Environment Agency
Anglian Region

Strategy for Groundwater Investigations and Modelling: Yare and North Norfolk Areas

Scoping Study

27 January 2000

Entec UK Limited

ENVIRONMENT
AGENCY

Environment Agency Anglian Region

Strategy for Groundwater Investigations and Modelling: Yare and North Norfolk Areas

Scoping Study

27 January 2000

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Report for

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Contents

1. Introduction

1.1 Strategy for Groundwater Investigations and Modelling

The Anglian Region 'Strategy for Groundwater Investigations and Modelling' was accepted by the Project Approval Board in February 1998. The Strategy was prepared following the publication of the Anglian Region Water Resources Strategy (September 1994).

The Water Resources Strategy identified the groundwater resources available for abstraction within the main aquifer units across the Anglian Region and identified the amount of resource which it was believed should be allocated to maintain acceptable river flows. This assessment of groundwater resources was based on simplistic groundwater balance techniques (see Annex 4 of Water Resources Strategy) using average climatic conditions. The Strategy for Groundwater Investigation and Modelling (The Strategy) which was prepared in the context of the National Environmental Strategy and the Water Resources Functional Strategy, sets out detailed proposals for the review of the groundwater resources in line with sound science and defensible technical practice. The national initiative for the implementation of this review of groundwater resources is being led by the National Groundwater and Contaminated Land Centre. The overall aim of the implementation of The Strategy is to provide a resource management tool that is demonstrably based on sound science and good technical practice. In the process of development of this tool (probably a distributed groundwater model) improved understanding and resource assessments of groundwater systems of main aquifers across the Region will be achieved.

The need for a more rigorous and technically defensible groundwater resource appraisal is driven by the combination of increasing resource usage and increased awareness of the importance of groundwater in environmental conservation. These drivers have led to a series of regulatory and consultative documents which provide (or imply a future) statutory obligation to improve resource assessments and to generate public understanding of these assessments. Specifically the key documents are:

- the EU Water Framework Directive and its requirement for the preparation of river basin management plans and their review on a 6 year cycle;
- the DETR White Paper, 'Taking Water Responsibly' which recognises the obligations imposed by the Framework Directive;
- The EU Habitats Directive and the obligation to review abstractions with potential impacts on designated conservation sites by March 2004;
- the developing Area Management Strategies as a first step to implementation of Framework Directive and White Paper requirements;
- the LEAP process and the issues identified in the LEAP reports.

The Strategy projects are focused on water resources issues and recognise that the complexities of groundwater - surface water interaction, do not permit groundwater resources to be addressed without clear evaluation of surface water flows. Consequently, understanding of the groundwater flow system and the complexities of groundwater-surface water interaction are a priority project activity. Additionally, the importance of groundwater quality as a tool to support conceptual understanding, and as a major input to resource assessment and conservation, cannot be overlooked.

The aim of the Strategy projects is therefore to understand and quantify hydrogeological regimes, including aspects of surface and groundwater, within catchments that have been grouped together into sensible investigation areas, from the perspective of water resources.

The Strategy divides the Anglian region into 4 aquifer basins (Figure 1.1):

The East Anglican Chalk Basin
The Lincolnshire Limestone
The Woburn Sands
The Lincolnshire Chalk/Spilsby Sandstone.

The largest of these basins (the East Anglia Chalk) is subdivided into several Groundwater Resource Investigation Areas (see Figure 1.1). These sub-units are set up so that, as far as is hydrogeologically reasonable, they coincide with Local Environment Agency Plan (LEAP) areas. There are two LEAP documents relating to the specific area of interest: the North Norfolk LEAP and the Broadland Rivers LEAP. The proposed study area for water resource investigations, the Yare and North Norfolk Area, incorporates the majority of these two LEAP areas, with the exceptions of the catchments of the Hun and the Waveney. Both of these catchments will be included in future studies.

The Yare & North Norfolk Project is one of the first two strategy projects to be implemented. This early implementation is in recognition of the conflicting demands on water resources in the area, arising from agricultural, public water supply, environmental and conservation interests. In particular, the area includes internationally important groupings of wetland sites, and the Norfolk Broads has conservation status equivalent to a National Park.

1.2 Structure of Strategy Projects and Approach to Seeking Approval

The Strategy projects are divided into 5 stages following Scoping Study and PID preparation: This report is the Scoping Study for the Yare & North Norfolk Groundwater Investigation and Modelling Project and has been prepared in parallel with a PID, presenting a business case for the overall project and seeking approval to proceed with Stage 1. The project stages are:

Stage 1	Development and documentation of conceptual understanding
Stage 2	Further investigation/monitoring
Stage 3	Construction and calibration of distributed model
Stage 4	Predictive simulations/management runs
Stage 5	Project reporting.

At this stage, costs beyond Stage 1 (particularly for Stage 2) are difficult to estimate with confidence. Stage 1 involves collating, analysing and interpretation data. Data coverage in space and time is addressed in the Scoping Study Report, but data quality and possible gaps cannot be rigorously appraised until Stage 1 is well advanced. Consequently, definition of Stage 2 requirements and costs cannot be made until late in Stage 1. Similarly the detailed scope and nature of Stage 3 activities is dependent on the outcome of Stages 1 and 2.

This problem was discussed with PAB during July 1998 and it was agreed that Strategy projects should adopt an approach to project approval similar to that for Research and Development projects. This approach requires that project approval for subsequent stage(s) is sought late in the preceding stage. A flow chart illustrating the proposed approval process for the Strategy projects is shown in Box 1.1.

It is important to note that, at this time, there is a fairly high degree of uncertainty in the estimation of required work and duration of Stage 2. If the project stages were to proceed sequentially, with breaks between them to allow time for the approval process, then this may have a severe effect on the overall project timescale, with the possible consequence of missing important deadlines. It is anticipated that the project can be managed such that there is a degree of overlap between Stages, with aspects of Stage 2 work commencing whilst Stage 1 is still on-going.

1.3 Organisation of this Report

The principal purposes of this Scoping Study report are:

- To provide full supporting documentation for the business case prepared for the Project Appraisal Board (PAB) and presented in the Project Initiation Document (PID);
- To identify the principal water resource issues and conflicts in the study area, which the groundwater investigations and modelling should address;
- To identify possible options for undertaking the Yare & North Norfolk Project;
- To provide a record of data availability and a Project Brief for Stage 1 of the groundwater investigations and modelling.

The Scoping Study for the area was based on consultation (both internal to the Environment Agency and external with stakeholder organisations) and desk study, to synthesise the issues and options appropriate for the groundwater investigations and modelling of the area. The work programme is defined in the Entec proposal to the Agency (15770N002, 4 March 1999) which was prepared in response to the 'General Project Brief for Scoping Studies' (Environment Agency, February, 1999) and the 'Project Specific Scoping Phase Brief' for the area (also Environment Agency, February 1999). The Scoping Study Report is organised to comply with the requirements of Task 10 of the Project Brief.

A brief summary of the hydrogeological understanding of the area, based largely on information from previous studies, is given in Section 2. The consultation process is described in Section 3. The issues which were identified during the consultation, and generally during the course of the Scoping Study are identified in Section 4.

The hydrogeological data and information available for the project area is summarised in Section 5 (supported by a more detailed documentation of the data in Appendices A and B). Section 6 outlines the range of outcomes for the project as a whole, and identifies the potential options within each stage of the project. Section 6 also provides an appraisal of the benefits and risks associated with specific options, and identifies the approach to be taken to manage the risks.

Section 7 provides more detail on the range of options for Stage 1 of the project, and Section 8 identifies the preferred option for Stage 1. This is the preferred option for which approval is to be sought in the PID that has been prepared in conjunction with this Scoping Study Report.

Section 9 goes on to discuss, in more general terms, the options, costs and benefits for the later stages of the project, Stages 2 to 5. A summary and recommendations of the Scoping Study are then provided in Section10.

Summaries of each of the external (stakeholder) consultations are given in Appendix C.

Box 1.1 Flow Chart Showing Strategy Project Stages and Approvals

Form A

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SCOPING STUDY
Identify Technical and Managerial Issues
Identify Data and Information Available

Identify Options and Costs for Stage 1
Identify Preferred Course of Action/Plan of Work for Stage 1

Identify Options and Costs for Stages 2-5
Identify Potential Outcomes and Costs for Whole Project

Prepare Business Case for Whole Project
Evaluate Benefits of Whole Project
Prepare Business Case for Whole Project

Prepare PID for Stage 1
Insert Business Case for Whole Project
Seek Approval for Stage 1

↓

STAGE 1: DEVELOPMENT AND DOCUMENTATION OF CONCEPTUAL UNDERSTANDING
Collect Data
Analyse Data
Interpret Data
Develop and Document Conceptual Understanding
Identify Preferred Course of Action/Plan of Work for Stage 2

Update and Refine Business Case
Review Potential Outcomes and Costs for Whole Project
Review Benefits of Whole Project
Update and Refine Business Case

Prepare PID for Stage 2
Insert Business Case
Seek Approval for Stage 2

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STAGE 2: FIELD INVESTIGATION/MONITORING
Enhance Existing Monitoring
Set Up New Monitoring Installations
Carry Out Field Investigations
Identify Preferred Course of Action/Plan of Work for Stages 3, 4 and 5

Update and Refine Business Case
Review Potential Outcomes and Costs for Whole Project
Review Benefits of Whole Project
Update and Refine Business Case

Prepare PID for Stages 3, 4 and 5
Insert Business Case
Seek Approval for Stages 3, 4 and 5

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STAGE 3: CONSTRUCTION AND CALIBRATION OF DISTRIBUTED MODEL

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STAGE 4: PREDICTIVE SIMULATIONS/MANAGEMENT RUNS

↓

STAGE 5: PROJECT REPORTING

2. Description of the Yare & North Norfolk Groundwater Resource Investigation Area and Current Understanding of the Hydrogeological System

2.1 Introduction

This section defines the boundaries to the Yare & North Norfolk Groundwater Resource Investigation Area. This area extends beyond the LEAP areas, which are based on the surface water catchments. It is important to set the boundary for the collation of data for analysis within this project to be larger in the first instance because the groundwater catchment area could extend beyond the surface water catchment area.

This section goes on to present a brief outline understanding of the groundwater and surface water system based on current data and information from previous studies. This provides background to the explanation of technical issues presented in Section 4. This section concludes with a current statement of the water resources of the area, and a summary of conservation interests throughout the region.

2.2 Location

The project area is shown on Figure 2.1. A 'buffer zone' around the boundary formed by the hydrometric areas has been included within the project area, primarily because groundwater catchments may not be coincident with surface water catchments. It is important to consider hydrogeological information from this 'buffer zone' in order to set the final boundaries of the study area. This information will also prove useful when adjacent areas are studied later on within the Strategy programme. The width of this buffer zone as shown is indicative only: in practice, the 'nearest' data outside the project area will be considered.

The topography of the area is quite subdued, with a maximum elevation of 101 m on the Cromer Ridge, which forms a topographic (but not necessarily hydrogeological) divide between the North Norfolk and Broadland areas. Large areas of the lower parts of the Broadland river catchments lie below sea level. The North Norfolk rivers discharge into and through extensive coastal marshes.

2.3 Geology

Figure 2.2 shows the geology and hydrogeology of the study area in outline (taken from IGS, 1976). Chalk underlies the whole area, dipping eastwards and north eastwards, and forms the main aquifer. The Chalk reaches a thickness of several hundred metres. The upper surface of the Chalk reaches a maximum elevation of 95 m about 10 km from its western margin, declining to 154 m below sea level at the coast at Great Yarmouth (Boar et al, 1994).

In the east of the area the Chalk is overlain by the Lower London Tertiary clays, which attain a maximum thickness of 95 m near the coast, but thin westwards, pinching out approximately 16 km from the present coastline.

A complex succession of Quaternary deposits overlie the Chalk and the Lower London Tertiaries. The marine sands of the Crag occur in the east, reaching a maximum thickness of almost 40 m, and locally form an important aquifer. Near the coast, the Crag is separated from the Chalk by the London Clay, but further inland lies directly on top of the Chalk, such that the two may be in hydraulic continuity.

Both the Crag and the Chalk are overlain by glacial sands and tills laid down in several distinct episodes. These tills are quite heterogeneous and there are also distinct differences between them (Hiscock, 1991). The Lowestoft Till present in the west and central areas mainly comprises chalky boulder clay, which becomes increasingly chalky towards the North Norfolk coast, producing a 'marly drift' variant. The North Sea Drift (including the Norwich Brickearth and Cromer Tills) is more predominant in the east and north east of the area, and comprises a greater proportion of sandy material.

The erosional and depositional history of the area has resulted in the occurrence of a number of 'tunnel valleys' within the Chalk. These are, often deep, erosional channels in the surface of the Chalk that have become filled with Quaternary deposits. Evidence for the presence of these tunnel valleys cannot always be seen at the surface. Many, but by no means all, tunnel valleys are associated with present day river valleys.

In several river valleys, notably the North Norfolk rivers and the Wensum close to Norwich, outcrops of Chalk occur, and there are also locally extensive areas where glacial sands and gravel at surface directly overlie the Chalk.

2.4 Hydrology and Drainage

The North Norfolk area is drained by a series of small rivers; the Burn, Glaven, Stiffkey and Mun, which discharge via extensive coastal marshes into the North Sea. The southern part of the area is drained by two main river systems, the Bure and the Wensum-Yare, both of which discharge to the sea at Great Yarmouth (see Figure 2.3).

Rainfall in the area is low, average annual precipitation ranging from around 580-700 mm across the area: highest rainfall occurs on the Cromer-Holt Ridge and the upper reaches of the Wensum, whilst lowest values are recorded on the North Norfolk Coast. Potential evaporation may not vary greatly throughout the area, at around 510-520 mm/a (East Suffolk and Norfolk River Authority, 1971), but actual evaporation will vary considerably as a result of different land uses. Residual rainfall, also presented by East Suffolk and Norfolk River Authority, is estimated in the range 150-200 mm/a across most of the area, but varying from over 240 mm/a to less than 100 mm/a on the North Norfolk coast.

The complexity of drainage and hydraulic processes in the near surface deposits is further complicated by the long history of human intervention for navigation, drainage, irrigation and conservation purposes, and by historic changes in land use and agricultural practice, which include:

- development of Broads by peat digging from the twelfth century onwards;
- river embankment and marsh drainage commencing at least as early as the sixteenth century;
- development of Drainage Commissions in the early nineteenth century, and their subsequent development into Drainage Authorities and Internal Drainage Boards;
- The growth of public water supply abstraction from the 1950s onwards;
- The widespread installation and upgrading of land drains in the 1960s and 1970s;
- Increased abstraction of water for irrigation. Irrigation demand expanded dramatically around 1976 and increased rapidly with intensification of agricultural practices through the 1980's and 90's;
- Conversion of grazing land to arable farming, particularly in the early 1970s;
- establishment of the Broads ESA in 1987, (and extension of the ESA in 1992) and subsequent reduction or reversal in the rate of conversion of grazing lands to arable;
- Broadlands Flood Alleviation Strategy (BFAS) programme of flood defence works;
- Recent activities to support wetland and river flow conservation and locally to promote enhancement of water supported habitats via Water Level Management Plans etc.

Many of the current drainage activities are the responsibility of Internal Drainage Boards (IDBs). Most of the IDBs in the area are managed under the auspices of the King's Lynn Consortium of Internal Drainage Boards (KLCIDB), although there are eight other IDBs in the lower reaches of the Yare.

Useful summaries of changes in land use that have affected the hydrology of the project area are to be found in Boar et al (1994), George (1992), Parmenter (1995) and Driscoll (1984, 1986).

2.5 Basic Conceptual Hydrogeological Understanding

Recharge to groundwater throughout the area is controlled by the distribution of Quaternary deposits at the surface. Where the Chalk outcrops. recharge by direct infiltration can occur, but elsewhere recharge is heavily controlled by the distribution and heterogeneity of the Quaternary deposits. Where sands and gravels occur at surface (predominantly along river valleys and in the east of the area), then rainfall can infiltrate easily, but where till deposits are present, then direct infiltration will be reduced. Runoff-recharge is expected to be concentrated along till margins, but George (1998) presents evidence from isotope studies that demonstrates that there can also be significant recharge through the Chalky Boulder Clay. Sand-rich layers within the tills can act as pathways along which groundwater can travel and provide recharge to the Chalk.

In the lower reaches of the catchments, groundwater levels are often below river level, and there may be leakage of water from the rivers to groundwater.

Groundwater levels reach a maximum of around 60 m AOD in the upper parts of the catchments. Annual fluctuations are typically 3-5 m in the interfluvial areas, although fluctuations of 9 m have been observed in exceptional years (East Suffolk and Norfolk River Authority, 1971), reducing to less than 1 m in the valleys (Hiscock, 1991). The regional movement of groundwater takes place from the high ground forming the interfluves towards and then along the river valleys. In the lower parts of the Bure, Ant and Thurne catchments, the Chalk is confined beneath the London Clay and groundwater heads are very close to sea level. There is no natural discharge from this confined part of the aquifer, and groundwater flow in the Chalk beneath the London Clay is virtually absent.

Artesian conditions have been observed in the upper Bure catchment in areas of thick Lowestoft Till.

Groundwater movement through the Chalk takes place preferentially within a fissured zone at the top of the formation, which occurs largely irrespective of stratigraphy. Hiscock (1991) suggests that the majority of fissuring in interfluve areas is found in the top 10 m of Chalk, whilst in valley zones this average depth increases to around 20 m. Locally there are exceptions to this.

The hydraulic properties of the Chalk vary considerably. In general, highest transmissivities are found in valleys, with decreasing permeability towards the interfluves, although Middleton (1996) was unable to demonstrate a statistically significant relationship. Toynton (1983) has demonstrated the sometimes very high degree of hydraulic anisotropy within the Chalk.

Groundwater flow within the Crag is intergranular, and there is less variation in hydraulic properties. Holman et al (1999) however, have identified the presence of laterally persistent clay horizons within the Crag in the Thurne catchment, which restrict the vertical hydraulic conductivity of the formation taken as a whole.

The presence of buried or tunnel valleys can affect the pattern of groundwater flow in different ways. Buried channels that are filled with low permeability Lowestoft Till will act as barriers to lateral groundwater flow whilst those filled with higher permeability North Sea Drift may form preferential pathways for flow, and also provide additional groundwater storage. Even where buried valleys form barriers to flow, it is possible that the hydraulic properties of the Chalk may be enhanced parallel to them, although there are conflicting views and evidence regarding this (Hiscock, 1991).

Discharge of groundwater takes place to rivers, to coastal marshes and mudflats, to offshore springs (in North Norfolk) and to numerous wetlands throughout the area. Each of these processes is locally complex, and there are differences in behaviour throughout the region. Groundwater flow to wetlands may either be laterally via spring flows, or by vertical seepage through the base of the wetland, or a combination of these. Evidence for the provenance of groundwater within wetlands can often be gained from hydrochemical and ecological studies.

The 'natural' hydrogeological system is shown schematically on Figure 2.4. This natural system has been significantly modified by the activities of man, specifically with respect to land drainage. A network of interconnected drains, managed mainly by Internal Drainage Boards, maintain water levels below ground level over extensive parts of the project area, such that the land may be utilised for agriculture. Transfer of water between these drains and the natural river channels takes place via a number of pumping stations and sluices.

The lowering of water levels caused by maintenance of this drainage network is responsible for local modifications to the pattern of groundwater flow. Holman *et al* (in press) present a water balance for the Thurne catchment that includes quantification of abstractions from the drainage system, which is seen to be (in quantitative terms) the second most important 'outflow' process after evapotranspiration. This work also quantifies the degree of saline groundwater intrusion in the Thurne catchment.

2.6 Water Resources

The demands on the water resources of the study area have been summarised in a number of key documents, 'First Survey of Water Resources and Demands' (East Suffolk and Norfolk River Authority, 1971), 'Water Resources in Anglia' (NRA, 1994), the Strategy (February 1998), the North Norfolk LEAP (1997) and the Broadlands Rivers Draft LEAP (March 1999). Table 2.1, based on information presented in these reports, summarises some of the key statistics relevant to the water resources of the area. The groundwater balance figures are as calculated by the NRA (1994) and presented in the LEAP documents.

The method of calculating the 'available resource' figures presented on Table 2.1 needs further explanation, since the Agency recognise the limitations of catchment wide balance calculations, and have stated that the method is '*a grossly simplified "water accountancy" procedure. The availability of water at any one spot or from any one groundwater unit will always be subject to local evaluation*'.

The method is an update of that established by the East Suffolk and Norfolk River Authority (1971) in their Section 14 report, and is described fully by the NRA (1994). The 'gross resource' is the long term average recharge (for the period 1961-1990 where possible), assessed by catchment-wide analysis of river flow, effective rainfall, catchment areas and geology. This figure is then reduced by an empirical factor (20% for Chalk catchments) to '*reflect the inadequacy of aquifer storage to fully even out the year to year variations in recharge*'. These empirical factors are '*based on experience, and may be subject to review*'.

The 'environmental allocation' is primarily the minimum required river flow, establishment of which would '*ideally ... involve detailed ecological studies, but no satisfactory objective method is yet available. In its absence current practice is to use the natural 95% flow*'. An additional environmental allocation is made to prevent saline intrusion in some catchments.

The environmental allocation is then modified to make allowance for treated sewage effluents and river abstractions to derive the 'groundwater allocation to rivers'. Finally the 'available resource' is calculated as the effective resource less the sum of the groundwater allocation to rivers and total groundwater abstractions.

Table 2.1 Yare & North Norfolk Area - Summary Statistics

Groundwater Balances (tcmd)

	Gross Resource (A)	Effective Resource (B=80% A)	Full Environ-mental Allocation (C)	Ground-water Allocation to Rivers (D)	Licensed Ground-water Abstraction (E)	Balance ('Available Resource') (F=B-(D+E))
Chalk						
Hun & Coast (34/01)	16.7	13.4	5.6	5.8	0.2	7.3
Burn (34/02)	24.6	19.7	11.3	10.6	2.4	6.7
Stiffkey (34/03)	34.8	27.8	14.7	14.9	10.8	2.1
Glaven (34/04)	37.8	30.2	24.4	24.0	7.4	-1.1
Mun (34/05)	21.1	16.9	10.0	10.0	6.8	0.1
Bure (34/06)	135.6	108.5	101.2	99.5	14.9	-5.9
Spixworth Beck (34/07)	16.7	13.4	9.3	8.9	3.5	1.0
Ant (34/08)	21.0	16.8	14.7	14.0	4.3	-1.5
Bure/Ant (34/09)	33.7	27.0	22.3	18.4	14.4	-5.9
Wensum (34/11)	219.6	175.7	90.7	76.3	38.3	61.1
Tud (34/12)	15.7	12.6	5.2	4.0	1.5	7.0
Yare (34/13)	63.4	50.7	17.7	13.1	23.7	13.9
Tas (34/14)	37.7	30.2	13.8	11.1	11.2	7.9
Tidal Yare (34/15a)	38.4	30.7	24.8	26.2	25.2	-20.7
Crag						
Thurne (34/10a)	14.8	11.8	6.6	5.8	1.1	5.0
Ormesby/Filsby (34/10b)	13.7	11.0	5.9	6.2	6.0	-1.3
Bure (34/10c)	9.0	7.2	3.1	2.6	2.0	2.6
Tidal Yare (34/15b)	3.3	2.6	3.3	3.2	0.1	-0.6

River Channel	
Length of Statutory Main River	~ 435 km fluvial, 243 km tidal
Abstractions	
Total number of licences	1519 (1297 groundwater only, 142 surface water only, 79 'mixed' licences)
Public Water Supply Abstraction Sites	83 (76 Groundwater/ 7 Surface Water, covered by 26 multi-source licences)
Spray Irrigation	456 licences (of which 203 > 50 tcma)
Industrial	60 (of which 20 > 50 tcma)
	there are also locally significant abstractions for sand and gravel washing
Discharges	
Sewage Treatment Works (>10 m3/d)	87 (AWS), 34 (private)
Trade Effluent	36
Open Landfills	11 (plus many historic closed sites)
Designated Conservation Sites	
Sites of Special Scientific Interest (SSSIs)	107
National Nature Reserves	12
Ramsar Sites	8
Special Protection Areas (SPAs)	4
Candidate Special Areas of Conservation (cSACs)	4
Habitats Directive Sites	32

Table 2.1 shows that the currently calculated available resources (the 'balance') vary widely across the study area: some catchments are in apparent surplus (notably the Wensum), whereas others are in deficit. Understanding and quantification of the processes controlling the available resource are essential to ensure equitable resource distribution and continued sustainable development in the area.

The table above also highlights the intense conservation interests in the study area, and the widespread use of water for both agricultural and public supply purposes. Such interests are not always complementary and are occasionally conflicting. The consultation process, which formed a major part of this scoping study, was an attempt to identify the key issues from the perspectives of the various stakeholders, to advise them of the proposed start of the groundwater investigations and modelling for the area and to establish their interest in continued involvement in the work.

