NAR CASTLE ACRE RD.BR.	TF 819 148
R02BF58M06	R.NAR WEST ACRE RD.BR.	TF 779 147
R02BF58M07	R.NAR NARBOROUGH RD.BR.	TF 747 132

The following is summary data for samples collected in 1992. This includes the Biological Monitoring Working Party (BMWP) Score which is an index calculated by totalling the scores associated with each scoring family/taxa found. The higher the BMWP score the better the water quality. The Average Score Per Taxon (ASPT) is calculated by dividing the BMWP by the number of scoring taxa found.

Sample Point Code: **R02BF58M03**
: R. NAR LITCHAM RD.BR.

	Most Recent Sample	Previous Sample
Sample Number:	000758	000403
Date :	9/11/92	06/07/92
BMWP Score:	67	57
Average Score per Taxon:	3.9	3.8
Lincoln Quality Index:	C 4.0	C 4.0
LQI Target Compliance:	C - Pass	C - Pass

Sample Point Code: **R02BF58M04**
: R.NAR WEST LEXHAM RD.BR.

	Most Recent Sample	Previous Sample
Sample Number:	000757	000404
Date :	09/11/92	06/07/92
BMWP Score:	96	57
Average Score per Taxon:	4.4	3.6
Lincoln Quality Index:	C 4.0	E 3.0
LQI Target Compliance:	B - Fail	B - Fail

Sample Point Code: **R02BF58M05**
: R.NAR CASTLE ACRE RD.BR.

	Most Recent Sample	Previous Sample
Sample Number:	000756	000405
Date :	09/11/92	06/07/92
BMWP Score:	84	96
Average Score per Taxon:	4.4	4.6
Lincoln Quality Index:	D 3.5	B 4.5
LQI Target Compliance:	B - Fail	B - Pass

Sample Point Code: **R02BF58M06**
: R.NAR WEST ACRE RD.BR.

	Most Recent Sample	Previous Sample
Sample Number:	000755	000406
Date :	09/11/92	06/07/92
BMWP Score:	152	94
Average Score per Taxon:	5.9	5.2
Lincoln Quality Index:	A++6.5	A 5.0
LQI Target Compliance:	B - Pass ++++	B - Pass +

Sample Point Code: **R02BF58M07**
: R.NAR NARBOROUGH RD.BR.

	Most Recent Sample	Previous Sample
Sample Number:	000754	000438
Date :	09/11/92	06/07/92
BMWP Score:	105	110
Average Score per Taxon:	5.0	4.8
Lincoln Quality Index:	B 4.5	B 4.5
LQI Target Compliance:	B - Pass	B - Pass

In addition, on an annual basis the actual scores are compared with scores predicted for each site by RIVPACS. The ratios of actual and predicted scores are used to assign a band (A - D) to stretches of river. Two of the above sites banded in 1992 and are assigned to an RQO stretch:

River:	Nar	
RQO Stretch:	Lexham Hall...Mileham	
Start NGR:	TF 86701690	End NGR: TF 89601980
Length:	6km	
Band:	**B**	

River:	Nar	
RQO Stretch:	Lexham Hall...Narborough	
Start NGR:	TF 86701690	End NGR: TF 74801320
Length:	14km	
Band:	**A**	