2.7 Conservation Interest

Table 2.1 has noted the number of conservation sites of various designations within the Project Area. These are shown on Figure 2.5: note that some sites have more than one designation. In addition to these sites there are numerous County Wildlife Sites.

The north Norfolk coastal area constitutes one of the largest expanses of undeveloped coastal habitat of its type in Europe. The habitats consist primarily of intertidal sands and muds, saltmarshes, shingle banks and sand dunes, with extensive areas of brackish lagoons, reedbeds and grazing marshes.

Similarly, the Broadland Area is considered one of Europe's finest wetlands and is of international significance: its importance lies in the size of the area and the diverse range of habitats and associated species. The Norfolk Broads are the only wetlands in the UK to have status equivalent to a National Park.

It is noteworthy that virtually all the sites of conservation interest in the area are water dependent: developing a thorough understanding of how the groundwater and surface water system interacts and maintains these sites is therefore paramount in ensuring proper future conservation management in the project area.

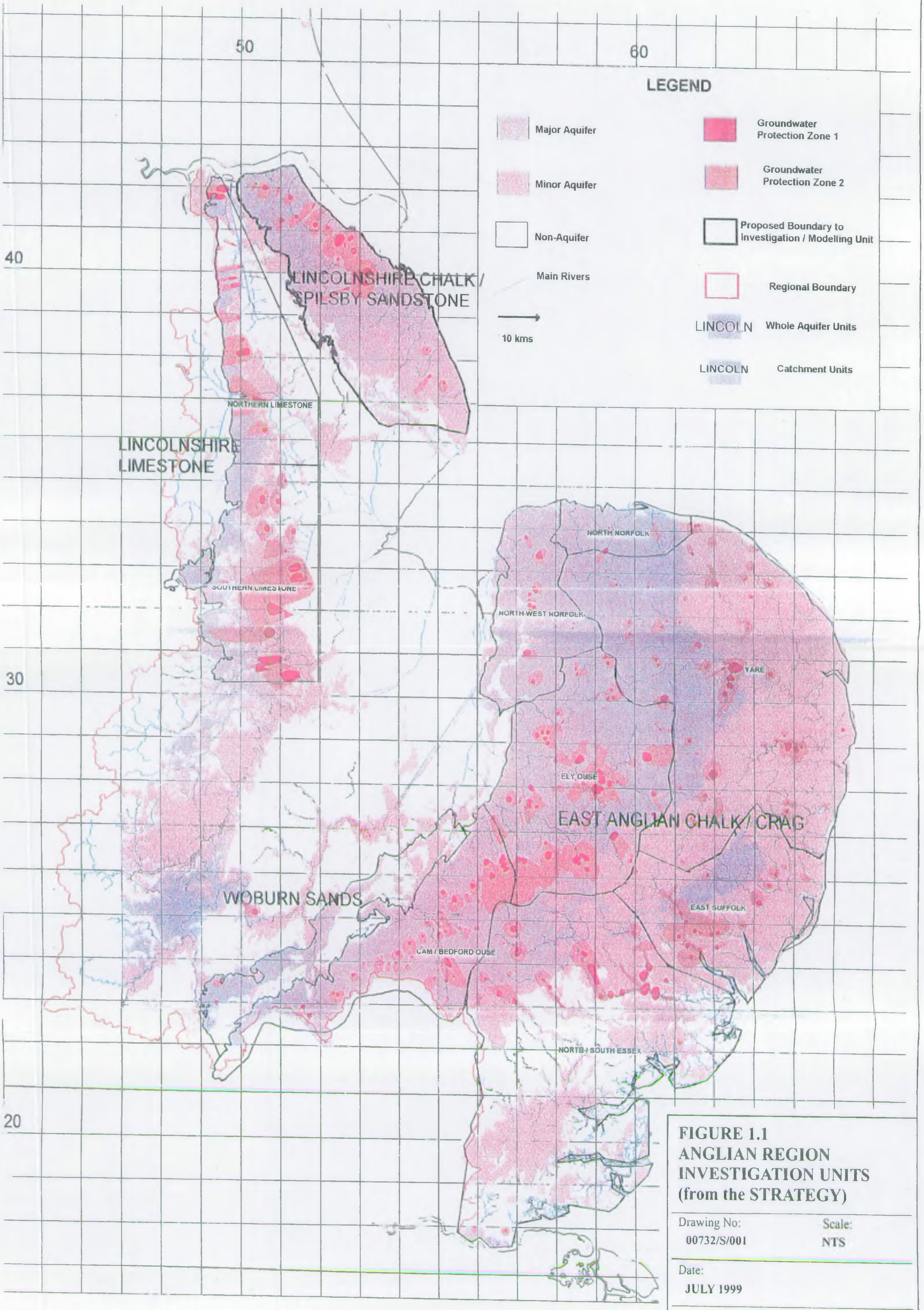

FIGURE 1.1
ANGLIAN REGION
INVESTIGATION UNITS
(from the STRATEGY)

Drawing No: 00732/S/001

Scale: NTS

Date: JULY 1999

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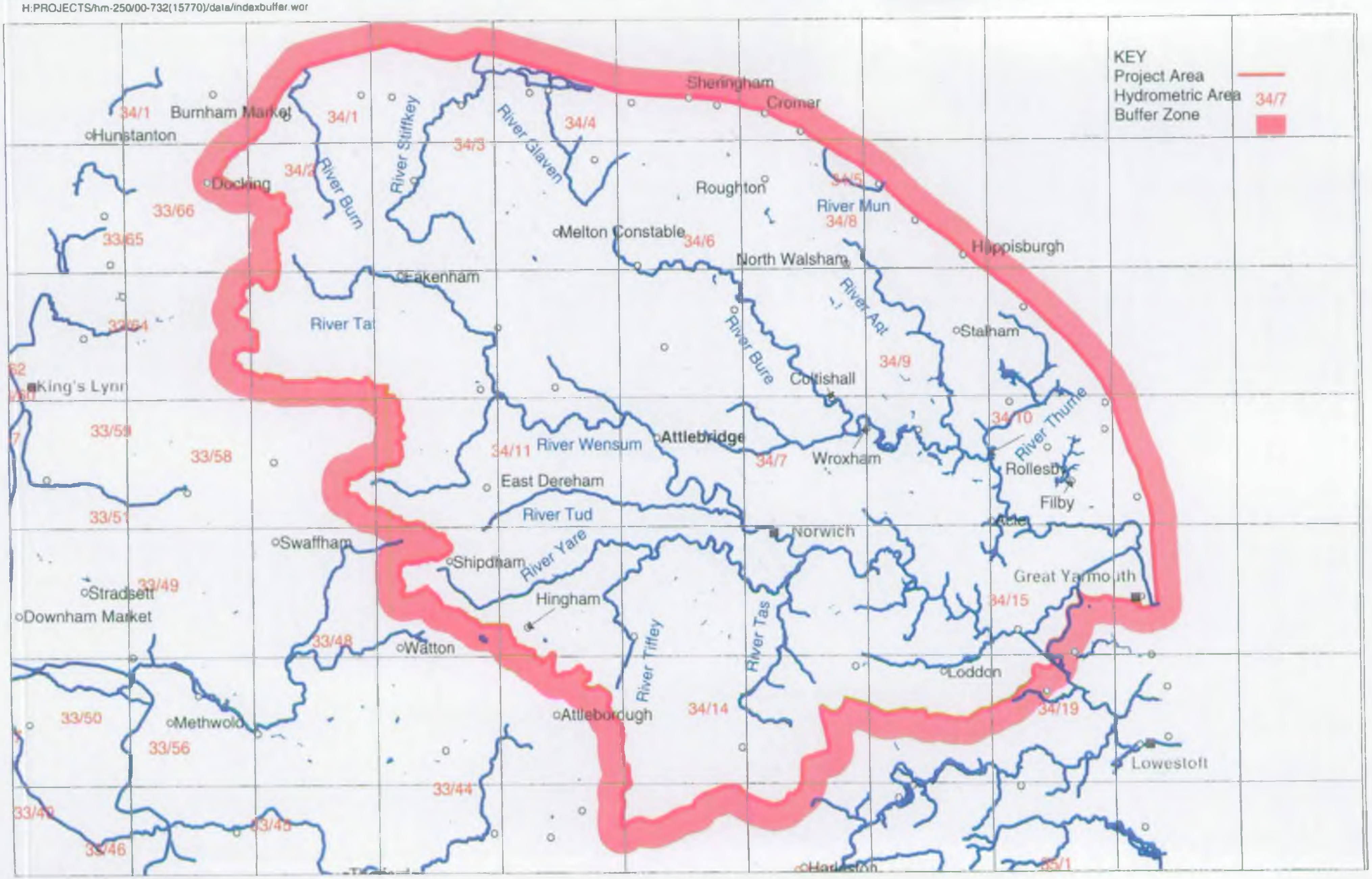

FIGURE 2.1 **YARE & NORTH NORFOLK: PROJECT AREA SHOWING MAIN RIVERS AND HYDROMETRIC AREAS**

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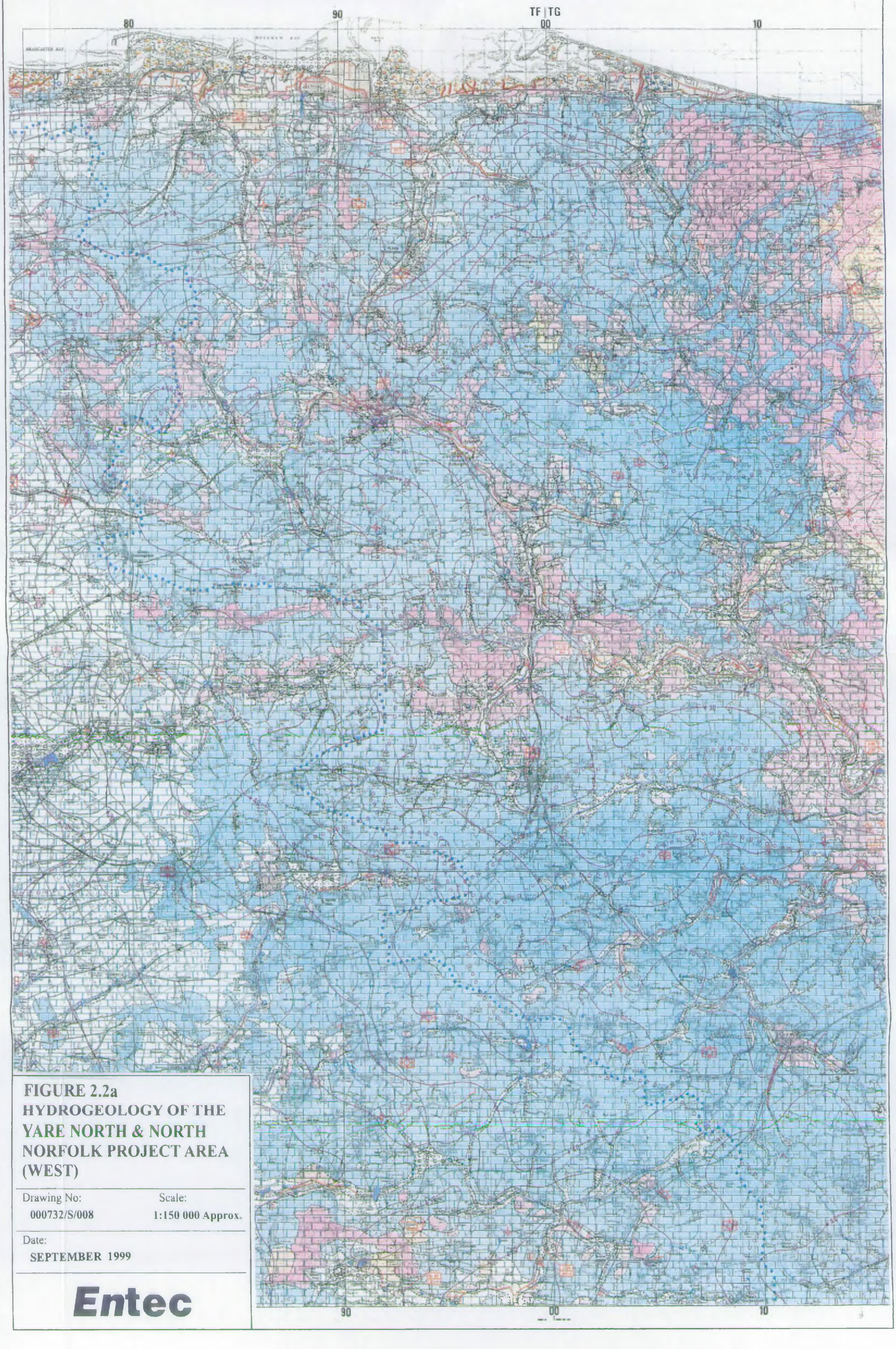

FIGURE 2.2a
HYDROGEOLOGY OF THE YARE NORTH & NORTH NORFOLK PROJECT AREA (WEST)

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Date: SEPTEMBER 1999	

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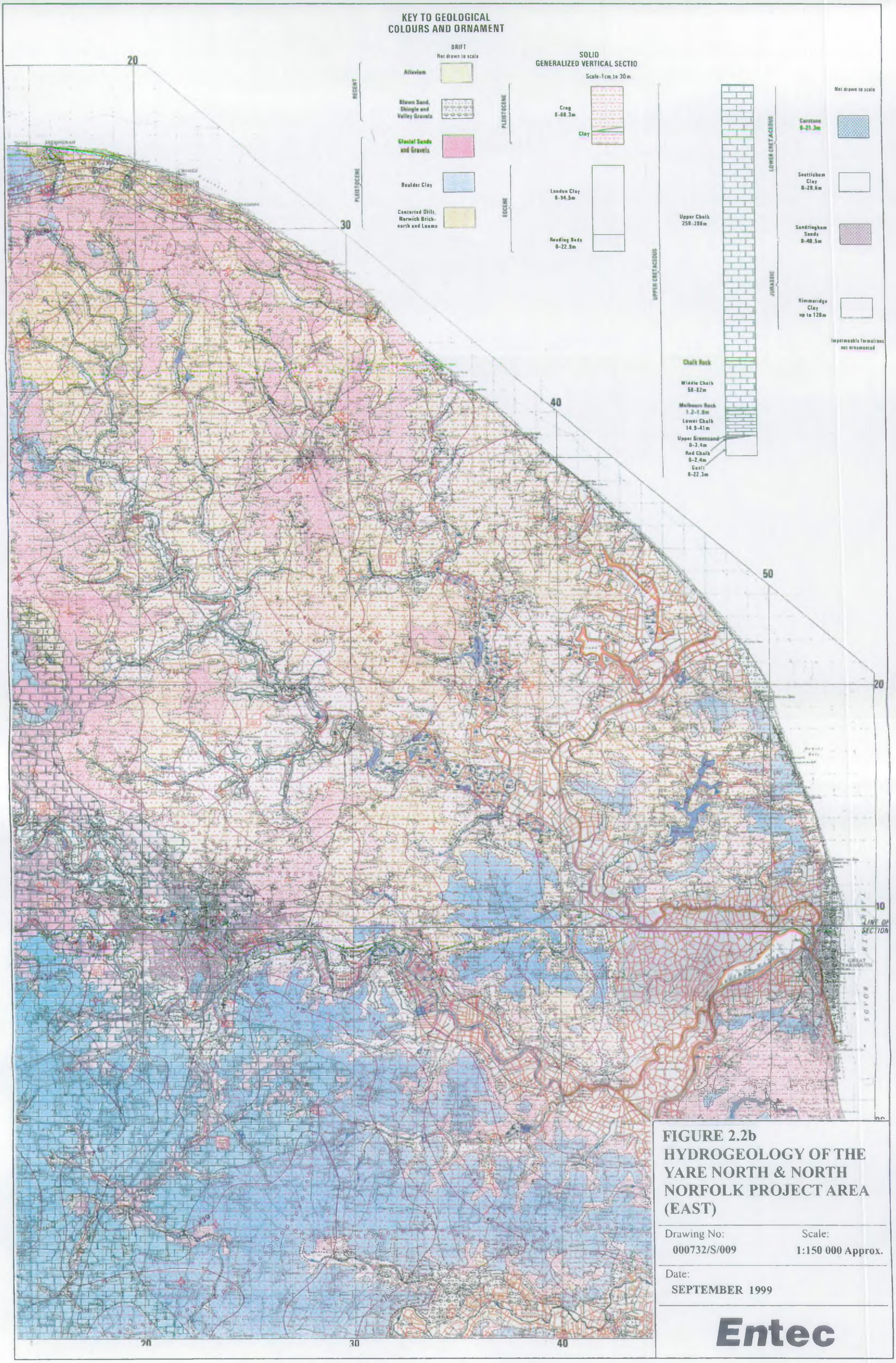

FIGURE 2.2b HYDROGEOLOGY OF THE YARE NORTH & NORTH NORFOLK PROJECT AREA (EAST)

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Date:
SEPTEMBER 1999

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FIGURE 2.3 YARE & NORTH NORFOLK: PROJECT AREA SHOWING MAIN RIVERS AND IDB DRAINS

Drawing No: **00732.S026** Date: **SEPTEMBER 1999** Scale: **AS SHOWN**

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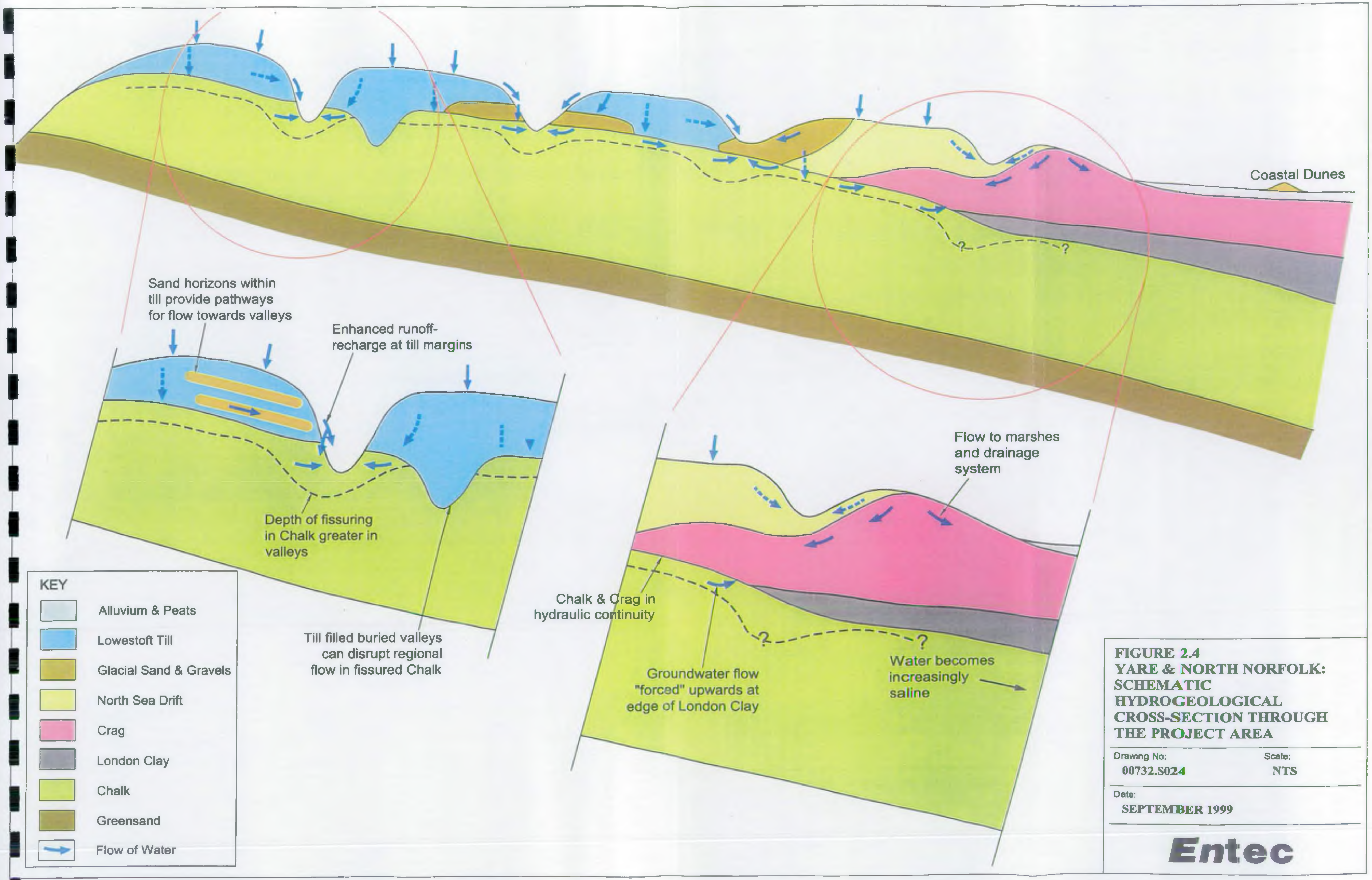

FIGURE 2.4
YARE & NORTH NORFOLK: SCHEMATIC HYDROGEOLOGICAL CROSS-SECTION THROUGH THE PROJECT AREA

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Scale: **NTS**

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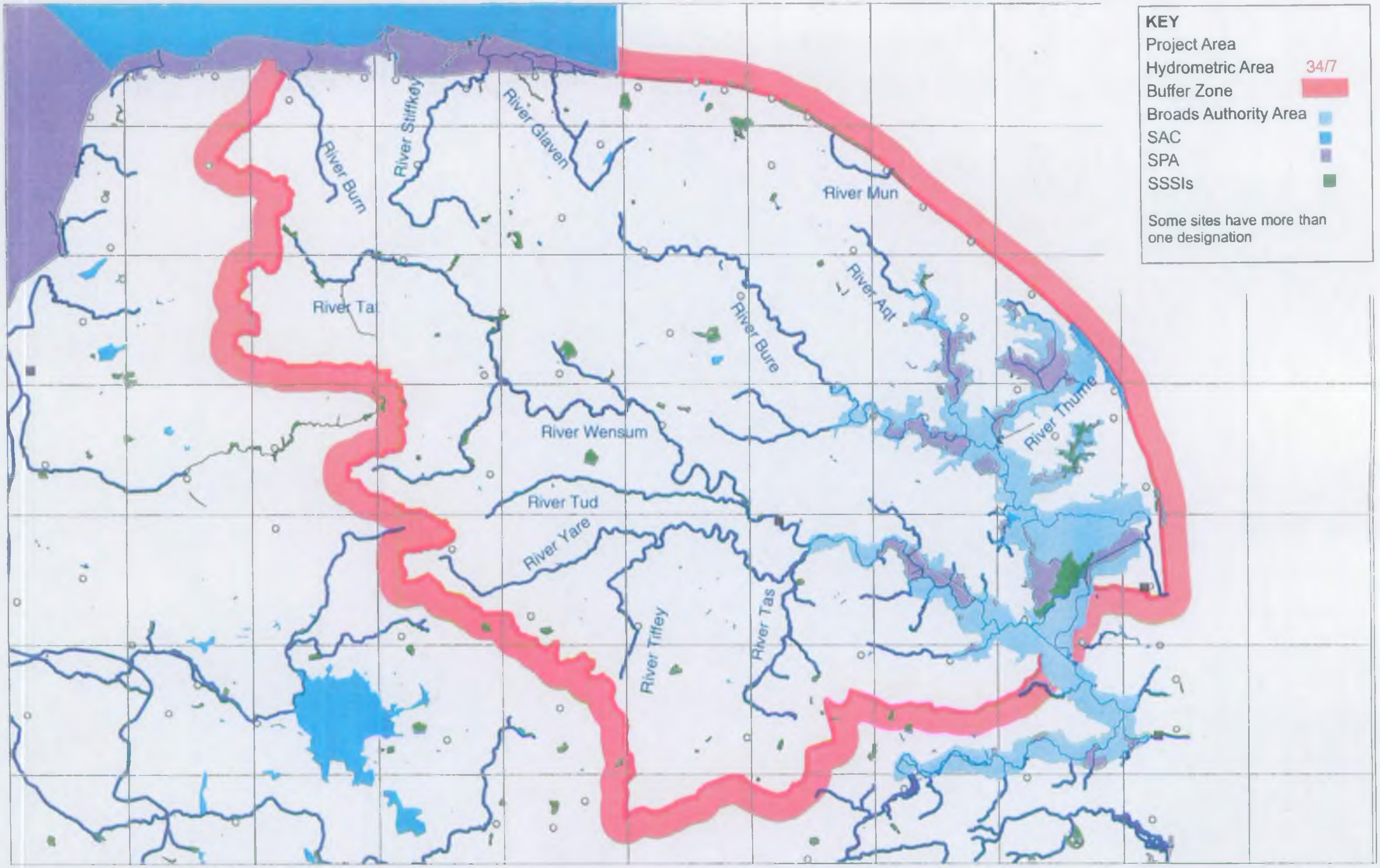

FIGURE 2.5 YARE & NORTH NORFOLK: CONSERVATION AREAS

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3. Consultation with Interested Parties

3.1 Introduction

This section briefly describes the consultation that took place with certain interested parties during the course of the Scoping Study. The consultation process was an attempt to identify the key issues from the perspectives of key staff within the Agency and those external organisations with a significant stake in the water resources of the Yare & North Norfolk area, to advise them of the proposed start of the groundwater investigations and modelling for the area and to establish their interest in continued involvement in the work. Additionally, the consultation attempted to identify the availability extent and condition of relevant data sources, within and external to the Agency.

This section of the report summarises the outcome of this consultation. A more detailed consideration of the issues is reserved for the following section. A record of each consultation meeting is given in Appendix C, which includes dates, names etc and any subsequent correspondence.

Table 3.1, based on information presented in these reports, summarises the key organisations that can be regarded as stakeholders in the water resources of the area.

3.2 Internal Consultation

Within the Environment Agency the regulation and control of the water resources and environment of the study area is principally the responsibility of the Area Office at Ipswich and the sub-Area office at Norwich. Consultation was therefore mainly with key staff covering the range of Agency functions at these offices:

- Water Resources:
    - hydrogeology;
    - water resource planning;
    - hydrometry;
    - licensing;
- Waste Management;
- Water Quality;
- Flood Defence;
- Fisheries, Environment and Recreation.

Further consultation took place with relevant regional staff at Peterborough.

Table 3.1 **Yare & North Norfolk Area, Water Resources, Local Government and Conservation Organisation**

Total Land Area: 2780 km^2

Environment Agency Organisation: Anglian Region (Eastern Area): Area office at Ipswich and sub-Area Office at Norwich

County Council: Norfolk

Borough Councils:

King's Lynn and West Norfolk
Great Yarmouth

City Council:

Norwich

District Councils:

Breckland
Broadland
North Norfolk
South Norfolk

Conservation Organisations:

English Nature (Norfolk)
Norfolk County Wildlife Trusts
Royal Society for the Protection of Birds (RSPB)

National Park Equivalent Status: Broads Authority

Navigation Authorities:

Broads Authority
Environment Agency
Great Yarmouth Port Authority

Flood Defence Committee:

Norfolk and Suffolk Local Flood Defence Committee

Water Utility Companies:

Anglian Water Services Limited
Essex and Suffolk Water Company

In addition there are a number of areas which receive no mains supply and rely on private supply boreholes

Organisations representing other water users:

National Farmers Union
Country Landowners Association

Internal Drainage Boards:

King's Lynn Consortium:

- North Norfolk
- River Wensum
- Smallburgh
- Middle Bure
- Repps Martham & Thurne
- Happisburgh to Winterton
- Lower Bure, Halvergate, Fleet & Acle Marshes
- Muckfleet & South Flegg
- Upper Bure
- Upper Yare & Tas

Lower Yare 1st, 2nd, 3rd, 4th
Limpenhoe & Reedham
Langley Chadgrave & Toft Monks
Burgh Castle & District

The over-riding impression gained from the consultation exercise was that there is currently an inadequate understanding of the groundwater/surface water system on a regional scale. Many individuals within the Agency have great in-depth knowledge of particular sites or particular processes/operations, but there has been little integration to understand the **interaction** between processes, and how they vary temporally and spatially throughout the area. There is a need to take a 'holistic' approach to pull together the information from various specialist disciplines and develop a consistent, scientifically defensible picture of how the system behaves. This integrated view will be necessary to cope with the requirements imposed by the Habitats Directive review, and by increased demands for abstraction licence determination arising from the increasing use of time-limited licences.

3.3 External Consultation

A detailed list of external consultees is given in Appendix C: these represent the principal stakeholder organisations in the area covering irrigation and drainage, public water supply, development planning and conservation interests. These consultations represented a logical continuation of the consultation process for the LEAP. It is likely that the Area Environmental Group (AEG), and possibly also the Local Flood Defence Committee (LFDC), will provide a valuable means of disseminating general information on the progress of these investigations.

The consultees can be grouped into four categories: water users, conservation groups, data holders and those with rational vested interests (e.g. District Councils), and their interests can represent conflicting demands on water resources and the water environment. Water undertakers have a duty to supply water to the population of the area, achieved through significant groundwater and surface water abstractions, whilst the agricultural community also use large amounts of water for irrigation purposes. The Internal Drainage Boards are also responsible for the pumping and transfer of large quantities of water.

The recognition of environmental water needs to maintain biodiversity in both nationally and internationally important groundwater supported habitats and through maintaining surface water flows to meet in river needs is the principal constraint on abstraction growth. Conservation of the unique nature of features such as the Broads and associated wetlands, the marshes of the North Norfolk Coast and the valley fens of the upper reaches of the rivers is a statutory obligation. Organisations at the forefront of this conservation activity include the Broads Authority, English Nature, the County Councils (through the County Wildlife Trusts) and the Royal Society for the Protection of Birds.

Strong support for the study proposals and a desire to be kept informed of progress was expressed by all of the organisations consulted.

In addition to stakeholders as outlined above, external consultations also covered other potential data holders such as the British Geological Survey, the University of East Anglia and the Institute of Hydrology. Each of these organisations has confirmed their willingness to make data available for the Study. The costs related to obtaining these data are discussed in Section 6.

3.4 Summary

The consultation process identified a clear recognition of the need for rigorous investigation and quantitative understanding of the water resources of the study area and an apparent willingness to co-operate in the development of this work. The organisation of this co-operation and the regular dissemination of information necessary to ensure that agreement is maintained throughout the investigations are addressed in Section 7.

4. Identification of Water Resources and Other Related Issues

4.1 Introduction: Generic Issues

This section identifies the water resources issues, together with related water quality, conservation and management issues within the Yare & North Norfolk Area. Many of the issues have been previously recorded in LEAP documents, but further specific issues arising from the consultation process are also identified.

An indication is given of the expected support that the Yare & North Norfolk Project would give to assist in resolution of the issues identified.

Table 2.1 has shown that the currently estimated availability of water resources is very variable across the study area, and that there are potential conflicts between the needs of agriculture, public supply and conservation and amenity requirements.

The abstraction licensing policy is currently undergoing major review (see Section 4.2) with possible far-reaching effects on water use. Future demand for spray irrigation across the whole of Anglian Region is estimated to rise by up to 50% over the next 25 years. Demand for public use will increase as new housing developments take place, although in terms of water abstracted this may be partly offset by improvements in supply efficiency by reducing leakage etc.

The current situation is that the best advice that the Agency can give on issues surrounding licensed abstractions contains gaps in knowledge and understanding. This shortfall applies both on the local and regional scale.

There is increasing concern amongst the various conservation bodies that a deterioration in the quality of many conservation sites is occurring and that this is at least in part due to an incomplete understanding of water movement.

Successful management of the water resources of the area must include the ability to predict, with a reasonable degree of certainty what will happen in the future in response to changed circumstances that might arise from climate change, differences in land use, sea level change, alternative abstraction management strategies etc.

Risks to water quality within the region arise mainly from agricultural practices which generate 'diffuse pollution' that ultimately leads to nutrient enrichment and increased sedimentation in the Broad, and from saline intrusion (via groundwater) and incursion (via surface water surges and inundations). There are additional localised risks to water quality arising from industrial activities.

Many of the issues within the area arise from uncertainty in the quantification of available resources and the complexity of the pattern of interaction of rainfall, runoff routing and groundwater recharge. While the understanding and quantification of these complexities may not **increase** resource estimates they should provide a technical framework within which the decisions affecting resource allocation can be reached in a more robust, yet still transparent and defensible, manner.

In following sections the LEAP issues are re-stated, and then the current scientific uncertainties are presented in the context of the inputs (recharge) to and outputs (discharge) from the hydrological system and the framework (geology) through which the water moves. These are followed by a description of more specific or localised issues.

4.2 Regulatory Framework for Abstraction Licensing

Abstraction licensing requirements were first consolidated nationally under the 1963 Water Resources Act and are currently defined by the 1991 Water Resources Act. The 1991 Act also incorporates some of the water quality protection requirements of the 1980 EU Groundwater Directive 80/68/EEC. This legislative framework has recently been comprehensively reviewed. The results of this review are presented in the 1999 Government White Paper 'Taking Water Responsibly' which recognises the obligations imposed by the draft EU Water Framework Directive (Revised, 1998). The government have clearly indicated their intention of introducing new primary legislation on water resources management incorporating the recommendations of 'Taking Water Responsibly' as soon as Parliamentary time permits.

The proposals of 'Taking Water Responsibly' place a regulatory requirement for many new licence or renewal applications to be supported by Environmental Impact Appraisals and require **all** licences to be time limited. (Note that in the Eastern Area of Anglian Region, the majority of the abstraction licences already contain time-limitation clauses). The determination of licence applications will adhere to a published Abstraction Management Strategy and could become an extremely rigorous exercise which may be subject to Appeal. The time limitation can be varied in some circumstances one of which is where the fullest appraisal of likely environmental and economic consequences has been made.

The Abstraction Management Strategy will be reviewed every six years, and will have a fifteen year look ahead. The conceptual understanding and numerical models that will be developed in the implementation of the Strategy for Groundwater Investigations and Modelling will provide the necessary framework and quantitative tool for development and refinement of a defensible Abstraction Management Strategy, and will therefore be complementary to it.

4.3 Issues Identified in LEAPs and Other Documents

The Yare & North Norfolk Project area comprises parts of two LEAP areas, namely North Norfolk and Broadland Rivers. The North Norfolk LEAP Consultation Report was published in June 1996, followed by an Action Plan in March 1997 and a First Annual Review in June 1998. The Broadland Rivers Draft LEAP - Consultation Report was published in March 1999: the finalised version is expected to be published in October 1999.

These LEAPs each identify a wide range of issues relating to the environment in general; some of these issues relate directly to the water environment. An important part of the aims and objectives of the proposed Yare & North Norfolk Project is to provide support for the resolution of some of these issues. These are summarised in Box 4.1.

Box 4.1 LEAP Issues and Support from the Yare & North Norfolk Project

LEAP Issue (Broadland Rivers)		Support from the Yare & North Norfolk Project
1	Impact of drought and long term climate change on river flows and water quality	The project will deliver a distributed model that can be used to make predictions of future changes in groundwater levels and river flows arising from climate change or drought scenarios.
3	There is a perception that existing available water resources may be inadequate to meet present and future demands	The project will deliver updated catchment water balances, increased conceptual understanding of system behaviour and a distributed groundwater model which can be used to assess potential options for future management of water resources throughout the area.
4	There is a perception that actual flows are inadequate to meet in-river needs	Although this project will not attempt to assign in-river needs (in habitat/ecological terms), it will provide a means by which total river flows can be quantified on a distributed basis, i.e. including headwaters and ungauged parts of the catchments, to assess whether these needs are met by particular development scenarios.
5	Adverse impacts on wetlands	Local studies to be implemented as part of this project will investigate the hydro-ecology of wetland sites designated under the Habitats Directive. Conceptual understanding of wetland/groundwater interaction is expected to be significantly increased. The project will provide tools to aid the quantitative assessment of impacts.
14	Nutrient control in Rivers Bure and Ant	The analysis performed within Stage 1, and the distributed model to be delivered in Stage 3, will add to the knowledge of nutrient loading and flows in rivers flowing into the Broads, specifically the Bure and Ant.
15	Minimise pollution risk of both surface and groundwater public water supply sources	The project will deliver a distributed groundwater model which could provide the flow framework for further studies into pollution migration.
16	Impact of new development on the sustainability of the environment	The analysis performed during this project will mean that changes in runoff resulting from increasing urbanisation can be quantified. The distributed model can be used to assess impact of future abstraction scenarios.
23	Need to better understand the requirements of headwaters in the Plan area	Although this issue focuses on understanding the requirements, this project will deliver increased understanding of the hydrology of the headwaters of catchments, and a tool that can be used to assess impacts on those headwaters.
LEAP Issue (North Norfolk)		**Support from the Yare & North Norfolk Project**
1	In-river needs are not quantified for water flows and levels	Although this project will not attempt to assign in-river needs (in habitat/ecological terms), it will provide a means by which total river flows can be quantified on a distributed basis, i.e. including headwaters and ungauged parts of the catchments, to assess whether these needs are met by particular development scenarios.
2	River flows in North Norfolk are perceived to be unacceptably affected by licensed abstractions.	Analysis of data during Stage 1 will indicate nature of groundwater surface water interaction. Quantification of processes will be possible using the proposed distributed groundwater model.
4	Catchment areas for wetland sites of conservation need to be identified.	Local studies to be implemented as part of this project will investigate the hydro-ecology of wetland sites designated under the Habitats Directive. Conceptual understanding of wetland/groundwater interaction is expected to be significantly increased. The project will provide tools to aid the quantitative assessment of impacts.
6	Ensure that the Environment Agency activities comply with new and existing EC Directives concerning nature conservation.	
16	Control of nitrate from agricultural sources.	The analysis performed within Stage 1, and the distributed model to be delivered in Stage 3, will add to the knowledge of the movement of diffuse pollution throughout the area.

As well as the issues specifically identified in the LEAP documents, two other documented sources of issues are worth noting here. The Northern Rivers Group (one of the 'Protection through Partnerships' initiatives in which the Agency is involved, and comprising the Agency, the Broads Authority and English Nature) was formed to establish a consensus on priorities for the future management of the Rivers Bure, Ant and Thurne. Their report 'A Catchment Vision for the Third Millennium' identifies eight key issues, two of which are quoted here:

- 'Freshwater flow: we do not understand the hydrology of rivers and broads in enough detail and therefore cannot set reliable minimum targets for freshwater flow, saline intrusion, water quality or flushing, to protect and enhance the environment or to develop appropriate long-term strategies';
- 'Water supply to fens and marshes: we have a poor understanding of fen and drained marsh hydrology and its link to the maintenance of their ecology, yet this understanding is the key to their restoration and conservation management to meet national and international commitments'.

In March 1997, the Broads Authority convened a workshop to develop priorities for Broads environmental research and monitoring. The findings of specialist discussion groups at this workshop are reported in the proceedings. The proceedings state that '*it is clear that the needs of the rivers have been very much ignored within the current framework of management*' and that '*decisions are still made subjectively, based on experience and consultation, but not employing specific management tools like GIS or detailed models*'. The proceedings go on to say that '*all ongoing research and management of the Broads is fundamentally controlled by the hydrological functioning of the wetland system. Development of a clear understanding of how the system functions in terms of hydrological response ..... is critical*'. It was concluded that there was a '*need for a better understanding of the hydrological processes to inform management and policy decisions and recommendations*' and that one aspect of achieving this objective would be '*to develop a model ... to ask "what if" questions*'. Increasing the understanding of the hydrology of the system was assigned the highest priority since it was considered to be '*fundamental to most other things*'.

It is worth noting that the proposed activities under Issue 3 of the Broadland Rivers LEAP ('There is a perception that existing available water resources may be inadequate to meet present and future demands') were identified as 'Research the possibility of producing a groundwater model of Broadland' and to 'Review water balances ... during 1999/2000'.

These previously defined issues, supported by the impressions gained from the consultation exercise, confirm that there is a widely perceived basic need to increase the level of understanding of how the hydrogeological system behaves. Widespread support was forthcoming from the consultees for an in-depth analysis of available information on a regional basis, leading on to the development of a 'tool-kit' (which may be a numerical model or models, together with supporting documentation, analytical models and other methods of calculation) which could be used to manage and allocate water resources based on 'best available' data and science.

4.4 Scientific Issues and Uncertainties

4.4.1 Inputs to the System

Hydrologically effective rainfall (HER) is calculated from an analysis of rainfall, evaporation and landuse data. The partitioning of HER between runoff, other 'near-surface' processes such as interflow, and recharge to the deeper 'regional' groundwater system subsequently requires an understanding of near surface geology, soils, land use, land drainage (both surface and underdrains) and an analysis of river flow hydrographs. It is important that this understanding is not restricted to present circumstances in the area but is extended to include major historical changes in landuse and drainage. Confidence in the conceptual understanding and ultimately model output and predictions can only be achieved by the close replication of historic time series records. This will be particularly important if deliverables from the study (either in terms of qualitative understanding or a quantitative numerical model) are to be used to assess probable future scenarios: some climate change scenarios for instance imply changes in land use, which will have an additional indirect effect on groundwater recharge.

Meteorological data within the study area (see Section 5.1.1 and Appendix A) are readily available: there is good coverage of rain gauges, and distributed long term average potential evaporation figures are available for the area, in addition to the standard MORECS squares data. Information on land use coverage is available for several points in time, and the distribution of soil types throughout the area is also available.

The principal uncertainties that will require systematic re-evaluation are:

- Distribution, character and behaviour of soils and near surface (drift) geology in governing the relationship between rainfall and rapid runoff;
- 'runoff-recharge' at the edge of poorly permeable surface materials;
- Development and distribution of land drainage, and interaction with the main river channels;
- Current and historic land use distribution, particularly changes in agricultural practices (related to drainage activities);
- Groundwater and surface water interaction and relative levels around river channels and wetlands.

4.4.2 Outputs from the System

Outflows from the system take place via a number of main routes:

- groundwater flows directly to the sea;
- groundwater flows to the marshes and mudflats around the coast (notably the North Norfolk Coast and Breydon Water);
- baseflow to rivers;
- groundwater and surface water abstraction;
- pumped drainage from IDB systems;
- evaporation from wetlands, Broads and parts of the drained marshlands.

Of these, the only category which is reasonably well quantified at present is groundwater abstraction for public supply. Abstractions for irrigation may be quite well recorded, but there are uncertainties regarding the amount of water returned to the ground by spray irrigation. Current practice is to assume that the water is consumed and that there is none returned to groundwater.

Groundwater outflows to the sea and coastal marshes are important as they maintain particular habitats: the quantities of flow are however poorly known and are difficult to measure or observe.

Quantities of water transferred around and ultimately removed from the system via IDB operations are not well known, since it is only in recent years that reliable persistent measurements and observations have been recorded. The provenance of the water pumped from these systems is also not well understood, and there are large uncertainties over the interaction between groundwater (in the Chalk, Crag and Quaternary deposits), 'natural' and artificial surface water systems.

Within the study areas, wetlands and other riparian areas cover a considerable area. Direct evaporation from theses areas could be a significant component of the water balance, at least locally.

There is a need to understand all of these processes in more detail, such that uncertainties in behaviour can be reduced, which will ultimately lead to a more robust calculation of available resources for the area.

4.4.3 The Groundwater and Surface Water Flow Framework

In the study area the framework through which groundwater moves is moderately complex. The main aquifer is the Chalk, the hydrogeological structure of which is complicated by stratigraphic 'layering', the presence of 'putty Chalk' and post-depositional patterns of fissure development, as well as the occurrence of deep erosional channels (or 'buried valleys') within it. These channels may be related to either present river channels or to Pleistocene glacial and periglacial events. In the latter case they may bear no real relationship to present drainage and may even cross apparent hydrological boundaries.

The Crag forms a minor aquifer by definition, but is locally important for groundwater supply, and can transmit significant quantities of water. Groundwater occurrence in the Crag is not especially well monitored (see Section 5.1.3), although the recently installed boreholes along the Bacton gas pipeline have improved the situation.

The Chalk and Crag are in hydraulic continuity in the area immediately east of Norwich, but further east are separated by the London Clay, beneath which the groundwater in the chalk is saline. Active leakage vertically through the clays is therefore likely to be minimal, but groundwater flow patterns around the edge of the London Clay are not well understood.

Both the Chalk and the Crag interact with shallower groundwater systems, particularly in river gravels and around wetland sites. The nature and degree of hydraulic continuity between the shallow and deep systems is not well known, and is a particularly important requirement for the assessment of ecological impact of groundwater abstractions.

The hydrogeological properties of all parts of the groundwater system are of course spatially variable, and local behaviour may depend upon the juxtaposition of materials of different properties. Ultimately the groundwater model must provide a realistic representation of distribution of the hydraulic properties and hydrogeological behaviour of the system.

In terms of the groundwater and surface water network, the main uncertainties relate to:

- reliability of some of the river gauging stations (see Appendix A);
- discharge rates from main Sewage Treatment Works;
- the spatial distribution of runoff and baseflow, including in the upper headwaters of the rivers;
- direction and quantity of flow within the artificially drained systems, and discharges to/from these systems to the natural channels;
- the non-tidal/tidal interface;
- storage/retention of water in the Broads;
- groundwater/surface water interaction;
- groundwater movement through complex superficial deposits;
- distribution of fissuring within the Chalk;
- effect of buried valleys;
- hydrogeological behaviour of wetlands.

Project support towards the resolution of these scientific uncertainties is discussed in Section 7.1.

4.5 Specific and Operational Issues

The LEAP and the consultation process have identified a series of issues arising from the operation, regulation and protection of the water resources and conservation interests of the study area, and the conflicting demands on these resources and interests. Resolution of some of these issues will be achieved directly by the proposed 'Groundwater Investigations and Modelling', whilst the project will also contribute indirectly to work required to resolve the remainder. The understanding attained through the activities of data synthesis, conceptualisation and ultimately model construction and operation will ensure that these issues can be addressed within a scientifically defensible framework, such that appraisal of local issues can be carried out within the regional context. There is also a widespread view that a detailed groundwater resource re-evaluation of the area is long overdue, and that there must be significant benefits from carrying out such an evaluation in an open and consultative manner.

Specific issues raised through consultation have been grouped into four categories on Box 4.2 (although it is noted that some issues could fall into more than one category), and an indication of the support provided by the Yare & North Norfolk Project is given:

Box 4.2 Specific and Operational Issues and Support from the Yare & North Norfolk Project

Issue	**Support from the Yare & North Norfolk Project**
Abstraction and Water Use	
Water resource availability for licensing	The project will deliver updated catchment water balances, increased conceptual understanding of system behaviour and a distributed groundwater model which can be used to assess potential options for future management of water resources throughout the area, including various abstraction/river support scenarios.
Is it possible to commission or de-commission the Bure Augmentation boreholes?	Project will re-assess field data collected during river support trials in the context of updated conceptual understanding to identify net benefit of scheme. Distributed model will permit quantification/optimisation of various river support scenarios.
Seasonal demand for irrigation and IDB pumping increases in the summer, with consequent potential effect on ecology.	Study will collate existing data and knowledge of operation of IDB systems, and as far as possible will develop a quantitative statement of the interaction of IDB drains with the groundwater and 'natural' surface water regime.
Can IDB pumping be optimised in relation to irrigation/drainage/conservation needs?	
Is it possible to use IDB drains for water storage? (an increase in water level of say 6" over 45 000 acres of drained marsh represents a large storage volume).	
Conservation	
Valley Fens encroached by scrub in response to 'drying out' of land. (Scrub can take hold very quickly and sometimes (temporarily) disappears in a succession of wet years)	Enhanced conceptual understanding (on regional and local scale), and distributed model(s), will permit assessment of quantification of changes in water levels.
Potentially 'recoverable' Broads may be lost because of intermittent saline incursion	Increased knowledge of flows entering Broads will contribute to managing risk of saline incursion.
In-river needs and Minimum Residual Flows	Although this project will not attempt to assign in-river needs (in habitat/ecological terms), it will provide a means by which total river flows can be quantified on a distributed basis, i.e. including headwaters and ungauged parts of the catchments, to assess whether these needs are met by particular development scenarios.
Freshwater springs on North Norfolk Coast (and also discharges to mudflats elsewhere) important for habitat/birds etc	Enhanced conceptual understanding, and distributed model will permit assessment of quantification of discharges.
Mix of waters derived from Chalk/Drift is often important for particular habitats/plant associations	
Small tributary streams are a vital part of the ecosystem (and are often 'overlooked' as studies tend to concentrate on larger streams/rivers): drying out for even short periods can be critical. Anecdotal evidence is that streams dry out more frequently now than in past, although there are no hard data	This project will deliver increased understanding of the hydrology of the headwaters of catchments, and a tool that can be used to assess impacts on those headwaters.
Is maintaining the status quo (in terms of water levels and flows) adequate, or is this actually causing wetland derogation	Local studies to be implemented as part of this project will investigate the hydro-ecology of wetland sites designated under the Habitats Directive. Conceptual understanding of wetland/groundwater interaction is expected to be significantly increased. The project will provide tools to aid the quantitative assessment of impacts.
Where are most appropriate sites for creation of wetlands (a target of the Norfolk Biodiversity action Plan).	