APPENDIX C

Wetland Conservation Sites

COUNTY WILDLIFE SITES - RIVER NAR CATCHMENT

NGR	Site Name & Description
TF 78 15	**Warren Farm Meadows**. Damp area of grassland & fen together with scattered scrub.
TF 78 15	**River Nar, Castle Acre Common.** Exceptional site documented by Nature Conservancy Council.
TF 73 16	**Pond north of Common Lane - E Walton.** Small but species rich and clear pond.
TF 73 16	**Land adjacent to Walton Common**. Wet meadow and alder carr.
TF 74 16	**Pond north of Common Lane - E Walton.** Good common aquatics.
TF 74 16	**Pond south of Common Lane - E Walton.** Good aquatics with gradual sloping margin.
TF 74 16	**Pond near East Walton.** Abundant aquatics including Nasturtum, Oenanthe aq. and Apium.
TF 72 17	**Narborough/Walton Stocks/Lambs Common.** Excellent site - tributary and associated habitats.
TF 76 14	**Trout Pond, Narford.** Mesotrophic lake bordered by tall fen.
TF 78 14	**South of Abbey Farm, West Acre.** Very damp grassland with river flowing through site.
TF 70 11	**River Nar**. Mesotrophic river surveyed by NCC.
TF 71 12	**North of Ashwood Lodge.** Eutrophic pond half filled with sallow coppice and woodland.
TF 70 13	**Gravel Pits, West of Petney.** Gravel pits of varying ages with scrub.
TF 70 14	**North east of West Bilney Hall.** Artificial lake with poor marginal vegetation.
TF 74 13	**Narborough Gravel Pits.** Group of mostly mature lakes formed by gravel abstraction.

TF 74 13	**Little Eight Acre Plantation.** Oak/birch woodland; acidic grassland & pond.
TF 71 20	**Watery Lane, Grimston.** Small impeded meadow with good herb content.
TF 76 13	**Narford Lake in grounds of Narford Hall.** Good waterfowl with heronry and neutral grassland surrounds.
TF 76 14	**River Nar west from West Acre.** Clear swift flowing river supporting a diverse flora.
TF 79 14	**Mill House Lake, West Acre.** Mesotrophic lake with limited access.
TF 73 12	**South of River Nar near Narborough.** Mesotrophic pond.
TF 74 13	**Narborough Trout Lakes.** Series of excavated mesotrophic lakes.
TF 74 13	**Narborough Hall Moat.** Mesotrophic lake with steeply sloping banks.
TF 79 15	**Adjacent to Mill Lane near West Acre.** Tall fen vegetation & adjoining grassland, adjacent to River Nar.
TF 84 13	**Osier Plantation, West of Little Dunham.** Large excavated pond vulnerable to agricultural runoff.
TF 81 14	**River Nar & associated habitat.** 0.69 km of mesotrophic river including valley bog.
TF 80 14	**River Nar & associated habitat.** 1.42 km of mesotrophic river with gravel pits/alder woodland /scrub.
TF 80 15	**West of Castle Acre.** Artificial lake formed by gravel abstraction.
TF 82 15	**River Nar, includes old gravel pit.** Important area for snipe.
TF 82 15	**River Nar from Newton heath to Castle Acre.** Grazed grassland of varying quality.
TF 83 16	**River Nar & associated habitats from West Lexham to A1065.** Rich grazed grassland.
TF 84 16	**River Nar & associated habitats east of West Lexham.** Regularly flooded grassland with abundant snipe.

TF 89 15	**Church Farm Pond.** Eutrophic pond with some overhanging scrub.
TF 87 16	**River Nar west of East Lexham to Source.** 9.36 km of mesotrophic river fully documented by NCC.
TF 89 16	**SE of Litcham Common.** Mosaic of wet habitats including four ponds.
TF 86 17	**East of Lexham Hall.** Eutrophic lake in Lexham Hall grounds.
TF 87 17	**East of Lexham Hall.** Mesotrophic pond with gradual sloping margin.
TF 89 17	**Warren Woods east of Litcham.** Large mosaic of wet habitats associated with River Nar.
TF 89 19	**North of Grenstein Farm.** Eutrophic lake, water is choked with aquatics.

File ref: EA/N/218/ 14 PAD

COUNTY: Norfolk

SITE NAME: River Nar

DISTRICT: West Norfolk

STATUS: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981.

Local Planning Authority: Breckland District Council, Kings Lynn & West Norfolk Borough Council.