Box 4.2 (continued) Specific and Operational Issues and Support from the Yare & North Norfolk Project

Issue	Support from the Yare & North Norfolk Project
Management and Future Planning	
Climate change/global warming will probably lead to increased 'storminess' in rainfall patterns and potentially less recharge. There may be more frequent tidal surges, as well as an increased frequency of severe droughts	The project will deliver a distributed model that can be used to make predictions of future changes in groundwater levels and river flows arising from climate change or drought scenarios.
Sea level rise and increased incursions/defence breaches	
Plans for new housing development, with consequent water demands	Updated water balances (in short term) and distributed model (in longer term) can be used to assess abstraction scenarios.
Water Quality	
Salinity changes, as evidenced by e.g. water quality surveys (EN dyke survey in late 1980s and late 1990s), Holman & Hiscock work in Thurne catchment, saltwater shrimps now present in South Walsham Broad	The project will deliver an enhanced conceptual understanding of system behaviour and a distributed groundwater model which can be used to assess potential options for future management of water resources. The conceptual understanding will include knowledge of the provenance of water entering the Broads, and will permit qualitative assessment of water quality issues. The distributed model could ultimately be used as a basis for more detailed quantification of changes in water quality brought about by mixing of waters from various sources.
Thurne catchment is particularly critical, with a widespread ochre problem.	
Concern over flows (especially in summer) in the Bure, particularly related to Belaugh intake, and how this affects flushing of the Broads.	
Nutrient enrichment a problem for Broads and fens (in terms of ecology and hydrology, as well as for amenity)	
What is the groundwater contribution to the Broads, and where does the diffuse pollution to the Broads actually come from?	
Urban pollution, especially arising from Norwich	

4.6 The Habitats Directive

The Conservation Regulations (1994), which enact the EC Habitats Directive, impose a statutory obligation to consider all plans, projects and consents that may have an adverse impact on wetlands within Special Areas of Conservation (SACs) or Special Protection Areas. The Agency have undertaken that, as one of the types of consent in question, all water abstractions that might adversely affect such sites must be reviewed by 2004. The Agency's approach to this review requirement is to undertake a **desk study**, followed by **appropriate assessment**. This appropriate assessment may consist of a pragmatic solution based around interpretation of water levels and vegetation community types, or it may require a local distributed numerical model to provide a more rigorously quantified assessment. At urgent priority sites, the Agency's target is to complete appropriate assessment by March 2002.

Within the North Norfolk & Yare North area there are 32 wetland SSSIs with European designation (for details see Appendix A). These SSSIs are components of four SACs (namely Norfolk Valley Fens, The Broads, the North Norfolk Coast and the Winterton & Horsey Dunes) and two SPAs (Broadland and the North Norfolk Coast).

The Agency has a statutory obligation to undertake this appropriate assessment, and such work should be scheduled within the Groundwater Investigations and Modelling in the Yare & North Norfolk areas. The recognition of the regional context of these sites and the extent to which they may have been impacted by long term regional changes in land use or drainage will be an important issue in the 2004 reviews.

The conservation issues surrounding wetlands and river flows are unlikely to be totally resolved by regional groundwater investigations and modelling alone. However, a regional model, properly designed, would permit assessment of the each site within the regional context, and could also provide realistic boundary conditions for more detailed localised models.

4.7 Complementary Studies

Within the North Norfolk & Yare North area there are a number of studies planned or in progress within, or part-funded by, the Agency which will address similar issues to or make use of similar data sources as the Regional Groundwater Investigations and Modelling work.

These studies should be seen as complementary, and include:

- Broadlands Flood Alleviation Strategy (BFAS). This PFI project, comprising a programme of bank strengthening and erosion protection, is due to start imminently, and is expected to include some hydraulic modelling of parts of the surface water system. Additionally, monitoring has been on-going for about one year.
- the latest study on the River Burn which commenced March 1999, specifically to look at groundwater/surface water interaction in a Chalk bourne stream. Detailed abstraction and irrigation information is being collected, complemented by increased frequency and coverage of groundwater monitoring.
- Study into solvent contamination potentially arising from the Sculthorpe RAF base in the Burn catchment.
- PhD study into freshwater discharges from the North Norfolk coast will commence in September at UEA.
- Pilot study for the review of the Regional Monitoring Network due for completion in Autumn 1999. This is effectively an asset survey and will provide a ranking of existing monitoring wells and ensure that well construction and geology are accurately recorded on the HYDROLOG database. Although the pilot study is not within the project area, the findings from it will have influence across the entire existing monitoring network.

In addition to these specific studies, the Agency is involved in many other initiatives with partner organisations, which are described in the LEAPs under the 'Protection through Partnership' banner. There is considerable scope for mutual benefit by liaison with people involved in these initiatives, since they share common aims, and a two-way flow of relevant information should be established. The groundwater studies can provide important information and understanding to help decision making in many of these initiatives, and similarly the knowledge and expertise of individuals involved in the diverse initiatives may provide useful input to the development of conceptual models of groundwater/surface water behaviour.

Generic initiatives which this investigation may assist include those shown on Table 4.2.

Table 4.2 Partnership Initiatives

Initiative/Project	Partners
Development and Water Supply	water companies, local authorities, developers, landowners, farmers
Biodiversity Action Plans	English Nature, local authorities, County Councils, Wildlife Trusts, RSPB, Biological Research Centre, Broads Authority, landowners, farmers, IDBs
Local Agenda 21 (Sustainable Development)	Local Authorities
Conservation enhancement projects	Wildlife Trusts, Norfolk Coast Project and others
Integrated River Basin Management, which specifically includes:	
Northern Rivers Group	Broads Authority, English Nature
Wensum Valley Project	local authorities, Farming & Rural Conservation Agency (FRCA), Norfolk Wildlife Trust, National Farmers Union, Norfolk Angling Conservation Association, IDBs, landowners and farmers
Trinity Broads Restoration	Broads Authority, Essex & Suffolk Water
Restoration of Barton Broad	Broads Authority, Millennium Commission, Anglian Water, Soap & Detergent Industry Associations' Environmental Trust
River Wensum SSSI Strategy	English Nature
Water Level Management Plans	English Nature, local authorities, Wildlife Trusts, RSPB, Farming & Rural Conservation Agency (FRCA), Broads Authority, IDBs, landowners & occupiers

It can be seen from the above table that the list of 'partners' in these initiatives is broadly similar to the list of consultees for this Scoping Study, and highlights the potentially far-reaching implications and value of this study. By furthering the understanding of water resources within the area, the Agency will be fulfilling part of their commitment to these partners.

The key issue to be addressed relative to these studies and initiatives is the avoidance of duplication of effort (and consequently unnecessary cost). In the performance of the data collation and appraisal that the first stage of the proposed investigations will require, the temptation to develop parallel systems of data handling and manipulation to those already employed elsewhere (whether within the Agency or external to it) must be avoided. Developments must be complementary to current systems and must be carried out in such a way that permits easy updating and maintenance of data.

5. Data and Information Currently Available

Details of the main data sets held by the Agency are given in Appendix A, and so a very brief summary only is given in this Section. Information held outside the Agency is also mentioned.

5.1 Data Summary

5.1.1 Meteorology

Number of (daily, manual) raingauges: 75, about 60 of which are still in use (although some of these are duplicate 'check' gauges).

Number of long term (pre-1960) raingauges: 4.

Number of raingauges with dataloggers (15-minute or event data): 6 (although this number is to be reviewed after further consultation with the Meteorological Office, also it is possible that some of the (?)AWS gauges have loggers).

Number of full weather stations: 3 (this may be revised: awaiting more details from the Meteorological Office).

Long Term Average rainfall on a 1 km^2 grid available for 1941-1970 at the Agency. Updated information is available from the Met. Office. as averages for each calendar month over the period 1961-1990.

MORECS data for 4 squares within the study area. Long Term Average (1941-1970) Potential evapotranspiration data on a 1 km^2 grid available from Institute of Hydrology.

5.1.2 Hydrology

Number of permanent river flow gauges: ~20.

Number of tidal gauges: ~18.

Sites with history of regular current metered flows: ~60.

Surveyed longitudinal profiles for all main river channels exist, supplemented by surveyed cross-sections at 100 m intervals.

5.1.3 Hydrogeology

Groundwater levels are monitored in the following numbers of boreholes:

Chalk: 104.

Crag: 37 (including 24 along Bacton pipeline).

Quaternary and Recent (excluding recent wetland installations): 62.

Wetland Quaternary and Recent: ~150 at 28 sites.

Historic coverage in the Chalk is reasonable, but the Crag has been poorly monitored until 1997, with the installation of boreholes along the Bacton pipeline. A programme of monitoring installations at key wetlands commenced in 1996.

There are analyses of almost 500 pumping tests on the Aquifer Properties Database, which were extracted from Agency records: these are almost exclusively in the Chalk. In addition there are several hundred more tests held in files in the Agency Ipswich office.

Groundwater Protection Zone (GPZ) reports exist for all major groundwater abstractions.

Wetland dossiers are available for many sites within the area.

5.1.4 Abstractions

The number of current abstraction licences in the area is as follows:

Groundwater: 1297.

Surface Water: 142.

Mixed: 79.

There are 26 Public Water Supply licences, the great majority of which are complex licences covering several abstraction locations, and often a mix of groundwater and surface water. These licences cover a total of 76 groundwater and 7 surface water locations.

The majority of the remainder (apart from very small abstractions) are spray irrigation licences, although there are some significant industrial abstractions also.

Returns exist for large abstractions on a monthly basis, going back to 1966. Daily quantities are available from the water utilities for some of their abstractions (since 1993).

5.1.5 Discharge consents

There are currently around 3 000 licensed consents to discharge within the project area. Most of the large discharges are from sewage treatment works. There are around 250 consents with a maximum daily flow of greater than 10 m^3/d.

Discharge data for all current discharges in excess of 5 m^3/d per day are held on the SIMS (Supply Information Management Systems) Database. The CFD (Charging for Discharge) database contains information on every discharge consent issued since the 1960s and is held at Peterborough.

5.1.6 Geology

Published geological maps at 1:50 000 cover the majority of the area, although selected maps have not yet been published:

Cromer (Sheet 131): expected to be available in about 1 year.

Wells (130): available in about two years.

Aylsham (147): available in about 4 years.

Digital versions of the 1:50 000 maps are available for about 50% of those currently published, although the remaining maps will be available soon.

Coverage of geological maps at 1:10 560 or 1:10 000 is shown in Appendix A. Coverage is almost complete for the south and east parts of the project area, but there are no published maps for the north and west at this scale.

5.1.7 Topography

The Agency hold full coverage of digital (raster only) 1:50 000 and 1: 10 000 Ordnance Survey topographic maps. The Agency also have complete coverage of digital gridded elevation data on a 50 m grid (the Ordnance Survey PANORAMA data set. Under the Memorandum of Agreement between the Agency and the OS, higher resolution data (PROFILE, on a 10 m grid) would be available from the OS on request.

A set of 1:2 500 maps are held by the Agency, which include the locations of river profile surveys for all main rivers (see Section 5.1.2).

Very high resolution (2 m grid) LIDAR surveys have been flown over large parts of the project area, mainly for Flood Defence purposes, and more are scheduled for late 1999. For this project, these data will be most useful in resolving topographic detail in relatively flat areas (floodplains, marshes, wetlands): coverage of these areas is virtually complete.

5.1.8 Soils and Land Use

Soil Survey 1:250 000 Map No. 4 covers the whole of East Anglian, a 1:100 000 sheet is available for Norfolk and there are a small number of 1:25 000 soil maps and accompanying monographs are available for parts of Norfolk:

- TF82 Helhoughton;
- TG11 Attlebridge;
- TG13/14 Barningham/Sheringham;
- TG31 Horning;
- TG40 Halvergate.

Distribution of soils catalogued according to the dominant HOST classification present is available on a 1 km^2 grid from the Institute of Hydrology, but of more use to this project is the 100 m grid digital soil association map available from the Soil Survey.

The Agency have (at the National Centre for Environmental Data and Surveillance at Twerton) the digital 'Land Cover Map of Great Britain' as produced by the Institute of Terrestrial Ecology. This is available in two forms, the most detailed being at 25 m spatial resolution. The information was derived from satellite images for 1990. An updated map will be produced for the year 2000.

Detailed (field scale) land use data is available for the Bure catchment for 1995, contained in a report held by the Agency.

The Agency have MAFF super-parish data for 1995. Parish returns for years prior to 1988 would be available from the Public Records Office if needed.

Paper maps produced during the First Land Utilisation Survey of Britain, covering the whole country at 1:63 360 in the 1930s, are available for inspection and copying at the London School of Economics. A small number of maps from the Second Survey, conducted in the 1960s, have been published at 1:25 000 scale: field maps at 1:10 560 covering the whole project area are available for inspection via the Survey Co-ordinator in London.

5.1.9 Water Quality

Routine groundwater quality monitoring (once or twice per year) was undertaken on sample from around 120 boreholes for the period 1994 to date. Prior to this, the sampling is somewhat random, being undertaken for particular needs as they arose.

Regular surface water analyses are available from several hundred sites.

In addition, some of the tidal gauges also monitor salinity.

In addition, the water sampling utilities provide groundwater quality data for public water supply (c. 100) boreholes. These data are supplied to the EA on magnetic tape but have yet to be incorporated into the LIMS system.

5.1.10 Groundwater Models

There are no regional groundwater resources models for the study area, although there are some smaller models produced during university research programmes. Capture zone models exist for many of the large public water supplies, derived during the GPZ programmes. Some of these are 'multi-source', including one for the Yare catchment.

5.1.11 Contaminated Land and Landfill

A number of landfills throughout the area have groundwater monitoring records reaching back several years (see Appendix A). These may be a useful supplement to the Agency monitoring network.

5.2 GIS

The Agency has a GIS under on-going development implemented in ArcView. This currently contains a wide range of raster and vector information. A complete list of information currently held on the GIS is given in Appendix A: existing GIS data sets of particular relevance to this project are:

- OS raster background maps;
- OS PANORAMA digital elevation data;
- hydrometric catchments;
- main rivers;
- conservation sites;
- monitoring sites.

This project will add to and refine the Agency GIS as data sets are processed and verified. It is expected that data sets added to the GIS during Stage 1 of the project will include:

- land use distribution (1930s);
- land use distribution (1960s);
- water level distributions at selected times;
- hydrogeologically relevant geological information;
- soil associations;
- long term average (1961-1990) calendar monthly rainfall;
- long term average potential evapotranspiration.

5.3 Data Outside the Agency

Outside the Environment Agency potentially useful sets are held by a number of organisations; particularly the British Geological Survey, the Meteorological Office and the Ordnance Survey, the Institute of Hydrology, the Institute of Terrestrial Ecology, The County Councils, Birmingham and East Anglia Universities, London School of Economics, Anglian Water Services, Essex and Suffolk Water, Broads Authority, IDBs.

The **British Geological Survey** hold geological maps (see Appendix A) in regional 1:50 000 and 1:10 000 scales and borehole databases (Geoscience and Wellmaster). Some geological maps are now available in digital form compatible with ArcView.

Some of the **Meteorological Office** rainfall data is held by the Agency. Additional data of particular value in assessment of rainfall distribution is the long-term average (1961-1990) rainfall calculated on a 1 km grid, available as annual average and calendar monthly average. There are several Met. Office weather stations recording different suites of information within or close to the project area, from which additional site-specific data could be obtained if necessary.

The **Ordnance Survey** provide 1:50 000 and 1:10 000 digital master data which is held at Brampton. Digital terrain data is provided in two formats PANORAMA (50 m DTM grid) and PROFILE (10 m DTM grid), although we understand that for flood protection purposes the Agency is currently acquiring LIDAR (2 m DTM grid) data which should be available in late 2000. This digital terrain data is necessary for input to runoff routing.

The **Institute of Hydrology** have a nation-wide DTM, including information on elevation and drainage direction, on a 50 m grid, although it is not known how representative this is in areas of low relief, such as drained marshland. IoH also have a database of underdrainage, digitised on a 5 km^2 grid.

The **Institute of Terrestrial Ecology** has derived countrywide land use distribution (held on 100 m square grid) from LANDSAT imagery recorded in 1990 and will repeat this process for the year 2000. Earlier land use surveys covering the area for the 1930s (1:63 360) and the 1960s (1:25 000 and 1:10 560) are held by the **London School of Economics** and **Professor A Coleman** (who co-ordinated the survey whilst at King's College) respectively. The 1990 survey is available through the Agency at Twerton. Experience has shown that the satellite image interpretation is consistent with the MAFF parish crop records, digitised as Small Area Statistics by the University of Edinburgh. These latter statistics exclude military and forest uses.

Norfolk County Council holds paper records and map locations of approximately 5000 boreholes with water level records for up to 15 years throughout Norfolk (probably around 1500 in the project area). These are accessible and potentially valuable in identifying variations in Drift geology. The County Council also holds air photos from the 1940s and 1987, and shallow hydrogeological information from about 15-20 mineral and waste disposal sites.

It is also believed that Norfolk County Council hold unpublished maps from a Broadland Land Use survey conducted in 1967, although this has not yet been verified.

Birmingham and East Anglia Universities hold a range of MSc and PhD dissertations relevant to the area, some of which are listed in the attached bibliography. These are available for consultation. UEA also hold a map showing the locations of aerial photo surveys.

Anglian Water Services: much of their data is returned to the Agency but additional data is available in the Source Reliable Output (SRO) file for each source supported by a more detailed Technical File. Daily abstractions are available for all groundwater sources from 1993 to the present. Treated sewage effluent flows are recorded daily (by telemetry) for major sites: these data have been recorded at some sites since 1993.

Essex and Suffolk Water hold water level information at their Ormesby offices.

The **Broads Authority** maintains a GIS developed in SPANS which contains the following information:

- Fen Resource Survey (1991-94). Vegetation classified into NVC types, also pH, conductivity and historical site data. Will be repeated starting 2001;
- Woodland survey: ongoing to be complete 1999/2000, NVC classification;
- 'Substrate' data, being collated 1999. Historical information on peat cuttings from nineteenth century;
- Land use: 1980s;
- Dyke surveys: 1987 and 1997 aquatic plant surveys.

The Broads Authority also hold additional information, not currently on GIS. This is largely of an 'ecological' nature, but there may be important clues to hydrological behaviour within it:

- Aquatic macrophyte surveys (from 1982, most sites annually). Some sites, e.g. Upton Broad, show strong correlation between macrophyte health and hydrology;
- Turf Pond monitoring: newly-created turf ponds are monitored for re-colonisation etc;
- Aerial photos: full coverage colour (1988, 1995), black and white (1980), plus some black and white from 1940s, 1950s, 1970s;
- Fen Dossiers for each site containing miscellaneous information;
- Management records on database (Access).

Broads Authority Report 13 (Parmenter, 1995) contains much information on historical (since 1797) land use changes within Broadland, including relative wetness of fens etc.

Norwich Museum hold some historical maps, and researchers there have also conducted salinity and vegetation surveys at various times (e.g. survey of 500 conductivity measurements in dykes done in 1997).

The Kings' Lynn Consortium of Internal Drainage Boards (KLCIDB) have a GIS under AutoCAD 14, although this will shortly move to AutoCAD 2000. Layers on this include:

- Boundaries of all IDBs;
- Pumping station locations (all applicable IDBs);
- Main Drains (all IDBs);
- Field Boundaries (all IDBs);
- Water control structures (not yet fully collated);
- Locations of areas subject to Water Level Management Plans;
- Borehole positions (data from the Agency);
- Conductivity measurements (information belongs to Broads Authority);
- Pumping Station records (pump hours per week, on database linked to AutoCAD).

Most weirs within the IDB drains are essentially control structures for ESA. There is no flow information available for these structures. Water levels at these structures are measured on an *ad hoc* basis for operational needs only.

English Nature hold a GIS of 2800 ditch locations in Yare (down to Norwich), Waveney (to Bungay), Ant, Bure and Thurne. Data on conductivity and plant species/communities in 1988/89 and more recently. Charles Beardall at the Agency has a copy of the data on spreadsheet, but not GIS.

For some key sites, English Nature have aerial photos every few years.

6. Yare & North Norfolk Project: Overall Project Structure and Management of Risks, Constraints and Uncertainties

6.1 Introduction

This section explains the way that the Yare & North Norfolk project will be structured, and at what points approval or guidance will be sought from the Agency Project Approval Board.

The scope of work that will generally be undertaken during the course of Strategy projects is described in some detail in the Strategy document. The scope of work is based on experience and from consideration of technical good practice. The scope of work is further summarised in Figure 6.1. This chart also indicates the broad timescales over which the activities would run.

The scope of work includes the following:

- collation of existing hydrological data and information;
- analysis of the data;
- interpretation of the data and information and calculation of a preliminary water balance;
- review of the conceptual understanding of the groundwater and surface water system;
- further field investigation and monitoring;
- construction of a distributed groundwater model with associated recharge model (or other more appropriate resource management tool);
- calibration of the recharge and groundwater models;
- analysis of the sensitivity of model results;
- local studies of wetlands;
- predictive simulations;
- handover of models and associated software;
- reporting.

In any groundwater investigation and modelling project it is helpful to allow these activities to overlap, such that technical progress and adherence to project timescales can be optimised.

It is likely that the Yare & North Norfolk Project will run for a period of around 4 years, and the detailed scope of work to be undertaken during later stages of the project cannot be assessed in detail at this stage. In order that the technical and financial risks can be carefully managed, a staged approach is appropriate, as outlined in Section 1.1.

For an investigative project such as this, the work required within any one Stage is to a certain extent dependant on the results of the preceding Stage. This is particularly true of the requirements for further investigations (Stage 2) following the compilation and analysis of existing data (Stage 1). Consequently details of the tasks and specific work requirements of Stage 1 are discussed in more detail in Section 7. To set these details in context this section presents a general discussion of the options available both following completion of any one Stage and for the complete study.

The purpose of subdivision into Stages and tasks is to provide a series of milestones and deliverables against which expenditure and performance can be assessed. This assessment in turn provides the basis for managing and limiting the risk of a substantial project running for a period of several years and, for reasons of either inadequate data or unsatisfactory performance, failing to meet its objectives. At the conclusion of each Stage a formally reviewed report will present the data collected, the interpretations carried out and the conclusions reached. Rigorous peer review of these reports will provide an important contribution to limitation of the risk of overall failure of the project to deliver.

An important consideration in planning this project has been the adoption of a schedule of work that permits overlap between the defined Stages where this will benefit the progress and outcome of the project. For example, although it is not currently possible to define the detail of work required in Stage 2, it is not necessary to wait until the very end of Stage 1 before seeking approval to proceed with parts of that work. Interim data analysis and interpretation during Stage 1 will indicate gaps in particular data sets that need to be addressed. It is anticipated that acquisition of data to fill these gaps will, in many cases, only be possible at certain times of year (e.g. current meter surveys at low flow periods in the summer). If approval to undertake this work were not sought until the end of Stage 1, this particular data acquisition task could be set back by one year at least, with potential consequences for ultimate project delivery.

Similarly, it is expected that some of the Stage 2 activities will be planned to collect time series data that will refine our understanding of particular processes that need to be incorporated into a groundwater model during Stage 3. It is most probable that one years data will be required from each such monitoring site. However, initial construction of the model need not wait until the full years data is available, as interim analysis will indicate the expected outcome: the full years data can be used to verify correct implementation of the model when it becomes available.

This protocol of 'overlapping Stages' is reflected in the proposed schedule of work shown on Figure 6.1.

6.2 Major Options

Following completion of the Scoping Study the decision to be reached in principle is whether or not to proceed with Stage 1 (Figure 6.2). A similar opportunity to halt or proceed is available at the conclusion of each subsequent Stage.

The business case to advise the Stage 1 decision is presented in the Project Initiation Document, to which this report is complementary. This business case is however built around the benefits that should accrue from overall project completion. For Stage 1 the key value judgements are the priority which the Agency attaches to resolution of the issues discussed in Section 4, the technical assessment of the relevance of the proposed tasks and the adequacy of the measures proposed for risk management. Should the decision be taken not to proceed with Stage 1 it must be recognised that the costs attached are potentially those that will be generated by escalation of the conflicting demands for water resources within the area.

Within Stage 1 the range of potential options is built from the recognition of a minimum standard of work and level of activity necessary to meet the '**best practice**' requirements of The Strategy. It is imperative that the work undertaken is of a high technical standard, and that each conclusion and interim decision reached must be scientifically and objectively defensible.

From this option additional components of some tasks, or additional tasks, are identified which minimise the risk of an unacceptable Stage or project conclusion and ensure that unnecessary expenditure is not incurred in subsequent Stages. The selection of the preferred Stage 1 option is discussed in the context of individual tasks in Section 7.

It is anticipated that the duration of Stage 1 will be in the order of 17 months, including a review period at the end.

At the conclusion of Stage 1 it is likely that the principal choice will be either to carry out a limited programme of further investigations or not to proceed with further project work. It is unlikely that uncertainties will be sufficiently constrained at end of Stage 1 to proceed with distributed groundwater modelling without limited further investigations. Stage 1 activities will define the potential Stage 2 options in detail. A further PID will be necessary to present the business case for the range of options. The level of conceptual understanding derived from the Stage 1 studies will define the scope of these further investigations. A view of the likely range of investigations that might be required is discussed in more detail in Section 9.

It is important to note here that the deliverables from Stage 1 will be useful in their own right and there are therefore good reasons why Stage 1 (as a minimum) should proceed. Subsequent options beyond Stage 1 must be considered on the relative merits of the business case developed.

With the current state of knowledge it is difficult to be prescriptive about the probable duration of Stage 2 activities. Figure 6.1 shows the estimated probable duration: note the overlap with the end of Stage 1 and the commencement of Stage 3.

As more data are gathered during Stage 2, the adequacy of the improved conceptual understanding and the design of the proposed distributed groundwater model derived from this understanding would be subject to rigorous peer review. The nature and specification of the model to be developed during Stage 3 activities will be dependant on the understanding developed of the regional hydrogeology and on the key issues to be addressed. It will also be guided by developments in computer hardware and software which have already revolutionised groundwater modelling in recent years. The precise structure of the model cannot be decided at present, but it is envisaged that, given a project area of around 3000 km^2 , a regular grid of 250 m would be appropriate. The number of 'layers' will depend upon hydrogeological conceptualisation, but it is anticipated to be between 3-8.

A regular grid is envisaged to ease data processing at the regional scale, although the adequacy of this will remain open to consideration and will be reviewed throughout. The currently proposed grid spacing (250 m) should be coarse enough to be manageable on the regional scale, but fine enough to permit adequate representation of heterogeneity within the regional model. This may mean that the regional model itself is sufficient for some 'local study' purposes, but in any event the fine grid spacing will permit good definition of boundary conditions for any separate more detailed site-specific models.

A period of around 24 months is presently estimated to build and calibrate an acceptable distributed groundwater model, which will allow for the development of site-specific models for local studies. This period is anticipated to have some overlap with the latter part of Stage 2, and includes reporting time at the end of Stage 3 (see Figure 6.1).

Any computer model of such a complex physical system can only be an approximation of reality. The establishment of confidence in this approximation as a predictive tool for resource allocation and strategic management, can only be derived from the comparison of model output to historical observation. Thus high quality data must be collected during Stage 1 (and Stage 2 if required), particularly groundwater level and river flow hydrographs, to permit robust model refinement during Stage 3. (This is in effect the final stage in the management of the risk that the model output might not contribute technically to issue resolution or could lead to erroneous strategic decisions). Sensitivity analysis and comparisons of model output with real data will provide the main input to the decision to proceed with Stage 4 (model application).

At this stage it is extremely important that the model is accepted as a realistic interpretation of the hydrogeological system and a robust and reliable tool for resource management. Regular stakeholder briefings throughout the project life should ensure that the investigation and modelling process is clear, and that the types of output from the model are understood.

The ultimate objective is to provide a tool that ensures that high quality technical evaluation is available to inform strong, considered decision-making.

6.3 Risk Management

The proposed Yare North & North Norfolk Project is based on the collection and interpretation of hydrological and hydrogeological data with complex interactions (probably supplemented by further investigations) so as to develop a conceptual understanding rigorous enough to be converted into a computer model of the system. This computer model then acts as a tool to support and inform decisions related to water resource allocation, regulation and protection. The commissioning of the Project involves the commitment of significant financial resources. The purpose of the risk management strategy adopted is to ensure that, at any given time, the exposure of this commitment to the risk of failure of the project to deliver is minimised. Project delivery is also related to acceptance by Agency Staff and by the stakeholders in the project area.

The key components of the approach adopted to risk management are:

- The definition of a series of clearly defined Stages and groupings of tasks within these Stages;
- The identification of a recognised series of deliverables throughout the project and individual Stages;
- The preparation of a detailed project Brief clearly identifying Stage 1 tasks and deliverables against which detailed cost estimates will be provided;
- The adoption of regular progress review meetings, involving the Project Team and independent External Advisors;

- The allowance of reasonable periods of time for report review and decision making. In particular the recognition that revised PIDs will be required for the progression from one Stage to the next;
- The recommendation that regular discussion and advisory meetings are held with stakeholder organisations throughout the project period;
- the adoption of flexible contractual arrangements for control of the works.

The task definition for Stage 1 and the schedule of meetings and reviews are discussed in detail in Section 7. Stage 1 activities are subdivided into three broad task groupings:

- Data collation;
- Data analysis;
- Data interpretation.

It is anticipated that each task group will require of the order of 3-6 months in an overall Stage 1 period of around 17 months (including final review). This provides the opportunity for formal project assessment against defined objectives twice within Stage 1. This potentially provides an acceptable balance between risk management through review and restriction of project progress by undue requirements for review time.

The proposed project organisation that will be required to provide the review inputs necessary for continuous assessment of project performance throughout and technical review of project deliverables and outputs is shown on Figure 6.3.

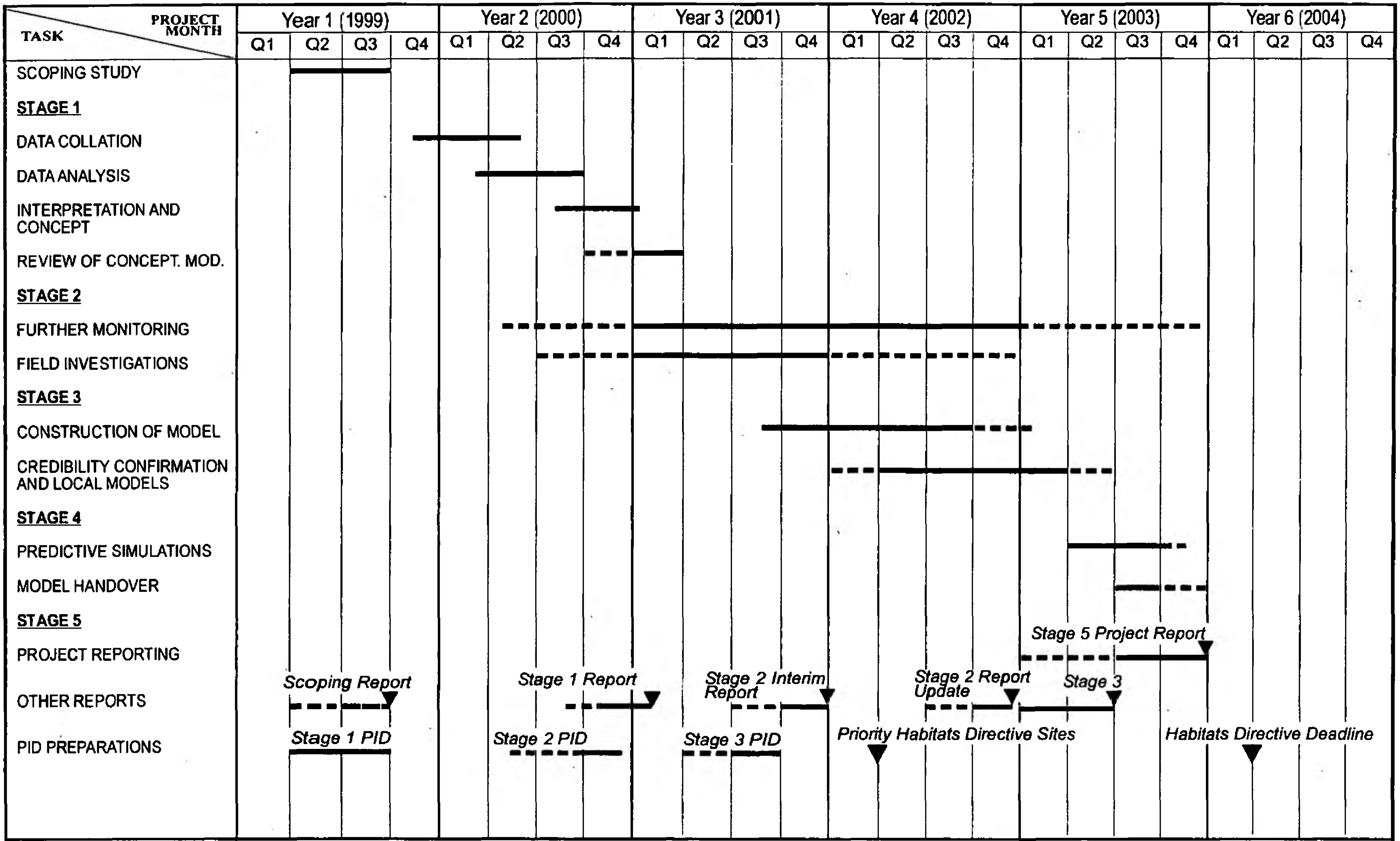

FIGURE 6.1 YARE & NORTH NORFOLK - ESTIMATED OVERALL TIMESCALE

Drawing No: 00732.S020 Date: SEPTEMBER 1999 Scale: NTS

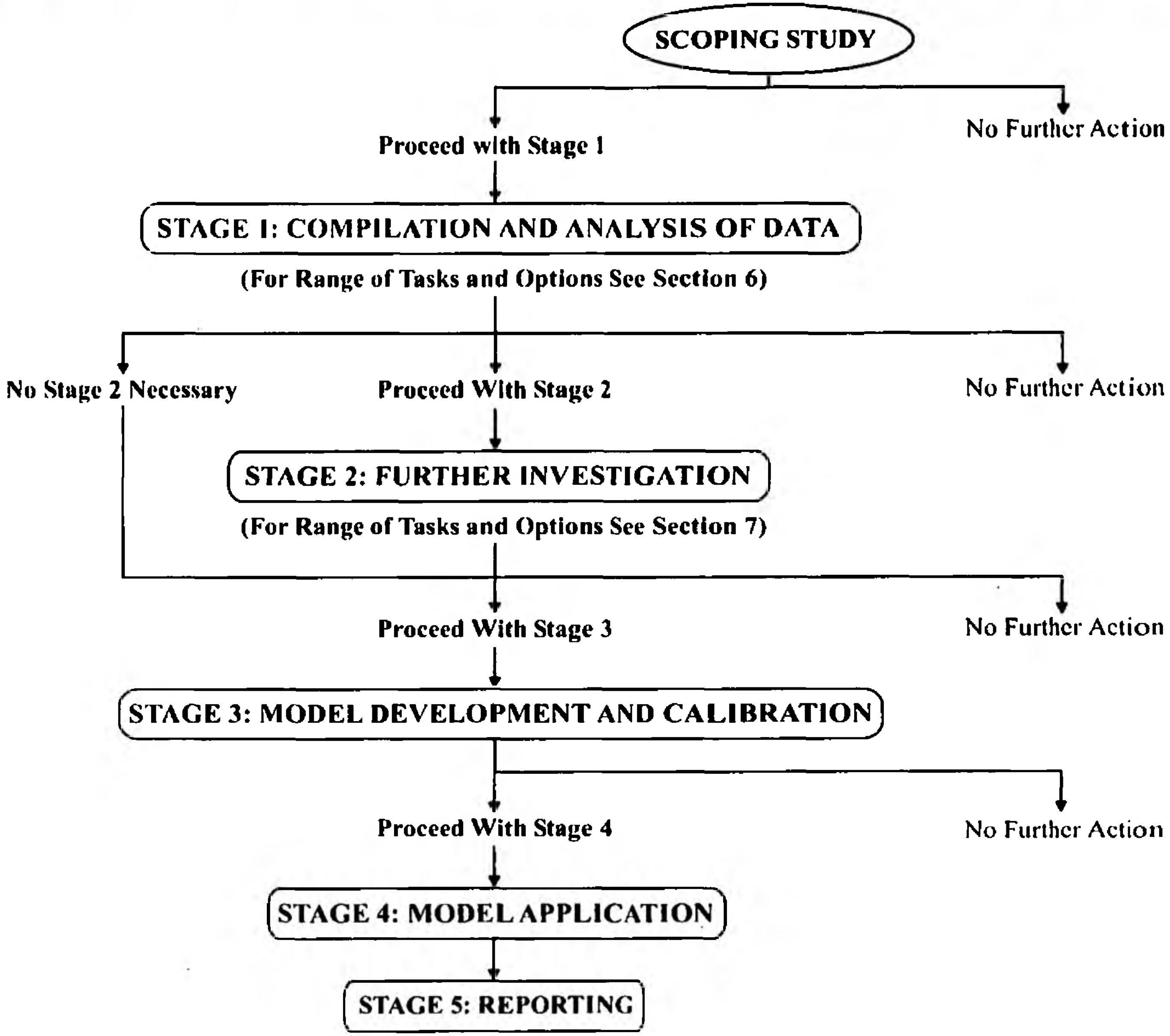

FIGURE 6.2 YARE AND NORTH NORFOLK PROJECT: GROUNDWATER INVESTIGATIONS AND MODELLING OPTIONS

Drawing No: **00732.S010a** Date: **SEPTEMBER 1999** Scale: **AS SHOWN**

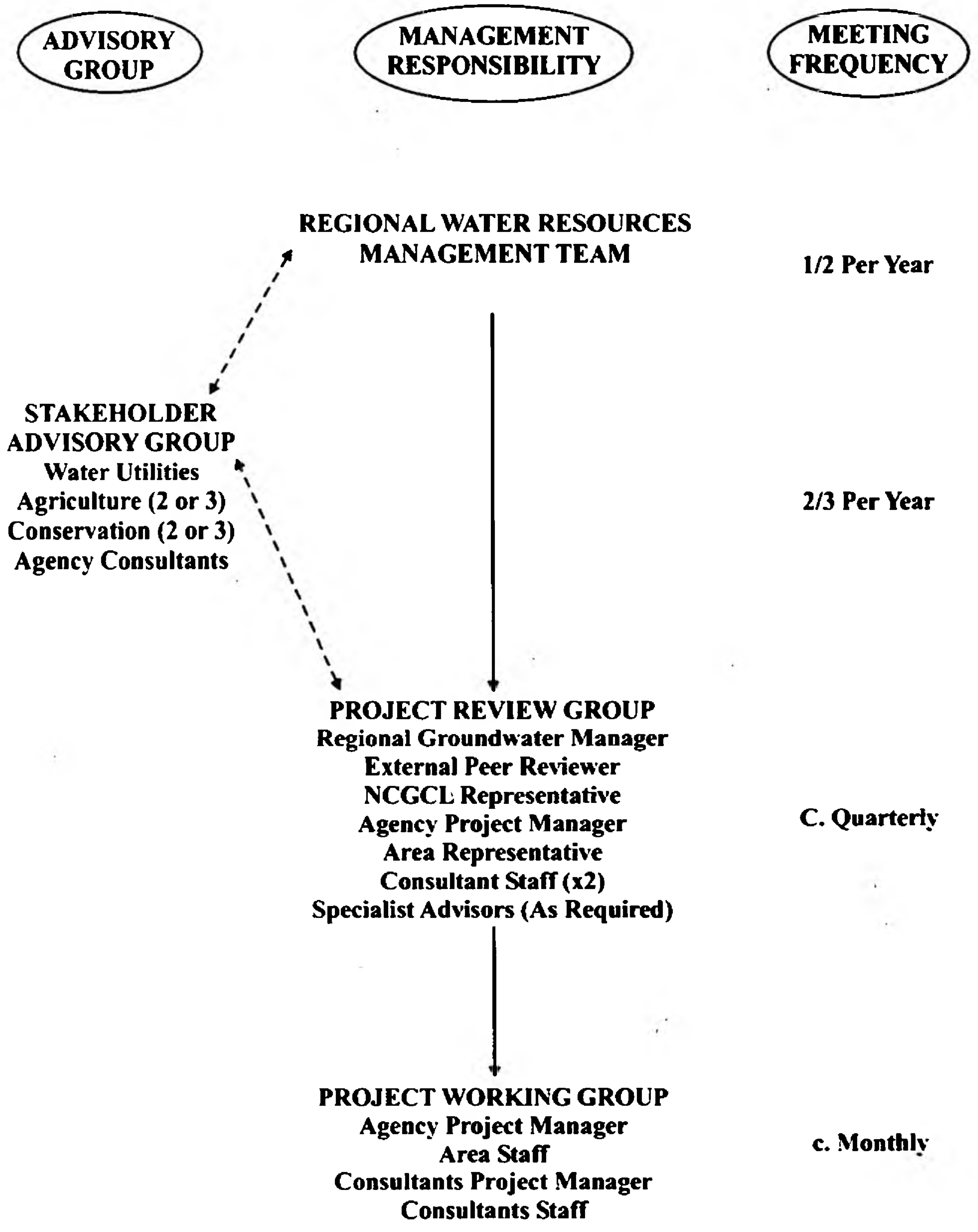

FIGURE 6.3 YARE & NORTH NORFOLK PROJECT: PROPOSED PROJECT ORGANISATION

Drawing No: 00732.S011a Date: SEPTEMBER 1999 Scale: NTS

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7. Yare & North Norfolk Project: Description of Tasks and Options for Stage 1

7.1 Introduction

Section 4 of this report highlighted the various issues and uncertainties relating to the water resources of the Yare & North Norfolk area, and also identified, in a general sense, the anticipated contribution from the project towards resolution of those issues. This section of the report provides more detail of the proposed work, which has been broken down into a series of tasks.

The tasks proposed for inclusion in Stage 1 of the Yare & North Norfolk Project are listed in Table 7.1. These task divisions are derived from the Agency's generic 'Working Draft of Tender Document for Groundwater Investigations' (1999) but have been reordered to provide a sequence of broadly equal subdivisions from data collation through analysis to interpretation/reporting. The general sequence and anticipated duration of Tasks is shown on Figure 7.1 which represents timings for the Stage 1 Option recommended at the completion of this section.

Throughout all these tasks it should be remembered that a significant body of work already exists which is pertinent to the study area, and the proposed investigations are not 'starting from scratch'. The Yare & North Norfolk project must **build** on previous work, critically reviewing it against more recent information where appropriate, and continually refining the existing understanding of the water regime in the area.

The subdivisions identified between tasks should be regarded as a convenient means of task description and progress monitoring. They should not be regarded as boundaries between individual compartments of work. At all stages of the work, it is essential that each team member is fully aware of progress and information derived from other parallel activities and communication between Agency and Consultant team members must be continuous and open.

Within each task a series of subtasks are identified, and alternative options for task execution are discussed. The preferred option is indicated for each task (and some sub-tasks). The options described within this Section of the report are taken forward to Section 8, which concentrates on the preferred option and proposed plan of work, and are summarised on Figure 8.1.

It should be noted that some of the options identified are not distinct options in their own right, rather they reflect greater levels of detail that could be incorporated into tasks should the technical need arise. In many cases, it is not possible to say *a priori* whether this level of detail will be needed. This uncertainty has been managed by making assumptions about the most probable outcome, but allowing some cost contingency as part of the management of risk for the project. This risk management is described in more detail in the PID associated with this Scoping Study.

It is worth reviewing here how the proposed investigations will reduce the uncertainties in the current understanding of specific aspects of system behaviour that were identified in Section 4 (Box 7.1).

Box 7.1 Uncertainties in Understanding of the Hydrogeological System

Uncertainty	**Method of reducing uncertainty in the Yare & North Norfolk Project**
Inputs to the system	
Distribution, character and behaviour of soils and near surface (drift) geology in governing the relationship between rainfall and rapid runoff;	Analyse distinct rainfall events, using distributed data sets, for a number of gauged catchments to identify differences in behaviour and potential causes.
'Runoff-recharge' at the edge of poorly permeable surface materials;	Examine evidence from groundwater levels and hydrochemistry. Evaluate sensitivity using runoff-routing method in water balance calculations.
Development and distribution of land drainage, and interaction with the main river channels;	Critical assessment of drainage direction in 'flat' areas. Examine IDB records where available.
Current and historic land use distribution, particularly changes in agricultural practices (related to drainage activities);	Collate land use distribution at several times, supplemented with anecdotal information on changes in agriculture.
Groundwater and surface water interaction and relative levels around river channels and wetlands.	Critical review of existing information. Design new monitoring installations at some wetlands.
Outflows from the system	
Groundwater flows directly to the sea; Groundwater flows to the marshes and mudflats around the coast (notably the North Norfolk Coast and Breydon Water);	Liaison with forthcoming PhD project at University of East Anglia. Detailed quantification of water balances for catchments with a component of outflow to the sea/marshes.
Baseflow to rivers;	Detailed examination of components of the total hydrograph. Integration of baseflow processes in conceptual and numerical models will permit sensitivity analysis.
Groundwater and surface water abstraction;	Collation of existing records. Un-metered flows estimated using Agency experience.
Pumped drainage from IDB systems;	Collate existing information from IDBs. Build on work by Holman to develop abstraction history from electricity records.
Evaporation from wetlands, Broads and parts of the drained marshlands.	Detailed water balances, building on work by Birmingham University (wetlands) and by Holman et al (Thurne catchment)
Flows through the system	
Reliability of some of the river gauging stations (see Appendix A);	Critical assessment of uncertainty in flows, and the effect on water balances/conceptual understanding.
Discharge rates from main Sewage Treatment Works;	Larger STWs now metered remotely. Smaller STW flows to be estimated from population density.
The spatial distribution of runoff and baseflow, including in the upper headwaters of the rivers;	Distributed effective rainfall/water balance and runoff-routing calculations include headwaters.
Direction and quantity of flow within the artificially drained systems, and discharges to/from these systems to the natural channels;	Review of Agency maps, liaison with IDBs, field confirmation. Incorporate into flow routing quantitative calculations.

Box 7.1 (continued) Uncertainties in Understanding of the Hydrogeological System

Uncertainty	**Method of reducing uncertainty in the Yare & North Norfolk Project**
The non-tidal/tidal interface;	BFASEM project will provide detailed information on river flows. Possibility of surveys to establish groundwater baseflows to tidal rivers.
Storage/retention of water in the Broads;	Project will quantify inputs to Broads. Analyse gauged outflow information.
Groundwater/surface water interaction;	Critical review of existing hydrogeological, hydrological and hydrochemical information. Design new monitoring installations at some wetlands.
Groundwater movement through complex superficial deposits;	
Hydrogeological behaviour of wetlands	
Distribution of fissuring within the Chalk;	Detailed assessment of geological information from boreholes. Possible evidence for buried valleys from pumping tests
Effect of buried valleys;	

7.2 Project Meetings (Task 1)

Project meetings are essential to keep the relevant interested parties informed of project progress and to provide opportunity for critical review, discussion and if necessary, modification of the project programme. Conversely, it is equally important not to become hide-bound by prescriptive scheduling of meetings, or to convene meetings unnecessarily frequently.

The preferred option for frequency of meetings and proposed attendees is as shown on Figure 6.3. The Project Working Group should meet regularly during the course of the work: it is anticipated that this will be approximately every 4-6 weeks on average, but the precise timing will be governed by project progress, such that there is a particular focus to the meetings. The Project Review Group, including external advisors, should meet at key stages, such that the external advisors can usefully fulfil their QA role. Presentations to the Stakeholder Advisory Group should be made every 4 months or so, to keep interested parties and consultees external to the Agency informed of developments, and to give them an opportunity to comment on project progress.

Minutes of these meetings will be important documents, and it is essential that they are produced in a timely fashion to avoid perpetuation of misunderstandings. It is anticipated that, in general, minutes of meetings will be produced within one week of the meeting taking place. Responses to the minutes should be received within a further week to avoid being 'overtaken by events'. In general, minutes will be circulated to attendees only, but the minutes of the Project Working Group meetings will be sent in addition to the external advisors as a means of keeping them regularly informed.

A minimum option here would be to reduce the frequency of meetings from that preferred, and present results to the Stakeholder Group only at the end of Stage 1. It is considered that this would give rise to both:

- Insufficient Agency contact with and review of the Project;
- Insufficient communication with stakeholders.

The long term risk attached to these deficiencies is the failure of Stage 1, and ultimately the total Project, deliverables to be adopted by Agency staff or accepted by stakeholders. Such failure would effectively remove all potential benefits from project activities.

Allowance should also be made for a number of site visits within the performance of the work, to verify or investigate particular features or uncertainties as they arise. Although these may effectively form part of the appropriate 'technical' task, the visits will undoubtedly serve more than one purpose, and are therefore grouped separately.

Table 7.1 Stage 1 Task List and Component Activities

Task	Title	Component Activities	
1	Project Meetings/Visits	1.1	Inaugural and Progress Meetings
		1.2.	Stakeholder Advisory Meetings
		1.3	Site visits
2	Data Assembly and Collation	2.1	Meteorology
		2.2	Hydrology
		2.3	Groundwater levels and quality
		2.4	Abstraction
		2.5	Discharge
		2.6	Topography and river bed profiles
		2.7	Surface Water Quality
		2.8	Hydrogeology
		2.9	Land Use
		2.10	Soils
3	Geology	3.1	Borehole logs
		3.2	Geological maps and reports
		3.3	Produce cross-sections and maps
4	Land Use and Drainage	4.1	Land use data
		4.2	Surface drainage data
		4.3	Underdrainage data
		4.4	Population distribution and leakage
		4.5	Integrate with shallow geology
		4.6	Derive digital distributed drainage network
5	Local Studies	5.1	Review of wetland dossiers etc
		5.2	Hydro-ecological desk studies
		5.3	Ecological desk Studies
		5.4	Design of monitoring networks for sites with none.