National Grid Reference: TF 897198 to TF 622184

Area: 233.43 hectares 576.8 acres

Length of River SSSI: 40.5 km

ORDNANCE SURVEY SHEET:	1:50 000	1:10 000
	133, 144	TF 61 NW,SE,SW TF 71 NE,SE,SW TF 81 NE,NW,SW TF 91 NW

Date Notified (under 1949 Act): Date of last Revision:

Date Notified (under 1981 Act): 1992 Date of last revision:

Other Information: New Site

Description and Reasons for Notification

The River Nar originates as a spring-fed stream, west of Mileham in Norfolk and flows for 42 km before joining the River Great Ouse at Kings Lynn, where a sluice prevents the penetration of seawater at high tide. The River combines the characteristics of a southern chalk stream and an East Anglian fen river. Together with the adjacent terrestrial habitats, the Nar is an outstanding river system of its type.

The solid geology of the catchment is dominated by chalk of the Upper Cretaceous, which is overlain by glacial drift deposits of varying thickness. The source of the Nar lies in an area of clays, sands and gravels, though near Castle Acre this gives way to exposed chalk. At West Acre the Nar flows over river valley gravels and then over alluvial silt from Narborough through the fens. The river water is base-rich, alkaline and recharged by clear springs flowing from the underlying chalk.

The upper Nar has a wide range of natural physical features incorporating riffles, pools, gravel beds and meanders, whilst the lower reaches below Narborough are embanked and steep sided with water flowing sluggishly through a predominantly arable flood plain. The variation in physical features and the influence of the underlying chalk give rise to a rich and diverse flora. Amongst the 78 species of riverine and bankside plants are many eutrophic and mesotrophic species, including 5 pondweeds and 8 bryophytes.

The flora of the first 10 km of the river, to West Lexham, is typical of a calcareous, lowland ditch community with an abundance of starwort *Callitriche* spp. and reed sweet-grass, *Glyceria maxima* .The next 12 km of the River, to Narborough Mill, is fast flowing over stoney substrates and is rich in chalk stream plants including narrow-leaved water-parsnip, *Berula erecta;* mare's-tail, *Hippuris vulgaris;* greater tussock-sedge, *Carex paniculata;* water crowfoot, *Ranunculus pseudofluitans var. vertumnus* and opposite-leaved pondweed, *Groenlandia densa*. The wet margins, with a constantly high water table typical of chalk streams, support a wide range of emergent plants. The final 18.5 km is embanked and although less physically diverse than the upper reaches, it possesses a contrasting flora with several species not found in the upper river. These plants are characteristic of sluggish flows and include 3 pondweeds,*Potamogeton* spp.; 2 water crowfoots, *Ranunculus* spp.; hornwort, *Ceratophyllum demersum;* water-milfoil, *Myriophyllum spicatum;* and river water-dropwort, *Oenanthe aquatica*.

The Nar is well-known locally for its brown trout, *Salmo trutta*. Since 1985, trout numbers have increased steadily; pike, *Esox lucius,* numbers have remained fairly stable whilst roach, *Rutilus rutilus,* and eel, *Anguilla anguilla,* have continued to be the dominant species in the river. A further 11 species have been recorded in the Nar although they contribute only a small amount to the total fish biomass e.g.: chubb, *Leuciscus cephalus;* tench, *Tinca tinca;* gudgeon, *Gobio gobio;* rudd, *Scardinius erythrophthalamus;* bullhead, *Cottus gobio;* rainbow trout, *Salmo gairdneri;* spined loach, *Cobitis taenia;* and roach x bream, *Abramis brama,* hybrids.

The chalk acts as a natural aquifer and thus maintains flows throughout the year, peaking in the spring with frequent flooding of adjacent land. This has led to the development of a range of adjacent semi-natural inundation communities and wetland habitats. Many have their water-tables intricately linked to and therefore dependent on the river whilst others are dependent on seasonal inundation. In the upper reaches of the river extensive areas of traditionally managed unimproved pasture survive. A combination of summer cattle grazing and hay making have encouraged the establishment of a variety of wetland species, including southern marsh orchid, *Dactylorhiza majalis subsp. praetermissa;* yellow rattle, *Rhinanthus minor,* and bogbean, *Menyanthes trifoliata*.

Where land adjacent to the river is seasonally flooded and has not been reclaimed as pasture, areas of rough fen and unmanaged scrub remain. Further downstream this scrub has developed into mature wet woodland, dominated by alder carr. The result is a river corridor of considerable importance to wildlife. Although the river channel can be regarded as nationally important in its own right, the quality and type of adjacent habitats increases its value for fauna which use both the river and floodplain. Breeding birds include snipe, lapwing, redshank, sedge and grasshopper warblers.

The variations in river profile including slope, width and depth are important factors in the provision of nesting sites for kingfishers and sand martins, and the combination of water meadow, fen, scrub and woodland in the upper Nar provides feeding and resting grounds for a number of other birds including grey wagtail, reed warblers, teal, marsh harriers, willow and marsh tits. Entomological studies are incomplete but 12 different species of dragonfly were recorded in 1991 at several locations along the Nar; this represents an outstanding assemblage for the UK.

Date notified: 19 March 1990

File Ref: EA/N/235 14WQB

COUNTY: NORFOLK

SITE NAME: CASTLE ACRE COMMON

DISTRICT: WEST NORFOLK

Status: Site of Special Scientific Interest [SSSI] notified under Section 28 of the Wildlife and Countryside Act 1981

Local Planning Authority: West Norfolk District Council

National Grid Reference: TF 802 152 Area: 17.7 [ha] 43.7 [ac]

Ordnance Survey Sheet 1:50,000: 132 1:10,000: TF 71 NE, TF 81 NW TF 71 SE, TF 81 SW

Date Notified [Under 1949 Act]: - Date of Last Revision: -

Date Notified [Under 1981 Act]: 1990 Date of Last Revision: -

Other Information:

A new site

Reasons for Notification:

This site consists of a large area of unimproved grazing marsh on the banks of the River Nar. The grassland communities are exceptionally diverse and make this the most important valley grassland site in west Norfolk. Many different grassland types are present and these reflect underlying variations in soil acidity and wetness. Acidic flush communities are an unusual feature and occur where springs emerge from sands at the base of the valley sides. The marshy conditions provide suitable nesting sites for several species of wetland birds.

The waterlogged soils in the valley-bottom support a marshy grassland flora dominated by a variety of species including Marsh Horsetail (Equisetum palustre) Bogbean (Menyanthes trifoliata), Marsh Valerian (Valeriana dioica), Marsh Pennywort (Hydrocotyle vulgaris) and Brown Sedge (Carex disticha). This rich community includes several other plants characteristic of such conditions, namely Flat Sedge (Blysmus compressus), Devil's bit Scabious (Succisa pratensis), Meadow Thistle (Cirsium dissectum), Southern Marsh Orchid (Dactylorhiza praetermissa) and Blunt-flowered Rush (Juncus subnodulosus). There is a graduation to tall fen vegetation on the wettest soils adjacent to the river and these areas are dominated by Reed Sweet-grass (Glyceria maxima), Common Reed (Phragmites australis) or Lesser Pond Sedge (Carex acutiformis).

Damp, slightly acidic grassland occurs on the drier margins of the site. The rabbit-grazed short turf is dominated by Sweet Vernal-grass (Anthoxanthum odoratum), together with a variety of other grasses including Creeping Soft-grass (Holcus mollis), Mat-grass (Nardus stricta) and Sheep's fescue (Festuca ovina). Herb species are well-represented and notable species include Meadow Saxifrage (Saxifraga granulata), Yellow Rattle (Rhinanthus minor), Tormentil (Potentilla erecta), and Heath Bedstraw (Galium saxatile).

The acidic flushes emerge from the base of a Bracken-covered slope and are marked by a narrow band of vegetation dominated by Bog-mosses (Sphagnum spp.). Plants associated with this unusual community include Marsh Cinquefoil (Potentilla palustris), Common Cotton-grass (Eriophorum angustifolium), Cross-leaved Heath (Erica tetralix) and Heath Rush (Juncus squarrosus).