Table 7.1 (continued) Stage 1 Task List and Component Activities

Task	Title	Component Activities	
6	Literature Review	6.1	Review and abstract full bibliography
		6.2	Identify and in-depth review of key documents
7	Data Catalogue	7.1	Integration with current practice and GIS
		7.2	Deliver databases, maps, spreadsheets etc.
	Interim Project (Collation) Review		
8	Rainfall Distribution	8.1	Distribution in space
		8.2	Distribution in time
9	Groundwater Head Interpretation	9.1.	Hydrograph analyses and comparison
		9.2	Integration with geology: groundwater movement within/between formations, inc. wetlands
		9.3	Map representation of contours at specific times and levels
		9.4	Pumping tests and parameters
10	Interpretation of Hydrochemical Data	10.1	Spatial and geological patterns
		10.2	Temporal trends
		10.3	Discharge to wetlands
		10.4	Risks to quality
11	Riverflow Analysis	11.1	Hydrograph naturalisation
		11.2	Baseflow separation
		11.3	Contributory areas and artificial drainage
		11.4	Accretion profiles
		11.5	Relationship of flows, rainfall intensity & SMD
		11.6	Groundwater interaction, including Broads and wetlands
		11.7	Relationship to IDB activities
		11.8	Interaction of fluvial/tidal reaches
12	Effective Rainfall Calculation	12.1	Potential evapotranspiration
		12.2	Evaporation from wetlands
		12.3	Impact of current land use
		12.3	Impact of historic land use
		12.4	Near surface soil processes
		12.5	Riparian zone behaviour
		12.6	'Interflow' processes
		12.7	Integration with geology and drainage
	Interim Project (Analysis) Review		
13	Calculation of Preliminary Water Balances	13.1	Individual catchment total and groundwater balances
		13.2	Regional total and groundwater balance (excluding tidally influenced area)
		13.3	Regional balances including tidally influenced area
		13.4	Variations with time
		13.5	Evaluation and uncertainty
14	Development of Conceptual Model	14.1	Synthesis of all data and interpretation into an internally consistent concept
		14.2	Assess plausible alternatives
		14.3	Assess and quantify uncertainties

Table 7.1 (continued) **Stage 1 Task List and Component Activities**

Task	Title	Component Activities	
15	Proposed Development and Refinement of Numerical Model(s)	15.1	Representation of concepts
		15.2	Boundary conditions
		15.3	Space and time discretisation
		15.4	Recharge input and groundwater/surface water interaction
		15.5	Parameterisation
		15.6	Requirement for local 'nested' models
		15.7	Integration across the Chalk Basin
		15.8	Data shortfalls
		15.9	Uncertainties
16	Define Further Investigations	16.1	Identify 'spot' measurement and surveys
		16.2	Identify long term monitoring needs
		16.3	Costs and benefits
17	Formulation of Stage 1 Report	17.1	Description of work completed
		17.2	Presentation of Task 2-6 (Data)
		17.3	Presentation of Tasks 8-11 (Integration)
		17.4	Water balances
		17.5	Conceptual and numerical Models
		17.6	Further investigation requirements
		17.7	Database maintenance requirements
18	Stage II PID	18.1	Summary of Stage 1 Report
		18.2	Review of overall project business case
		18.3	Phase 2 costs and benefits
		18.4	Programme review
19	Stage III PID		Provisional, depending on Stage 2 requirements

7.3 Data Collation

7.3.1 Task 2 Hydrogeological and Meteorological Data Assembly

This task refers principally to data already held in digital or paper format within the Agency, water companies, the Ordnance Survey, the Meteorological Office and the IDBs (see Section 5 and Appendix A). There are options associated with many of the data sets in terms of depth and extent of coverage. Although it is anticipated that most emphasis in the interpretation of data will be placed on the period 1970 to date (which will be referred to as the 'main project period', so chosen because it includes a number of 'wet' and 'dry' climatic periods), useful information about the behaviour of the system may be gained by collating selected long term records, where available. Certain statistical analyses may also be facilitated with longer time series of data. The cost implications of acquiring these data are small, and the potential benefit in developing understanding is high.

Meteorology

The primary data sets of interest are rainfall and potential evapotranspiration, and how they vary both temporally and spatially.

The main rainfall data sets are:

- daily data held by the Agency;
- 15-minute data held by the Agency;
- Data held by Norfolk County Council for 'roadside' gauges;
- Long Term Average (1941-1970) data on a 1 km^2 grid (held by the Agency);
- Long Term Average (1961-1990) data on a 1 km^2 grid for each calendar month (held by the Met Office).

It is believed that the Met Office do not hold any additional rainfall records.

The preferred option for rainfall is to collate all Agency held daily data, the Long term Average data (calendar monthly from the Met. Office) and selected 15-minute data. It is anticipated that this will permit adequate definition of spatial variability for recent years, and there are several long term records back to early this century. There is good coverage of rainfall information throughout the majority of the 'main project period'.

Selected 15-minute data will be used to assess the hydrological response to short duration events, which may be important to developing the understanding of runoff processes.

Although not the preferred option, the option to collate additional data from the NCC gauges, as well as additional 15-minute data, should be retained as a possibility should detailed spatial variability and/or short-term response become important issues.

The main data sets related to potential evaporation are:

- MORECS 1600 km^2 data, held by the Agency;
- Single site MORECS, held by the Met Office;
- Long Term Average (LTA) data (1941-1970) on a 1 km^2 grid, held by the Institute of Hydrology;
- Component 'weather parameters', such as relative humidity, sunshine hours etc., held by the Met. Office, which could be obtained and used to calculate PE using alternative methods to MORECS if appropriate;
- Some measurements on wetland sites undertaken by Birmingham University in the late 1980s/early 1990s.

The preferred option is to use MORECS 1600 km^2 data, supplemented by the LTA distribution. Spatial variability (as measured at climate stations) is not expected to be great, and it is considered that this option will be adequate for the majority of the area covered by this project. The site specific data reported by Birmingham University will also be collated.

It is possible that this may not be adequate in some isolated areas, such as the North Norfolk Coast: this may require collection of new data.

Hydrology

The main river flow data sets are:

- daily flows at gauging stations;
- 15-minute flows at gauging stations;
- routine current meter gauging;
- current meter gauging to derive accretion profiles;
- ad hoc gauging undertaken during licence determinations (held within the licence files).

All these data sets are held by the Agency. The preferred option is to collate daily flows and current meter gaugings for routine checks and accretion profiles. The usefulness of the ad hoc gaugings will depend on the frequency of measurement (spatially, which could supplement the accretion profile data) and the time of year at which measurements were undertaken.

It is anticipated that the 15-minute data would only be examined either to resolve persistent discrepancies in water balance calculations, or to assess rainfall-runoff relations for individual events in fine detail.

Surface water levels are measured in a variety of environments:

- tidal reaches of rivers (recent digital data, historically paper charts);
- dyke levels in wetlands;
- lake levels in some Broads.

The preferred option is to collate the wetland and Broads levels, and the digital tidal level data. It is unlikely that tidal levels in the rivers will be sufficiently useful in terms of this projects objectives to warrant digitisation of the historic paper charts.

The on-going Broadland Flood Alleviation Strategy Environmental Monitoring (BFASEM) programme analyses (amongst other things) tidal levels at selected locations, and has extracted annual maximum water levels from paper chart records. Appropriate exchange of data between the Yare & North Norfolk project and the BFASEM project should be established.

Groundwater levels and quality

Groundwater levels are available from the following sources:

- Agency routine monitoring network, including wetland monitoring;
- 'spot' readings from well logs;
- 'spot' readings from the licence determination files;
- monitoring associated with landfill sites (held by the Agency);
- monitoring associated with RAF Sculthorpe (held by the Agency);
- groundwater contour maps in the Section 14 report;
- groundwater contours on the published hydrogeological map.

Groundwater levels form a key data set, and the preferred option is to collate extensive information from all these sources, with the exception of the ad hoc measurements in the licence determination files; this latter source will be searched only for sites known (to Agency licensing staff) to have useful groundwater level monitoring.

The main sources of groundwater quality data are:

- Agency held routine monitoring;
- data in Hiscock (1986);
- data associated with specific studies, such as landfill investigations.

The preferred option is to collate the digital Agency data and that provided in Hiscock (1986) since these provide good regional coverage. Data associated with landfill investigations is likely to be specifically targetted, and may not add to regional understanding.

Abstraction data

The main data sets are:

- surface water licensed quantities (held by the Agency);
- monthly returns for major abstractions (Agency);
- daily take at selected river intakes (Anglian Water Services and Essex & Suffolk Water);
- groundwater licence information (Agency);
- monthly groundwater returns (Agency);
- daily groundwater abstractions (Anglian Water);
- electricity usage records for IDB pumping stations.

Abstractions form a fundamental part of the water balance, and so the preferred option is to collate all these data sets. A lesser option would be to ignore the daily data and the IDB electricity records, but this is not recommended, since there may be important insights into overall system behaviour in these data sets.

Discharges

The main data sets are:

- surface water consents to discharge (held by the Agency);
- daily flows from selected Sewage Treatment Works (Anglian Water Services);
- electricity usage records for IDB pumping stations.

Again, these data form a fundamental part of the water balance, and the recommended option is to collate all these data sets. (Note that discharges from smaller STWs can be reasonably well estimated from a knowledge of the populations served).

Topographic Information

Data sets potentially available include:

- OS paper maps;
- PANORAMA: OS digital data on 50 m grid (held by Agency);
- PROFILE: OS digital data on 10 m grid (available to the Agency on request from OS);
- LIDAR (elevation on 2 m grid) surveys for selected areas (held by Agency);
- surveyed cross-sections for main rivers, held on paper maps at Agency Norwich office;
- surveyed cross-sections in lower river reaches, available (as drawings only) on BFAS CD-ROM;
- fly new LIDAR surveys;
- Digital Terrain Model on 50 m grid, held by Institute of Hydrology (derived from OS information, with additional input relating to drainage networks. The data set may not be entirely reliable in 'flat' areas).

The preferred option is to use existing PANORAMA data, supplemented by existing LIDAR on 'flat' areas such as floodplains, marshes etc., and 'calibrated' against river stage and bed elevations extracted from the cross-sectional surveys.

An option should be retained to examine topography (specifically drainage direction) in more detail using either PROFILE or existing LIDAR surveys. Note that LIDAR surveys have been flown over the majority of river corridors and 'flat' drained marshland areas within the project area, with the exception of some small areas on the North Norfolk coast. Although it is thought unlikely that new LIDAR surveys will be commissioned by this project, it remains an option to fill in these few gaps.

Surface Water Quality

Data sets potentially available include:

- Public Register information (held by the Agency);
- 'historic' information held by the Agency on microfiche;
- records held by Anglian Water Services and Essex & Suffolk Water;
- salinity measurements from some tide gauges;
- Broads Authority/English Nature survey of 'ditches';
- ad hoc information for Thurne catchment held by Norwich Museum.

The preferred option is to collate Public Register information, supplemented by the BA/EN survey and data from Anglian Water. Data on microfiche will only be accessed if water chemistry proves to be useful in distinguishing between alternative concepts of system behaviour. The salinity measurements from the tide gauges are unlikely to add significant information to this project. The Thurne data are written up in the literature and need not be collated separately.

Again, the BFASEM project collates some surface water quality measurements, specifically chloride and salinity, pH, temperature, dissolved oxygen and conductivity.

Hydrogeology

Data on hydrogeological properties are available from:

- the published Aquifer Properties Manual/Database;
- pumping tests undertaken as part of licence determinations, but which were not included in the Aquifer Properties Manual.

The preferred option is to use the Aquifer Properties Manual data, although the option to trawl through the licence determination files should be retained, in case the distribution/resolution of date in the Aquifer Properties Manual proves to be inadequate.

Land Use

Information on land use is available from a variety of sources. Options for data collation include:

- obtain copies of 1930s First Land Utilisation Survey maps (from the London School of Economics);
- manually extract grid of land use from 1930s maps;
- manually extract grid of land use (say on 250 m grid) from 1960s Second Land Utilisation Survey maps (available for inspection via Professor Coleman, London);
- ITE Land Cover Map (held by the Agency);
- ITE Land Cover 2000 map (available late 2000, will be obtained by the Agency);
- MAFF parish statistics;
- Edinburgh University 25 km^2 data (agricultural coverage only), available annually;
- processing of selected LANDSAT images (by the Agency NCEDS, Twerton);
- aerial photograph collections held by NCC at Gressenhall.

The preferred option is to use the 1990s ITE map and a manually digitised gridded version of the 1960s Land Utilisation maps: this will capture the main changes over the period of most interest at good spatial resolution. These should be supplemented by the ITE Land Cover 2000 map when this becomes available. Copies of the 1930s maps, available at low cost, will also be obtained to set the historical perspective.

Data from the Edinburgh University database may be used as a relatively inexpensive rough guide to changes within the period separating the Land Utilisation maps and the ITE dataset, although this would not permit derivation of detailed distributed data sets. Similarly, it may be useful to examine selected aerial photographs for particular sites (although these will not be purchased).

The option to process selected LANDSAT imagery, most probably from the 1970s or 1980s should be retained as a possibility.

Soils

Data sets available are:

- paper maps at various scales, with associated memoirs;
- dominant HOST classification soil type on 1 km2 grid (available from Institute of Hydrology);
- digital soil association distribution on 100 m grid (available from Soil Survey).

The preferred option is to obtain the digital soil association distribution, (this would permit derivation of HOST types if needed), although the paper maps and memoirs will also be obtained as background information.

7.3.2 Task 3 Geology

Geological information clearly forms a key data set, since the geology is the framework through which the groundwater moves. In terms of potential options for this project, there are two major aspects to consider, i.e. the source of geological information and how best to store that information for future use by the Agency.

The main potential data sources are:

- paper geological maps and associated memoirs;
- digital geological maps (which will be obtained by the Agency as they are released);
- paper well logs held by the Agency (which should be a duplicate of the data set held by BGS Wallingford);
- shallow borehole data in BGS Mineral Assessment Reports;
- data in the BGS Geoscience database (held at Keyworth, and a superset of the Wallingford data);
- data held by NCC;
- new field mapping.

Options for storage of geological data include:

- WellMaster, being developed by BGS Wallingford to store a digital version of their paper records. The Agency and BGS have in principle agreed to a Memorandum of Understanding that aims to populate WellMaster with information over the next few years;
- HYDROLOG, already in use by the Agency to store hydrometric data, this is also being used in Central Area (and also in Thames Region) to store geological information;

- a much simpler form of database, little more than a spreadsheet containing information on formation boundaries, depth of fissuring etc.

More detail on these options is given in an annex to this report.

The aim of geological analysis **for this project** is to produce an understanding of the geometry and juxtaposition of **hydrogeological units**, which may not correspond directly to geological formations.

BGS have not yet transferred any records for Anglian Region to WellMaster, and therefore there are currently no readily available digital geological borehole records that this project can take advantage of.

The preferred option for geological data collation is to use the paper logs held by the Agency, supplemented with data from the Mineral Assessment Reports, selected information from a relatively small number of boreholes on the BGS Geoscience database (deep boreholes or those that fill spatial data gaps) and some information from the NCC archive.

The currently preferred option for data storage is to use a relatively simple spreadsheet, since this is adequate for the purposes of the project. Discussions will be held with BGS however, to ensure that the nomenclature and geological divisions used are compatible with those used in WellMaster, such that the information can be downloaded into WellMaster at some future time (we understand that this approach has been used recently on a data collation project in Cheshire).

Alternative options within this task include:

- enter 'hydrogeological' data directly onto WellMaster (it is possible to enter 'partial' datasets for a borehole, that can later be upgraded with other information on borehole construction, chemistry and water levels);
- enter data onto HYDROLOG;
- collate entire data set from BGS Geoscience archive;
- collate entire data set from NCC;
- undertake extensive new field mapping of superficial deposits.

Whichever options for collation and storage are chosen, the output from this task will be maps and sections showing **hydrogeologically relevant** geological structure. Great care will need to be applied to any contouring undertaken as part of this task: any automated contouring will need to be checked manually. Further checks on contouring can be introduced by 'building downwards' from land surface using formation thicknesses, and comparing the resulting elevations with maps derived from formation elevation data directly.

7.3.3 Task 4 Soils, Land Use and Drainage

Understanding of the land use and land drainage of the project area will be critical to developing a quantifiable conceptual understanding of the area. This is a task for which limits are difficult to identify and the requirement for additional work in Stage 2 can only be identified from review of Stage 1 conclusions.

The preferred and alternative options for collation of land use and soils data have been given in Section 7.3.1. Under Task 4, this will be supplemented by a review of the detailed land use survey of part of the Bure catchment undertaken by Reading university for the Agency.

It is expected that part of this task will comprise discussions with appropriate staff from the Agency and IDBs to develop as detailed an understanding as possible of the history of drainage development in the area. Likewise, additional contact with the NFU, MAFF and/or ADAS may be useful in deriving the detail of historic changes in land use and drainage management. It will be important to derive an acceptable means of converting available electricity records from IDB pumping stations to quantity of water pumped. Relationships have been derived for selected pumping stations, but this should be extended to the remaining stations.

These data sets and discussions will be supplemented by information from the Institute of Hydrology underdrainage database and limited field inspection.

This task will also include the derivation of a digital representation of the current drainage network for subsequent use in later tasks (specifically Tasks 11 and 12). It is proposed that the 'outflow direction' data set from the Institute of Hydrology DTM is considered as a first pass at this drainage network. This data set was derived from OS information, supplemented by some drainage direction information derived directly from maps. The IH consider that there may be some localised errors in 'flat' areas such as the drained marshlands (hydrometric areas 32 and 33, not within this project area, have been 'specially treated' in an attempt to overcome these problems).

It is vital that the pattern of the drainage network is adequately represented, and so the IH dataset will be (manually) critically compared to information from the IDB drainage maps held by the Agency. If necessary, the network can be re-calculated using a combination of these maps, the existing IH data, OS PANORAMA data, LIDAR (if available early in Stage 1, if not then there may be a need to update/verify the network later) and digitised channel patterns.

Whichever technique is used, it is important to verify the digital network by visual comparison with published maps and by consultation with Agency staff and appropriate staff from IDBs. Experience elsewhere has shown that a few iterations, building in more local knowledge each time, may be required before an acceptable result is produced.

The distribution of soil types across the area may have an influence on water behaviour. It is proposed to obtain a digital data set of the distribution of soil associations on a 100 m grid: this distribution will be used in assessing the distribution of runoff and recharge throughout the area.

7.3.4 Task 5 Local Studies

There are 32 wetland SSSIs with European designation within the Yare & North Norfolk areas (see Appendix A). Twenty of these already have hydrological dossiers. Eight have full hydro-ecological desk studies. Fifteen of the sites have hydrogeological monitoring system installed, typically consisting of one deep and 2 or 3 shallow piezometers and 1 or 2 gaugeboards. Figure 7.2 summarises the current status of wetland information in the area.

This task will therefore comprise review of the existing dossiers, full hydro-ecological studies of 12 sites, ecological studies of 12 sites to supplement existing hydrological reports, and probable design of monitoring for 17 sites (2 of which will be funded from AMP3). Although the installation of monitoring would effectively be part of Stage 2, a site visit to each of the locations will be necessary during Stage 1 to verify detail locations, access etc. and also to permit familiarisation with each site. Because of the relatively accelerated programme of compliance with the Habitats Directive, it is possible that Stage 2 activities at these sites will start in advance of other 'regional' sites.

It is not anticipated that detailed new ecological surveys will be carried out, since a large amount of information for each site already exists within English Nature, the Broads Authority and the Agency. The task will comprise liaison with these organisations and collation of the data. Any significant historical changes in site ecology will be especially important to note, as will an assessment of particular susceptibility of fauna and/or flora to potentially drier conditions.

The aim of the hydrogeological studies is to collate information from sites close to the wetland and develop a conceptual model of the local system behaviour, including the production of geological cross-sections and an assessment of possible alternative interpretations. This will allow the design of monitoring installations to confirm (or deny) the proposed conceptual models. Depending upon local site conditions and availability of existing information, it is anticipated that newly proposed monitoring will be along similar lines to that at wetland sites already monitored, and will include some of the following:

- installation and long term monitoring of piezometers at different depths in the solid geology and superficial deposits beneath the wetland and in shallow hand augered piezometers.
- levelling surveys of bank tops, drain bottoms and stream beds which may strongly influence wetland water level regimes.
- intensive monitoring of an extensive network of temporary shallow hand augered piezometers, surface water gaugeboards and site raingauge over a short period (e.g. a month). All the water levels should be surveyed to Ordnance Datum. This type of study can provide invaluable insight into shallow groundwater flow paths, the influence of surface drainage and short term responses to rainfall and evapotranspiration.
- flow measurements of discrete surface water inflows and outflows.
- hydrochemical and ecological surveys which may identify distinct zones where Chalk groundwater discharge or interflow contributions from the superficial deposits are more dominant.
- judicious use should be made of dataloggers to examine short term changes in measured levels/flows.

Preliminary estimates of the effect of nearby abstractions could be made using simple approaches such as the MIROS method (Williams et al, 1995), which combines water balance calculations with straightforward analytical calculations. This method also allows computation of the so-called Sum Exceedence Value (SEV), which can be linked to the success (or otherwise) of different vegetation types. It is expected that these simple calculations would be refined by the use of local numerical models later in later stages of the project.

It is anticipated that site specific wetland dossiers and reports arising from this part of the work will be produced as standalone documents, and will not form part of the 'Stage 1' project report.

The Stage 1 report will integrate hydrogeological concepts arising from the study of wetlands however.

7.3.5 Task 6 Literature Review

Appendix B provides a bibliography of reports and published papers relevant to the study area, as currently identified. It is anticipated that this list includes all of the key references relevant to the study area. As these documents are reviewed, more references will come to light and the bibliography will expand considerably. On-line searches of library catalogues available on the Internet will also be undertaken: this too is expected to add to the list of references that will need to be reviewed.

The purpose of the literature review is to provide a brief summary and review of each entry and to identify a ranking in order of significance. The suggested categories in this ranking are:

A Key information/data source;

B Some relevant data or information;

C Valid interpretation and opinion;

D Minor source of information;

E Of little use to this project.

These categories can be combined as necessary.

Documents identified as key sources will be extensively reviewed, and new data sets (or at least new additions to existing data sets) may be obtained from them.

There is undoubtedly much overlap between this task and other, more specific, tasks. However, the main aim of the literature review task is to produce a deliverable comprising a database incorporating summaries of all documents reviewed, and an indication of how the information in the document has been used in this study.

The Literature Review must be undertaken, otherwise there is a danger of 'missing' some important existing information. As such, there are no alternative options under this task.

7.3.6 Task 7 Data Catalogue

As a milestone to define the substantial completion of Data Collation it is proposed that the data assembled is delivered (in digital format wherever possible, and compatible with standard Agency software, i.e. ArcView, MS Office) to the Agency and that a brief manual is prepared describing:

- Integration with existing Agency databases;
- Integration with GIS;
- Procedure for updating;
- Appreciation of data quality and coverage.

This is not intended to be a major reporting activity, rather it provides an assurance of data assembly in a format compatible with both Agency practice and data analysis requirements and provides an opportunity for a reassessment of future activities.

The only alternative option under this task is not to deliver the data catalogue at this stage, but wait until the end of Stage 1. It is considered however that delivery would be a suitable 'break point' for interim project review, and also that, by bringing forward these interim deliverables the Agency may obtain benefit sooner than would otherwise be the case.

7.4 Data Analysis

Tasks 2 to 7 will produce a series of quality assured data sets which will require analysis and integration before interpretation and conceptualisation can proceed. Many of the options for Stage 1 are related to the assembly of these data sets, as noted in Section 6.2.

In terms of data analysis, the main options arise from alternative ways, and depth of detail, of assessing the complexity of the hydrogeological regime in parts of the project area. Particularly complex hydrogeological issues are likely to emerge relating to:

- groundwater interaction with the Broads;
- groundwater interaction with wetlands;
- groundwater-river interaction;
- the tidal parts of the system;
- the effect of artificial drainage systems;
- the North Norfolk Coast;
- palaeovalleys within the superficial deposits;
- interaction between the Chalk, Crag and overlying minor aquifers.

In order to understand the water regime throughout the **whole** project area, then **all** of these complexities must be addressed. Depending on the detailed quality and quantity of information, decisions will have to be taken at appropriate points as to the most appropriate techniques of data analysis.

7.4.1 Task 8 Rainfall Distribution

Options for rainfall data collation have been discussed in Section 7.3.1.

This analysis will provide rainfall distribution in space and time for input into subsequent water balance calculations and analysis of ground and surface water hydrographs. Quality of record from each available gauge will have been established under Task 2, and there will be a need under Task 8 to 'gap-fill' in a documented and realistic way in order to produce continuous daily records at each gauge to be used. This will most probably be done by applying simple regression techniques to adjacent gauges, although a viable alternative would simply be to use the record from the nearest gauge without modification.