Several pairs of Snipe nest on the marshy areas and other breeding birds include Lapwing, Sedge Warbler and Cuckoo.

SITE NAME: CASTLE ACRE COMMON, NORFOLK

REF NO:	OPERATIONS LIKELY TO DAMAGE THE SCIENTIFIC INTEREST
1.	Cultivation, including ploughing, rotovating, harrowing, and re-seeding.
2.	The introduction of grazing. or Changes in the grazing regime (including type of stock or intensity or seasonal pattern of grazing and cessation of grazing).
3.	The introduction of stock feeding. or Changes in stock feeding practice (including changes in the number of animals stocked).
4.	The introduction of mowing or other methods of cutting vegetation or Changes in the mowing or cutting regime (including hay making to silage and cessation).
5.	Application of manure, fertilisers and lime.
6.	Application of pesticides, including herbicides (weedkillers).
7.	Dumping, spreading or discharge of any materials.
8.	Burning.
9.	The release into the site of any wild, feral or domestic animal*, plant or seed.
10.	The killing or removal of any wild animal, excluding pest control.
11.	The destruction, displacement, removal or cutting of any plant or plant remains including herb, hedge, moss or turf.
12.	The introduction of tree and/or woodland management+ or Changes in tree and/or woodland management.+

*'Animal' includes any mammal, reptile, amphibian, bird, fish or invertebrate.

+including afforestation, planting, clear and selective felling, thinning, coppicing, modification of the stand of underwood, changes in species composition, cessation of management.

/Cont.

13a. Drainage (including the use of mole, tile, tunnel or other artificial drains.

13b. Modification of the structure of watercourses (eg rivers, streams, springs, ditches, dykes, drains), including their banks and beds, as by re-alignment, re-grading and dredging.

13c. Management of aquatic and bank vegetation for drainage purposes (see also 11).

14. The changing of water levels and tables and water utilisation (including irrigation, storage and abstraction from existing water bodies and through boreholes).

15. Infilling of ditches, dykes, drains, pools or marshes.

16a. Changes in freshwater fishery production and/or management*.

* including sporting fishing and angling.

20. Extraction of minerals, including peat, sand and gravel, topsoil, subsoil, chalk, lime and spoil.

21. Construction, removal or destruction of roads, tracks, walls, fences, hardstands, banks, ditches, or other earthworks, or the laying, maintainance or removal of pipelines and cables, above or below ground.

22. Storage of materials.

23. Erection of permanent or temporary structures, or the undertaking of engineering works, including drilling.

26. Use of vehicles or craft likely to damage or disturb features of interest.

27. Recreational or other activities likely to damage wetland vegetation and turf.

28. Changes in game and waterfowl management and hunting practice.

Date notified: 20 May 1989

File Ref: EA/N/254 14WHR

COUNTY: Norfolk

SITE NAME: NARBOROUGH RAILWAY EMBANKMENT

DISTRICT: Breckland

Status: Site of Special Scientific Interest [SSSI] notified under Section 28 of the Wildlife and Countryside Act 1981

Local Planning Authority: Breckland District Council

National Grid Reference: TF 750118 - TF 763107   Area: 7.9 [ha] 19.52 [ac]

Ordnance Survey Sheet 1:50,000: 132   1:10,560: TF 71 SW, SE

Date Notified [Under 1949 Act]: -   Date of Last Revision: -

Date Notified [Under 1981 Act]: 1989   Date of Last Revision: -

Other Information:

A new site.

Reasons for Notification:

This site is an attractive embanked section of the disused railway line between King's Lynn and Swaffham. The embankment was constructed in the 19th century from locally extracted chalk rubble and a herb-rich chalk flora has developed on the banks. It is probably the most diverse chalk grassland site now left in Norfolk with several chalk-loving species occurring in great abundance. This profusion of flowering plants attracts and supports a wide range of butterflies including several locally scarce species. Further site interest is provided by calcareous scrub and interesting assemblages of mosses and molluscs.

Large areas of the embankment support a very rich and pure chalk flora in which grasses are sparse and short-growing, Rough Hawkbit [Leontodon hispidus] is dominant in many areas, with frequent Carline Thistle [Carlina vulgaris], Stemless Thistle [Cirsium acaule], Hairy Rock-cress [Arabis hirsuta], Purging Flax [Linum catharticum] and Larger Wild Thyme [Thymus pulegioides]. Autumn Felwort [Gentianella amarella] is also fairly frequent and Wild Marjoram [Origanum vulgare] is locally abundant. On the track itself, Eyebright [Euphrasia nemorosa) is dominant over large areas and there is frequent Small Scabious [Scabiosa columbaria], Kidney-vetch [Anthyllis vulneraria] and Ploughman's Spikenard [Inula conyza].

Shallow chalk workings occur in places at the base of the embankment and these damp hollows contain Pyramidal Orchid [Anacamptis pyramidalis], Marsh Helleborine [Epipactis palustris] and Southern Marsh Orchid [Dactylorhiza praetermissa].

Parts of the track are overgrown with calcareous scrub in which Buckthorn [Rhamnus catharticus] is unusually abundant. Sweet-briar [Rosa rubiginosa] is also very common on the banks.

The diverse and very abundant butterfly population includes several locally scarce species such as Dingy Skipper, Grayling, Green Hairstreak, Purple Hairstreak and Brown Argus. There are also large populations of the commoner species such as Brimstone, Small Heath, Meadow Brown and Common Blue.

Young secondary woodland has developed in places on the banks and along the margins of the site.

Date notified: 26 May 1989

Operations requiring prior consultation with NCC

Site name: NARBOROUGH RAILWAY EMBANKMENT, NORFOLK

Ref No	Type of Operation
1.	Cultivation, including ploughing, rotovating, harrowing, and re-seeding.
2.	The introduction of grazing or changes in the grazing regime [including type of stock or intensity or seasonal pattern of grazing and cessation of grazing].
3.	The introduction of stock feeding or changes in stock feeding practice, including changes in the number of animals stocked.
4.	The introduction of mowing or other methods of cutting vegetation or changes in the mowing or cutting regime [including hay making to silage and cessation].
5.	Application of manure, fertilisers and lime.
6.	Application of pesticides, including herbicides [weedkillers].
7.	Dumping, spreading or discharge of any materials.
8.	Burning.
9.	The release into the site of any wild, feral or domestic animal*, plant or seed.
10.	The killing or removal of any wild animal*, including pest control.
11.	The destruction, displacement, removal or cutting of any plant or plant remains, including tree, shrub, herb, moss, and turf.
12.	The introduction of or changes in tree and/or woodland management+.
13a.	Drainage [including the use of mole, tile, tunnel or other artificial drains].
14.	The changing of water levels and tables and water utilisation [including irrigation, storage and abstraction from existing water bodies and through boreholes].
15.	Infilling of ditches, pools, or pits.
20.	Extraction of minerals, including topsoil, subsoil, chalk, and spoil.
21.	Construction, removal or destruction of roads, tracks, walls, fences, hardstands, banks, ditches or other earthworks, or the laying, maintenance or removal of pipelines and cables, above or below ground.
22.	Storage of materials.
23.	Erection of permanent or temporary structures, or the undertaking of engineering works, including drilling.
26.	Use of vehicles or craft likely to damage or disturb features of interest.
27.	Recreational or other activities likely to damage the chalk grassland, scrub or sheltering trees.
28.	Introduction of game or waterfowl management or changes in game and waterfowl management and hunting practice.

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* 'animal' includes any mammal, reptile, amphibian, bird, fish or invertebrate.

\+ including afforestation, planting, clear and selective felling, thinning, coppicing, modification of the stand of underwood, changes in species composition, cessation of management.

APPENDIX D

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