There will ultimately be a need to understand the distribution of rainfall between gauges, for use in water balance and recharge calculations. As part of this analysis, the spatial pattern of rainfall will be analysed to reveal any potential altitude or other spatial dependency. A number of alternative distribution methods will be assessed to gain a feel for the uncertainty in this data set. It is most likely that rainfall will be distributed in proportion to the long-term average 1 km^2 distribution, available for the period 1961-1990 on a calendar monthly basis. (Note that this data set already includes some altitude weighting, as calculated by the Met Office).

Results of the rainfall analysis will be presented as a series of distribution maps for up to three separate years at two different seasons, as cumulative departures from long term averages and as digital time series data in daily and monthly time steps. If required, pre-calculated distributions for any month can be purchased from the Institute of Hydrology.

If pre-calculated data sets are obtained, it is recommended that the assumptions made relating to altitude or other spatial weighting are critically reviewed (since it is believed that the interpolation algorithms are applied nationally, and do not necessarily take local factors into account).

The preferred option for this task also includes examination of rainfall intensity records from selected gauges to assess the pattern of occurrence of severe events in relation to daily rainfall, time of year, location etc., since this may have a bearing on 'effective rainfall' calculations. Undertaking this activity will permit an assessment of the uncertainty involved in using daily data only. Omission of this activity could result in severe mis-estimation of effective rainfall, a key component of the water balance.

7.4.2 Task 9 Groundwater Head Interpretation

This task is effectively the qualitative analysis of the groundwater hydrographs and their integration with the geological understanding and surface levels. As noted under Task 2, 'spot' water levels from a number of sources will also be examined to extend data coverage, either spatially or temporally. Following this pumping test data and aquifer properties will be reviewed to give an analysis of the lateral and vertical variations of hydraulic conductivity and storage.

The analysis will be based on the comparison of groundwater hydrographs with features such as:

- Rainfall distribution and intensity;
- Borehole construction and length and depth of monitoring zone;
- Distance from river channels, wetlands or drains and relationship to surface water and bed levels;
- Borehole geophysical records and other indicators of fracture distribution;
- Stratigraphic location of monitoring zone.

Groundwater levels form a key data set, and all boreholes for which reasonable time series are available should be analysed. This should include all the Agency routine monitoring locations, boreholes associated with the Bacton pipeline, and wetland piezometers. Results of this analysis will be integrated with more widely distributed sporadic or short time interval data to provide regional maps and cross sections of groundwater levels at different times and in relation to geological subdivisions and surface water bodies.

It will be particularly important to assess differences in groundwater head in the vertical direction both within and between different geological formations where these data are available, since these data can yield most insight to the conceptual model of flow through the system.

Groundwater levels recorded at high frequency (hourly or 15-minute) by dataloggers can be extremely valuable in assessing the system response to discrete events. For example, differences in the timing of response to pumping in water levels observed in piezometers at different depths can yield important clues to 'vertical' hydraulic properties. Similarly, the response of groundwater levels observed close to rivers/drains to changes in river or drain stage arising from tidal processes, fluvial events or drainage operations can be informative. In certain circumstances, rapid groundwater response to rainfall events may be seen. All these styles of response, which may only be measured in sufficient detail by dataloggers, can add to the conceptual model of system behaviour.

Analysis of the groundwater level data is considered sufficiently important that there are no 'reduced' options associated with this part of the task. An extended option would be to include analysis of the ad hoc measurements in the licence determination files.

Changes in groundwater level patterns will be, at least in part, geologically controlled and relating these variations to the geological understanding (Task 3) will identify a framework for analysing the distribution of the pumping test results held by the Agency and in the published literature (particularly the Aquifer Properties Manual). It is anticipated that this will in turn identify broad hydrogeological subdivisions of the geology which, may or may not, be controlled by stratigraphy. Within these subdivisions, or 'hydrogeological units' it may be possible to identify sub-domains that exhibit similar types of groundwater response.

For this part of the task, an option at this stage is to reanalyse the pumping test data in the Ipswich records. There are around 500 tests for which parameters exist on the Aquifer Properties Manual database, and it is presumed that these are the 'best' tests. However, there are a considerable number of other tests (of varying duration, extent and quality) not included in this number (possibly around 2000), which could be re-assessed to extract whatever meaningful information can be derived from them. This would be an extensive task with possibly limited benefit as it is expected that Agency staff will probably have already analysed those tests of suitable data quality. However, it is possible that hydrogeological knowledge (either locally or regionally) and methods of interpretation may have improved since the time of analysis, and therefore this option should still be considered as part of the process of applying the best possible analysis techniques to the available data.

7.4.3 Task 10 Interpretation of Hydrochemical Data

Collation of water quality data sets has been discussed under Task 2.

The processing, analysis and interpretation of these data has two main aims during Stage 1. The first of these is the need to provide maps of key water quality parameters that would be of use to Agency licence determination officers, water resource planners etc. The second aim would be to assess how hydrogeochemistry could be used to further hydrogeological understanding.

The first aim is mainly a data presentation task, whereas the second involves detailed analysis with the objective of improving understanding. The preferred option is to undertake both parts.

Areas to which hydrochemistry could contribute include the substantiation of hydrogeological subdivisions, to support the interpretation of interaction between surface water and shallow and deep groundwater, and to help identify any changes in system behaviour through time. Experience elsewhere suggests that the data quality will be such that the number of analyses suitable for the first two purposes may be limited, however temporal changes in system behaviour can often be identified from much smaller data sets, for instance a series of conductivity measurements.

For hydrochemistry map production, the data collated under Task 2 would be compiled into a single database. Experience from other regions indicates that incompatibility of parameter names and units (e.g. mg/l HCO_3 or $CaCO_3$, or mg/l N or NO_3) can complicate this task. Where possible the quality of the data would be assessed using ionic balances and consideration of spatially anomalous data for evidence of contamination. Maps would be produced showing the recent (1998-1999) distribution of key parameters, distinguishing where appropriate between waters derived from different aquifers. The key parameters would most likely include:

- electrical conductivity or TDS to provide an indication of the degree of mineralisation or salinity of the water.
- chloride to help outline areas of brackish or saline waters and to update the existing (~1976) 1:100 000 scale Hydrogeological Map of the Region.
- hardness as a general water quality parameter and again to update the existing (~1976) 1:100 000 scale Hydrogeological Map of the Region.
- nitrate to help outline areas of recent recharge, but also identify nitrate sensitive areas. We would anticipate showing designated NVZ's.
- iron as this is sometimes high in the Crag and affects the potability of the water resource without treatment.

The second component of this work would be to build on the hydrochemical knowledge derived from the literature review (Task 6) by carrying out an appraisal of existing hydrogeochemical studies.

This appraisal would identify where existing hydrogeochemical studies (notably Hiscock, 1985) had contributed to hydrogeological understanding, for example by defining recharge mechanisms, groundwater flow regimes from interfluves to valleys and at the limit of the Eocene, groundwater ages, etc.

The methods and conclusions of previous studies will be critically reviewed in the light of uncertainty which could affect the degree of confidence in the results (for example, data quality issues and recent developments in the understanding of hydrogeochemical processes such as the denitrification potential of glacial tills). The availability and reliability of recent hydrochemical data would then be reviewed to determine whether sufficient information exists to employ similar methods to refine, update or extend the understanding.

It is anticipated that, as a minimum, it should be possible to extend the 'water types' map (and inherent hydrogeological understanding) produced by Hiscock for the Wensum-Bure catchments to the remainder of the project area, although data coverage may be relatively sparse in some areas. Recommendations could then be made as to the cost effectiveness of any further hydrochemical work that might be scheduled for Stage 2.

In summary, it is anticipated that this hydrochemical evaluation will provide a qualitative contribution to the understanding of:

- Groundwater/surface water interaction;
- Recharge processes through the Drift;
- Groundwater movement within the Chalk and Crag;
- saline intrusion from the coast in response to deepening of drainage levels or abstraction;
- flows to wetlands;
- runoff of agricultural pollutants into surface watercourses.

7.4.4 Task 11 Riverflow Analysis

Understanding of the river flow hydrographs throughout the area will be an essential component of the data analysis contributing to both the quantification and routing of runoff and the understanding of the pattern of surface water/groundwater interaction.

There are gauges on most of the major rivers close to the tidal limit. River reaches above these locations are amenable to 'standard' hydrograph analysis. Complete understanding of the components of the hydrograph is unlikely to be achievable until modelling (Stage 3) provides an acceptable quantification of recharge to or discharge from groundwater, but a preliminary analysis can be made, comprising naturalisation and baseflow analysis.

The naturalisation process will allow for known surface water abstraction and discharge, to produce a 'natural' river flow that still comprises runoff, interflow and net baseflow. The Institute of Hydrology baseflow separation method can be applied to this natural flow to provide a preliminary indication of baseflow. The naturalisation task may be complicated by interaction of the 'natural' river channels with IDB systems, even in the fluvial reaches (the 'finger boards').

The naturalisation activity requires some processing of data sets collated during Task 2, as well as supporting anecdotal information. These include:

- generation of IDB pumping from electricity records;
- discussions with IDB and Agency staff regarding operation of drainage pumps/sluices etc;
- generation of estimated discharges from rural Sewage Treatment Works;
- generation of estimated discharges from larger STWs prior to commencement of the daily flow records;
- generation of estimated surface abstractions where these are not known.

It will also be important to bear in mind the accuracy of flows recorded at all gauging stations (error estimates for a range of flows are available, see Appendix A).

No flow measurements are recorded in the tidal sections of rivers, and so no hydrograph analysis is readily possible. (Note that it may be possible to collect some flow data at suitable times of the tidal cycle within Stage 2 of this project using ADCP technology). River level records from the tide gauges will be analysed in an attempt to define any seasonal or longer term changes. (This will draw on any analyses already conducted under BFASEM). The levels can also be compared to any groundwater observations close to the rivers to assess the nature of groundwater /surface water interaction in the lower reaches.

Note that the BFASEM project does not currently collect any flow data from the tidal reaches of rivers, but liaison with this project should be maintained to maximise the benefit derived from any field surveys aimed at collecting such information.

In relating these analyses to drainage patterns and contributing areas it will be essential to understand the complexities of irrigation and drainage off takes and returns that occur on many of the main rivers, particularly in their lower reaches, and it will no doubt be necessary to consult with IDB staff with a knowledge of pumping operations. This relating of hydrograph analysis to understanding of drainage will be complemented by correlation with groundwater levels (Task 9) and examination of accretion profiles in relation to near surface geology and groundwater levels. A key feature here will be flow profiles across the edges of poorly permeable surface deposits (where runoff-recharge might be expected) and it is likely that this will be an area for further data collection. It is only possible to collect such data reliably during periods of relatively low flow: it is expected that some data collection will occur in summer 2000, i.e. within Stage 1, to avoid delays in the overall project timescale.

Quantification of the relationship of river flows to the numerous wetland sites, the Broads and the regional groundwater data will be a key contribution to the development of the conceptual understanding of the area.

Major areas of uncertainty and anticipated data scarcity associated with riverflow analysis include:

- interaction with wetlands;
- storage in/flow through the open water bodies of the Broads;
- lack of quantification of IDB activities, drainage returns in winter, irrigation abstraction in Summer;
- interaction of fluvial/tidal systems;
- interaction of tidal system with groundwater.

All of these issues must be rigorously addressed and related uncertainties evaluated.

Another important sub-task to be conducted here is the analysis of suitable isolated rainfall events to investigate the relationship between rainfall intensity, antecedent conditions (i.e. the current soil moisture deficit) and runoff generation. Experience has shown that empirical relationships can be derived, and incorporation of such relationships in the conceptual thinking can make a significant difference to water balance calculations. These empirical relationships can be assessed against the equivalent relationship that would arise from using the HOST classification (see Task 4). Liaison with Agency hydrologists will be important here, as work may already have been done in the development of transfer functions relating rainfall to river flows as part of the Anglian Flow Forecasting and Modelling System (AFFMS).

An option under this task would be not to try and understand the interaction of natural flows with the artificial drainage system, since this may be a very complex task. However, it is considered that this knowledge may be very important in developing water balances and the preferred option is to include this analysis.

7.4.5 Task 12 Effective Rainfall Calculation

Derivation of effective rainfall represents the first step towards production of total and groundwater balances. By incorporating existing knowledge of parameter distribution and drainage networks, and then comparing calculated streamflows (which will be total except for baseflow) against gauged flows at several stations, this task is intended to build confidence in the understanding of the distribution of physical processes across the study area.

Preferred options for collation of data sets that will be used within this task have been discussed in Section 6.2.2, and the consequent preferred option for Task 12 would be to use those data sets to perform calculations in a distributed sense. Alternative options do exist. It would be possible to undertake 'lumped' effective rainfall calculations ONLY (i.e. single, non-distributed calculations for each combination of land use, rainfall gauge etc.): whilst this would be a useful 'first pass', it would not improve the understanding of the distribution of different types of behaviour, and the possible consequences for recharge and river flow at individual locations. It would also not permit quantitative assessment of enhanced 'runoff-recharge' around the edge of poorly permeable surface deposits.

A more time-consuming option would be to process weather parameters (see a non-preferred option under Task 2) to provide site specific evaporation data, or to use site specific MORECS, to modify the evaporation distribution used in effective rainfall calculations.

The distribution of evaporation will require further modification related to land use variations both in space and time. In addition, it may be necessary to make special allowances for evaporation from wetlands, other riparian zones and coastal areas.

The distributed rainfall (Task 8) and evaporation data will be processed using accepted soil moisture accounting techniques to provide an estimate of hydraulically effective rainfall over the area. Particular attention here will be paid to the changes in agricultural land use and land drainage (which may have significantly reduced the coverage of riparian areas for example) through time.

Integration of the drainage, landuse, soils and shallow geology information will provide a first view of runoff routing and recharge (on a regular grid distributed across the study area) for input to water balance assessments.

Partitioning of this hydraulically effective rainfall between runoff and recharge is a function of shallow geology and crop type. Mains leakage will also provide some below ground input. The proposed process is illustrated in Figure 7.3; prior data analysis will indicate whether there are any more components to this process that need to be considered.

To maximise understanding and appreciation of the uncertainties involved, it is recommended that this task proceeds through increasing levels of complexity:

- 'simple' soil moisture accounting, with no 'rapid runoff', no limitation on infiltration capacity, no mains leakage or routing;
- incorporate mains leakage;

- incorporate limited infiltration capacity (which will generate an 'interflow' component);
- incorporate routing through the drainage network;
- include surface water abstractions and discharges;
- permit 'runoff-recharge' at the boundaries of poorly permeable surface deposits;
- incorporate IDB pumping.

Since some of these progressive developments require the use of parameter values that cannot easily be measured (e.g. runoff-recharge infiltration capacity) it will be necessary to perform some sensitivity analysis in order to try and quantify the remaining uncertainty in effective rainfall distribution calculation.

In practice there may be much overlap/iteration between this task and Task 13.

Analyses Review

On conclusion of Task 12 comparison of climate, groundwater data and surface water data will provide an opportunity for reappraisal of the subsequent interpretative input and timing of the interpretative tasks.

Deliverables at this stage would be a brief summary of the data analyses carried out with a preliminary summary of the integration of the analyses and a review of the proposed interpretation.

7.5 Data Interpretation and Integration

The data interpretation tasks fall into three broad categories:

- The quantitative integration and interpretation of the data;
- The reporting and presentation of data, results and conclusions;
- The review and preparation for the start of Phase 2 or possibly Phase 3 activities.

7.5.1 Task 13 Calculation of Preliminary Water Balances

The reason for preparation of preliminary water balances is to check on the estimates of natural and anthropogenic inflow and outflow components. In this way a preliminary view of the consistency of the data sets and uncertainties within them is obtained. Both total and groundwater balances should be calculated at this stage.

These water balances will be calculated for each of the fluvial catchments, for which the 'outputs' are reasonably constrained by virtue of the river gauging data. Water balances for the tidal parts of each catchment will be less well constrained, but can be estimated by assuming similar behaviour to the fluvial parts, and pro-rating catchment areas. Results will be presented for an 'average' year and as time series for the main project period (probably 1970 to 1998/99). The components of these water balances are shown in Table 7.2. 'Interflow' processes are assumed to take place 'above' the main contiguous groundwater body, and are therefore not shown on Table 7.2.

Table 7.2 Potential Water Balance Components

	Inputs	Outputs
Total	Rainfall	Groundwater abstraction
	Discharges from Sewage Treatment Works etc.	Surface water abstraction
	Drainage returns (IDB pumping)	Actual evaporation (inc. open water/riparian losses)
	Saline intrusion of groundwater	Total river flow
	Inundation/leakage from tidal channels	Outflow to coastal springs/offshore groundwater
Groundwater	Total recharge, i.e. infiltration and runoff-recharge	Groundwater abstraction
	Stream loss to aquifer	Actual evaporation (inc. open water/riparian losses)
		Flow to gaining streams
		Outflow to coastal springs/offshore groundwater

The principal option at this stage will be the extent to which water balance calculations include or exclude the tidally influenced areas. An objective review of the water balances, including an assessment of uncertainties and sensitivity, should help in defining key data gaps for consideration under Stage 2 activities.

The preferred option is to calculate water balances for both the fluvial and the tidal areas, although it is accepted that verification of the tidal area balances will be difficult.

7.5.2 Task 14 Development of Conceptual Model

The data collation, analysis and water balances will provide the information from which a first stage quantified understanding of how the real flow system operates can be developed.

It is possible that the analysis undertaken to this point will have revealed uncertainties, such that a small number of **alternative conceptual models** may be developed. (It is anticipated that many uncertainties will simply reflect potential differences in the relative importance and magnitude of particular processes, i.e. not requiring any differences in conceptual behaviour).

Descriptions of the conceptual model(s) will include quantification of component processes: it is expected that a range of values will be assigned to all processes, and that for some this range may be relatively large.

These conceptual models will form the foundations on which the distributed numerical model will be built, and as such the ideas embodied within them will require testing and iteration with the water balances from Task 13 (and at a later stage with the numerical model itself).

The conceptual model(s) will be substantiated by appropriate hydrogeological cross sections and plans (incorporating geology and groundwater levels and chemistry), review of water balances and an assessment of the complexities of groundwater-surface water interaction.

A particular issue to be addressed will be the appropriate boundary conditions for the numerical model. Data collection will have covered an envelope wider than the surface water catchments (See Figure 2.1), but there is a possibility that the data analysis and interpretation will have revealed significant uncertainty as to the location of appropriate hydrogeological boundaries. The comparable Ely Ouse study is likely to be at the same stage of development, and so there should not be any great difficulty in resolving boundary conflicts along the common boundary between these two project areas. The boundary with the 'North West Norfolk' and 'Waveney' study areas will not have been assessed in the same detail.

There are no options suggested within this task, since the development of the conceptual model(s) is fundamental to the project as a whole.

7.5.3 Task 15 Proposed Development and Refinement of Numerical Model(s)

Provided that an adequate conceptual understanding has been developed, then it should be possible to produce a clear specification for numerical model development, including:

- Grid spacing and orientation;
- Layering (geometry of the system);
- time discretisation;
- Boundary conditions;
- Parameterisation (aquifer types and properties);
- Representation of flow between layers;
- Initial conditions;
- Distribution of recharge;
- Implementation of groundwater surface water interaction;
- method of calibration assessment (calibration 'targets');
- proposed sensitivity analysis;
- integration of local models.

Consideration will be given as to how the numerical model may help to distinguish between the viability of alternative conceptual models.

It is suggested that runoff routing and recharge are derived by use of appropriate algorithms (Figure 7.3) on the same grid as the proposed groundwater model to ensure consistency and ease of data transfer.

Time discretisation will need to be carefully considered: it is anticipated that the model will need to demonstrate good representation of the real system over the period 1970 to the present, since this encompasses a range of hydrological conditions (i.e. 'droughts' and wet periods) and also includes the time over which water use has increased most rapidly. There may be a need however, to try and understand historic changes, possibly pre-dating extensive data sets, since these may provide some guidance at later stages of the project when future scenarios need consideration.

Numerical considerations also mean that there will be a need to simulate several (possibly many) annual cycles before the period of interest (i.e. 1970 to present), otherwise the model may still be 'adjusting' to the imposition of cyclical stresses during the early part of that period. This can be referred to as 'transient initiation' and is necessary if the model results for the full period of interest are to be used. The time required for this transient initiation is a function of hydraulic properties and the length of groundwater pathways through the system. As such it varies across the area, but the maximum estimated time should be considered. It is expected that for this project area this will be a few decades. This could mean that a reasonable representation of inputs to the system over a long historic time period (say back to early this century) may have to be developed. Clearly there will be gross uncertainty in this, but efforts should be made to develop a 'best guess history'.

This task would only be carried out if the conceptual understanding developed throughout Tasks 1-14 justifies it. If extensive further investigations are necessary, then a sensible option might be to defer Task 15 until these investigations have been completed.

7.5.4 Task 16 Define Further Investigations

The range of investigations that might be required for the Yare and North Norfolk Area extends from none through carefully targetted investigations of specific features to new monitoring installations and extended monitoring. These will be identified based on the uncertainty in the conceptual understanding and the requirements of translating the concepts into a numerical model: justification for further investigations will be based on assessment of costs and benefits.

It should be noted here that there is a risk that some field activities will need to be undertaken during Stage 1 to permit the overall project to proceed to timescale.

7.5.5 Task 17 Stage 1 Report

The organisation of the Stage 1 Report will reflect the task organisation and grouping and will be based on the principle of clearly separating data collation and analysis from interpretation. The collated data, hydrographs and databases will be presented as Appendices (based on the submissions prepared in Task 7) and the Main Report will present the analysis of the data sets, their integration and subsequent interpretation and conceptualisation. A generic report structure is:

- Introduction and Literature Review;
- Geological Framework;
- Topography and Drainage (including historical development);
- Soils and Land Use (including historical development);
- Climate and Meteorology;
- Abstractions, Discharges (including IDB activities, drainage returns and abstraction);
- Surface Water Flows (including the Broads);
- Groundwater Levels and Hydraulic Parameters;

- Hydrochemistry;
- Effective Rainfall, Runoff and Recharge Processes;
- Preliminary Water Balances;
- Conceptual Model;
- Proposals for Numerical Groundwater Flow Modelling;
- Uncertainties and Further Investigations.

This Stage 1 Report will be a stand alone, fully reviewed document and is intended to provide an accessible and accepted quantified water resources review of the Yare and North Norfolk areas.

It is anticipated that local studies (into Habitats Directive sites) will be reported separately, although where they contribute to the regional picture, aspects will be included in the relevant sections of the main report.

7.5.6 Task 18 Update PID

Effectively the Stage 1 Report will provide a Scoping Report to support proposals for further Stages of the project: at this time Stage 2 will be scoped and justified in detail. The PID will provide a brief summary of this report and a technical and business case supporting the proposals for further work. (Note that the PID may be further refined towards the end of Stage 2, when the detail of Stage 3 tasks will become clearer).

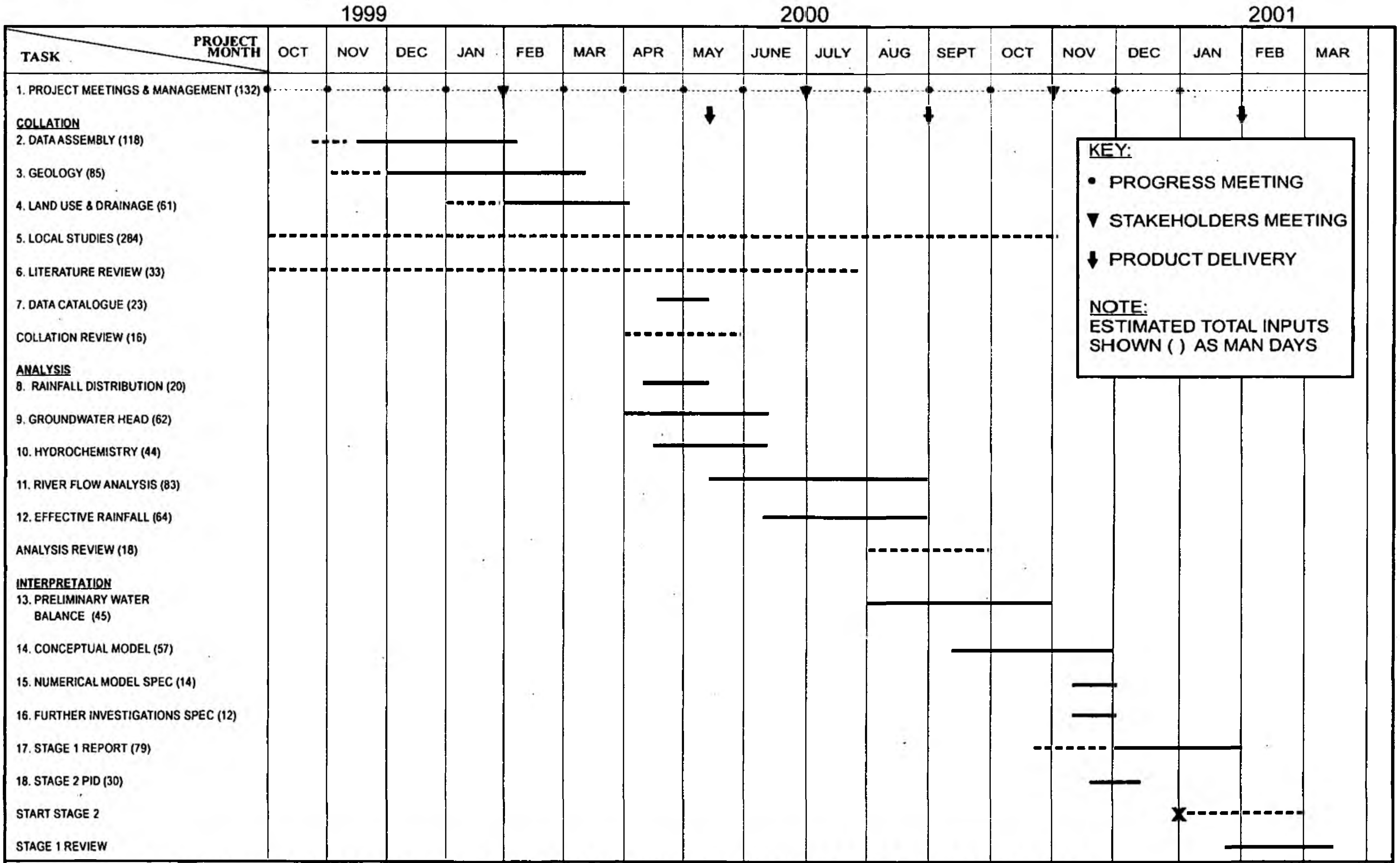

FIGURE 7.1 YARE & NORTH NORFOLK PROJECT: STAGE 1 SUMMARY PROGRAMME

Drawing No: **00732.S022** Date: **SEPTEMBER 1999** Scale: **NTS**

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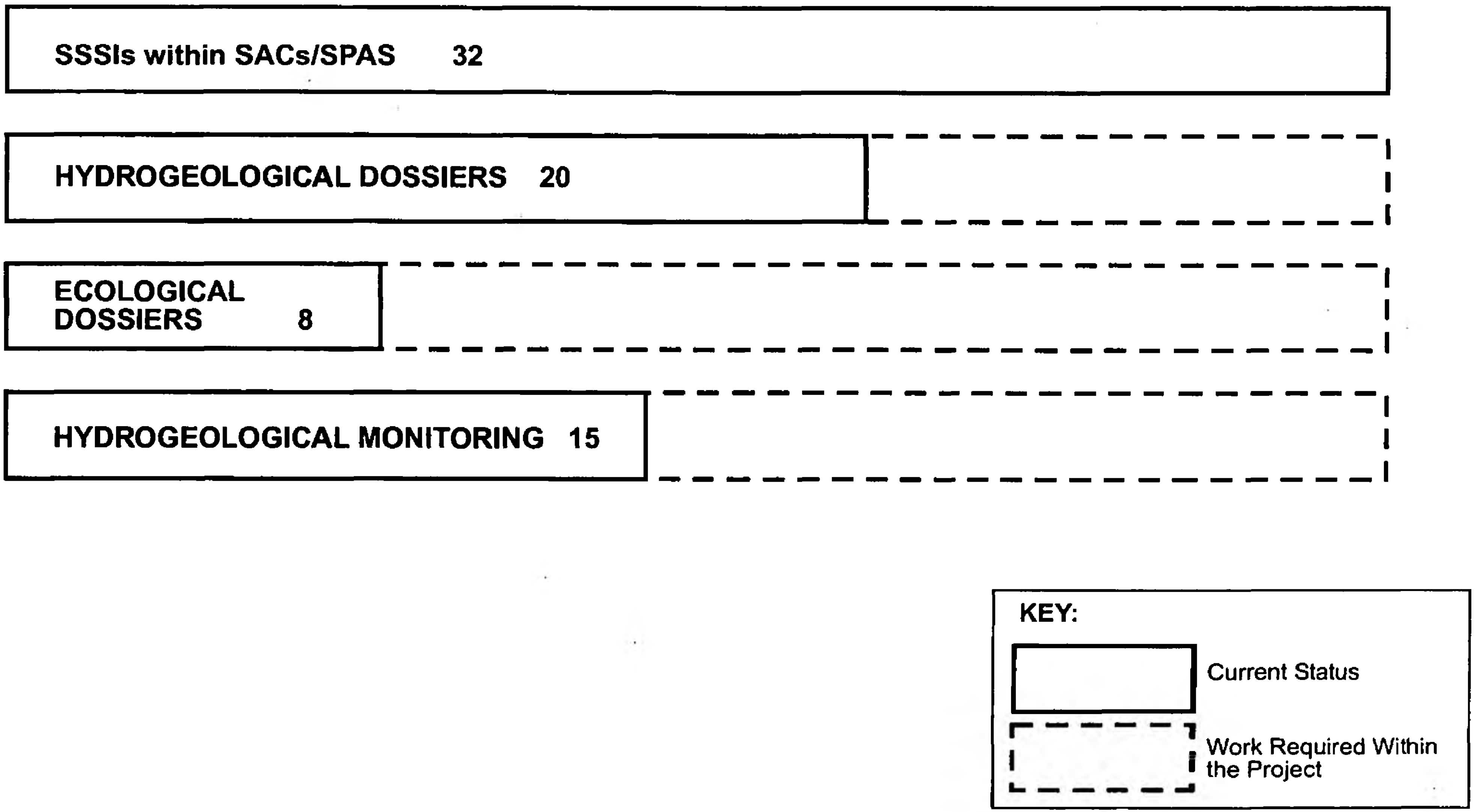

FIGURE 7.2 **HABITATS DIRECTIVE WETLAND SITES WITHIN YARE AND NORTH NORFOLK AREA**

Drawing No: **00732.S019a** Date: **SEPTEMBER 1999** Scale: **NTS**

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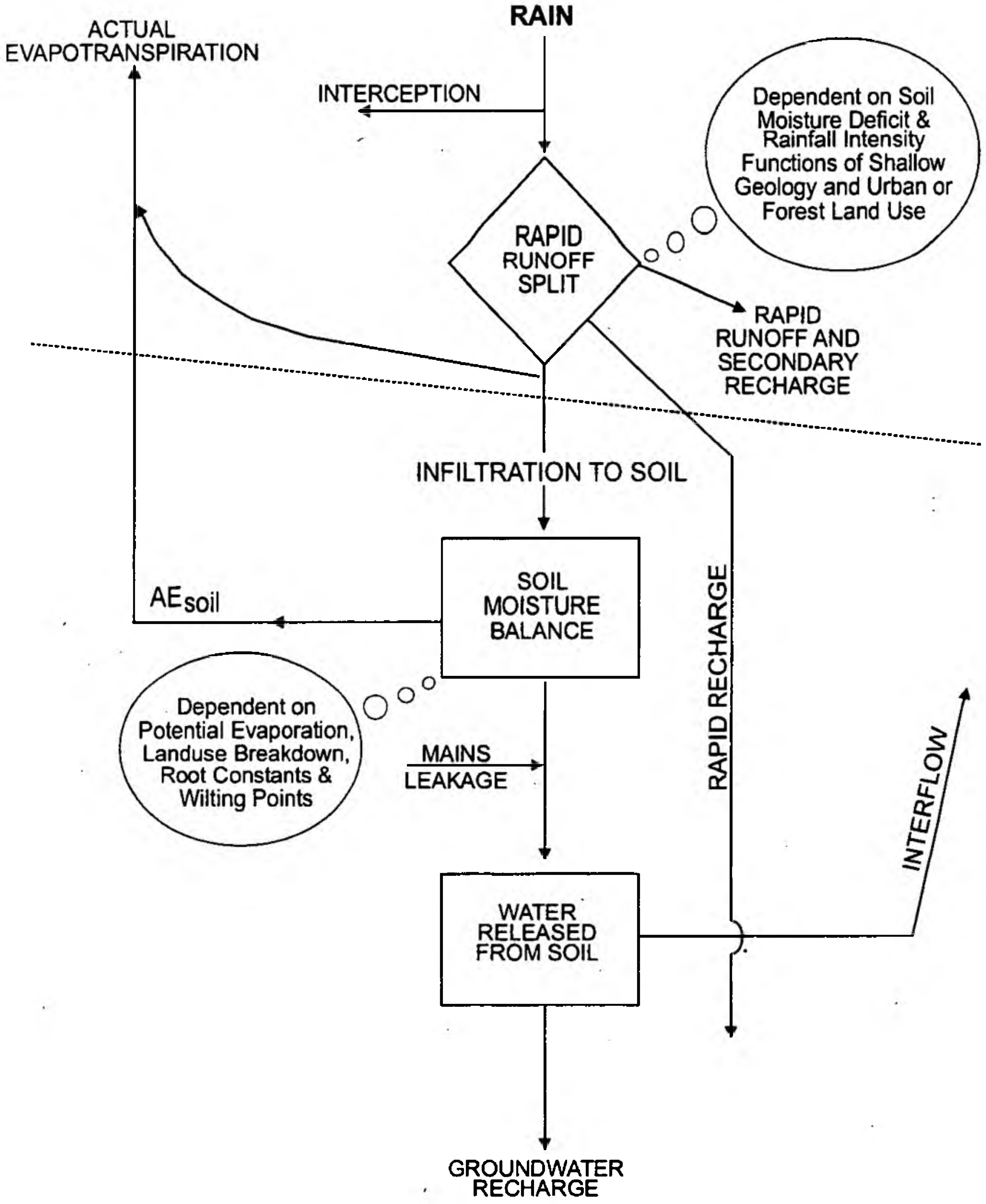

FIGURE 7.3 EFFECTIVE RAINFALL CALCULATION AND PARTITIONING

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8. Yare & North Norfolk Project: Stage 1 Preferred Options and Plan of Work

8.1 Introduction

The tasks outlined in the previous Section are grouped in general categories, which relate to:

- Meetings and review;
- Data Collation;
- Analysis;
- Interpretation.

Within each task there are a range of options that vary the amount of work required and will control the inputs necessary for task completion. Some of these options reflect different 'approaches' to the work: these require differing time inputs and would be expected to affect the outcome of Stage 1, either in the level of conceptual understanding achieved, in the degree to which approval of interested stakeholders is maintained, or in the nature of project deliverables. Other options result from inherent uncertainty in the amount of work required to achieve adequate understanding of individual or integrated data sets, and can perhaps be better described as 'risks': these may affect the time inputs required, but are not expected to affect the anticipated outcome of Stage 1. For example, it is estimated that an understanding of the hydrochemistry can be achieved for an input of 44 staff-days, but there is a risk that the development of this understanding may in fact require 107 staff-days. The outcome in terms of understanding is the same, but the time inputs required are greater.

The 'risk'-type options are dealt with within a risk management framework, such that a contingent cost is allowed for in the PID that accompanies this Scoping Study. The 'approach'-type options are indicated below.

The range of options available within each task is summarised on Figure 8.1, which also indicates estimated time inputs (including Agency, Consultant and External Advisor time).

8.2 Categorisation of Options

There are potentially a wide range of permutations available from the options identified: they can however be broadly classified into a relatively small number of categories.

Reduced Consultation and no interim review: The preferred option is based on approximately monthly meetings of the Project Working Group, four of which would be expanded to include the Project Review Group. In addition, three meetings of the Stakeholder Advisory Group have been allowed. The preferred option also requires Agency and External Advisor input for two periods of interim review on completion of data compilation and analysis. A reduced option could be approximately quarterly project meetings with a single stakeholder meeting at the end of Stage 1, and omission of all interim review activity: it is considered that this would result in greater review demands on completion of the final report and would seriously impair the opportunity which current contractual relationships provide of modifying task requirements as work proceeds.

Undertake Stage 1 water balances and conceptualisation using non-distributed data sets only: the preferred option is to use distributed data sets wherever possible, in order to further the understanding of the variation of hydrological processes throughout individual catchments and the whole project area. A reduced option would be to use readily-available data sets that represent processes integrated over catchments (for example, percentage of land use cover over the entire area above a gauging station, rather than the spatial distribution of land use derived from the ITE map, published Land Utilisation maps, satellite imagery and other sources). Although this would permit relatively rapid calculation of water balances, it would not represent a significant advance on the existing water balances, and would give no scope for detailed examination of local issues in sub-catchments.

Options for geological data storage: the preferred option is a simple approach whereby hydrogeologically relevant geological information from boreholes is stored on spreadsheet or a simple tabular database. An option is to populate the BGS WellMaster database as part of this project. Although the long term view is that migration to WellMaster probably will occur, it is not seen as a priority within the scope of this project.

Pumping test reanalyses: The preferred option is to use pumping test analyses contained within the Aquifer Properties Manual, but an option exists to undertake re-analysis of the many pumping tests held within the abstraction licensing files at Ipswich (see Task 9 in Section 7.4.2). The potential gain to be derived from this exercise, in terms of the requirements of this project which aims to understand the regional hydrogeology rather than the specific behaviour of individual boreholes, is anticipated to be minimal.

Retrieval of hydrochemistry data from microfiche archive: it is thought that the hydrochemical analysis detailed in Task 10 (Section 7.4.3) will be sufficient to identify any enhancements to conceptual understanding that may be derived from the study of water quality records. It is not anticipated that the analysis will indicate that retrieval of data from the microfiche archive would be especially beneficial. Even if this is the case, it is more likely that this would be scheduled to take place within Stage 2.

Drift and drainage remapping: if properly specified and executed, this option would undoubtedly refine the understanding of recharge and runoff routing, but the extended time frame that this activity would impose on the whole project could jeopardise achieving important project deadlines, and the benefit would therefore be reduced appreciably.

8.3 Comparison of Input Estimates

Time inputs for Agency and Consultant staff and External Advisors have been estimated for the preferred option and for the options noted above. The estimated total input time for the preferred option is 1306 staff-days. Variations from this estimate for the other options are shown on Figure 8.2. From this it is apparent that each of the potential reductions from the preferred option impact the total input by around 7% each. The impact of each of the potentially extended options are in the range 5-20%. If extreme combinations are considered, then the range of input required ranges from 14% less to 30% more than the preferred option.

MANAGEMENT REVIEW & CONSENSUS

1. MEETINGS
c. Monthly +3 Stakeholder (132)
c. Quarterly +1 Stakeholder (-57)

REVIEW OF DATA
Complete (16)
Do Not Complete (-16)

REVIEW OF ANALYSIS
Complete (18)
Do Not Complete (-18)

FINAL REPORT REVIEW
Complete (26)

COLLATION

2. DATA ASSEMBLY
Complete (118)
Lumped Catchment (-16)

3. GEOLOGY
Agency+Some BGS+NCC (85)
Add WellMaster Population (+47)
Add Remapping (+250)

4. LAND USE+DRAINAGE
ITE map (1990). plus Land Utilisation Surveys (61)
More Satellite Imagery (+20)
Remapping (Included in 3.)
Lumped Catchment (-12)

5. LOCAL STUDIES
Assessment of Habitats Directive Sites (284)

6. LITERATURE REVIEW
Complete (33)

7. DATA CATALOGUE
Complete (23)
Do not Complete (-23)

ANALYSIS

8. RAINFALL DISTRIBUTION
Complete (20)
Lumped Catchment (-6)

9. GROUNDWATER HEAD
Without Pumping Test Reanalysis (62)
With Pumping Test Reanalysis (+78)

10. HYDROCHEMISTRY
Regional Assessment (44)
Include Archive Data (+63)

11. RIVER FLOW
With drainage interaction (83)
Rivers only (-23)

12. EFFECTIVE RAINFALL
Complete (64)
Lumped Catchment (-16)

INTERPRETATION

13. WATER BALANCES
With Tidal Areas (45)
Without Tidal Areas (-10)
Lumped Catchment (-12)

14. CONCEPTUAL MODEL
Complete (57)
Lumped Catchment (-12)

15. NUMERICAL MODEL SPEC
Complete (14)
Defer (-14)

16. FURTHER INVESTIGATION
Specify and Define (12)

17. REPORT
Complete (79)
Defer (-79)

18/19. PID
Complete (30)
Defer (-30)

NOTES:
- Preferred Options are underlined.
- Figures in brackets are estimated staff days input (including Agency, External Advisors and Consultant Staff) for the preferred option and changes to input requirements for the alternatives.

FIGURE 8.1
YARE & NORTH NORFOLK PROJECT-
SUMMARY OF STAGE 1 TASK OPTIONS AND INPUT ESTIMATES

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Date: SEPTEMBER 1999	

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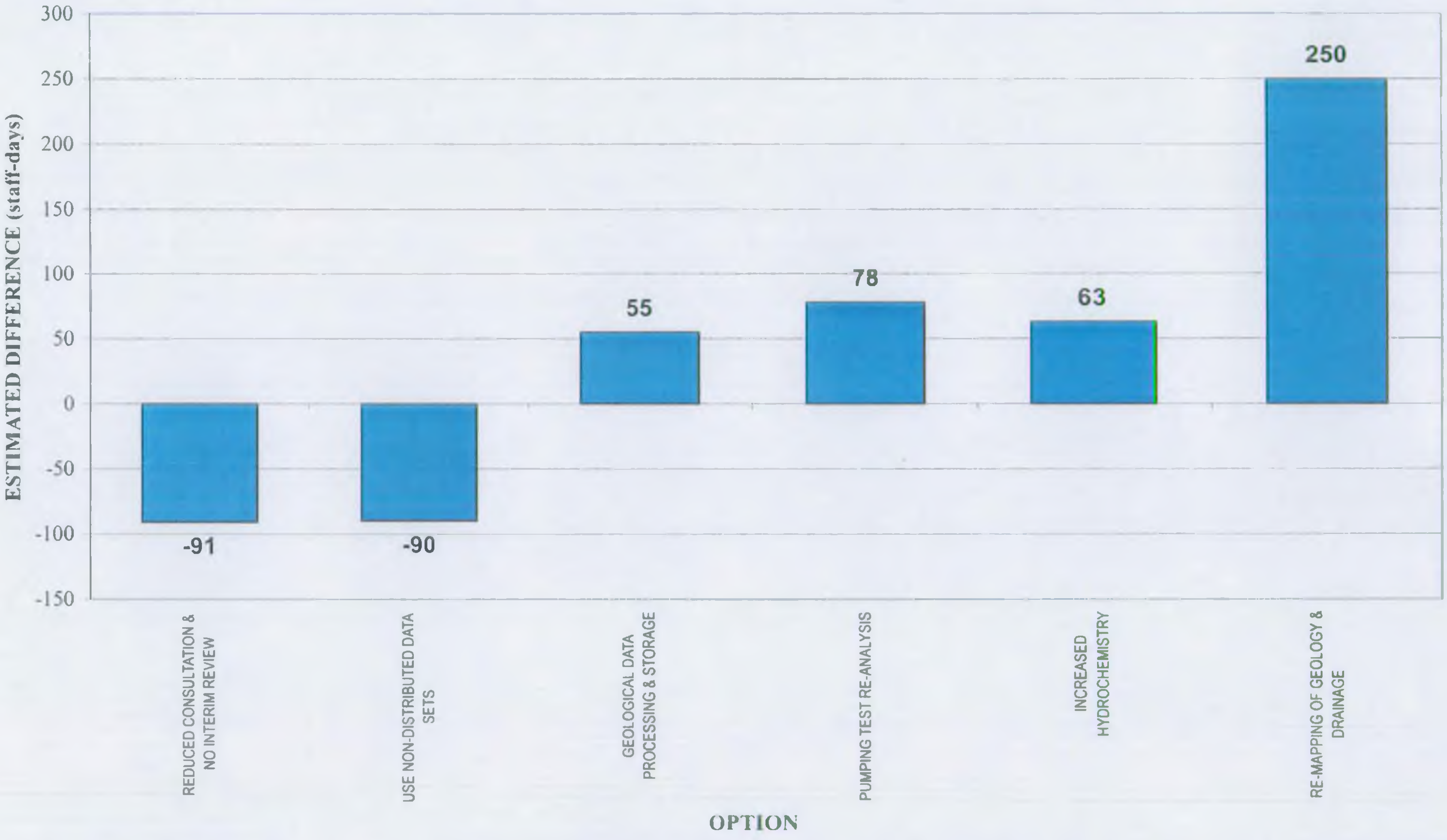

FIGURE 8.2 YARE & NORTH NORFOLK PROJECT: VARIATIONS FROM PREFERRED OPTION ESTIMATE

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9. Yare & North Norfolk Project: Stages 2 to 5: Potential Options and Outcomes of the Overall Project

9.1 Introduction

At this Scoping Stage of the Yare & North Norfolk Project the biggest uncertainty of scale in future activities is the extent of additional investigations that may be required during Stage 2. These investigations will be focussed on either improved quantification of processes contributing to recharge to or discharge from the system, or on reducing conceptual uncertainty to a level at which digital model realisation is justified. This section addresses the range of options for these investigations and identifies a 'most likely' course of action based on the present impression of the data quality and coverage.

After Stage 2 the range of options decreases, although the option to curtail the project, should priorities change, remains. During Stage 3 (Numerical Model Development) costs may be uncertain (see PID) as development of models of complex natural systems cannot always be accurately predicted. At Stages 4 and 5 the extent to which the model is used will largely be a function of the Agency's priority issues in 2003/2004.

9.2 Stage 2

During or towards the end of Stage 1 sufficient information will become available to provide a detailed description of the range of options for further investigations. These investigations will focus on reduction of conceptual uncertainty to a level that minimises the risks associated with proceeding to development of a numerical distributed groundwater model(s) of the Yare & North Norfolk area. Reasons for not proceeding with Stage 2 could range from the understanding being sufficiently certain that no further investigations are necessary to being so uncertain that the time or costs for the necessary investigations are prohibitive. Both of these scenarios are considered unlikely. The range of potential investigations between these two extremes is the principal topic of this section of the report. Figure 9.1 illustrates this potential range.

A key aspect of all these alternatives will be the allowance of sufficient time to process and interpret the results obtained. Towards the end of Stage 2 an updated PID for Stage 3 will be required.

Habitats Directive/AMP3 Only: Under the Habitats Directive the Agency have a statutory obligation to carry out study and investigations of European designated wetland sites potentially impacted by abstractions. There are a significant number of such sites within the project area. Many of these sites are already instrumented with piezometers, gaugeboards etc, to measure ground and surface water levels, but there are a number of sites (12) where there is no existing monitoring. Desk study, planning of proposed investigations and preliminary land acquisition for those sites requiring new monitoring installations will have been done within Stage 1. The actual monitoring installation will form a component of Stage 2 (although it is noted that the timing of Stage 2 activities focussed on Habitats Directive sites may have to occur on a shorter timescale than more 'regional' considerations). AMP3 investigations will be similar to those required under the Habitats Directive but will cover SSSI's without European designation. The AMP3 programme will not be fully defined until autumn 2000. The timing of monitoring installation and future modelling for these sites may be such that it will be appropriate to carry out this work under Stage 2. This would enable the local work to be set in the context of the regional conceptual understanding and might also be an opportunity to develop a source of funding external to the Agency.

Compliance with the Habitats Directive is an obligation, not an option. The Agency has, quite rightly, determined that 'appropriate assessment' cannot be undertaken without some site specific monitoring, and as such the work proposed here will go ahead. This work is therefore the minimum Stage 2 activity and is included in each of the subsequent options. If there are no other components to Stage 2 this work could continue in parallel with Stage 3 (Model Development).

Further Desk Study: In connection with the geology, drainage, hydrochemistry and land use components of analysis to be undertaken in Stage 1, limits have been imposed on the estimated inputs that, at present, are deemed to represent a judicious balance between cost and benefit (in terms of increased understanding). It is possible however that major uncertainties may remain on conclusion of Stage 1 or that Stage 1 activities will identify valuable additional data sources. Should either of these alternatives identify a need for further substantial synthesis of existing records (say in excess of 5% of the agreed Stage 1 input) it may be appropriate and cost effective to include this work within Stage 2.

Information sources which might require work at this stage are:

- purchase of additional satellite imagery, most probably LANDSAT images from the 1970s and 1980s, and processing to derive land use distributions**;
- more detailed investigation of the artificial drainage network;
- more detailed investigation of historic land use changes and land use distribution;
- collation and processing of site-specific evaporation data from the Met Office**;
- collation and analysis of hydrochemistry data on microfiche archive at the Ipswich office**;
- Detailed search of local museum archives.

It is likely that some additional work of this nature will be included in Stage 2 activities. (Note that those items marked ** could be undertaken within Stage 1, depending upon interim findings of Stage 1).

Specific Local Studies: (These are local studies in addition to those that will be required at wetland sites covered by the Habitats Directive). In Section 4 of this report an appraisal is made of issues and uncertainties in the Project Area. It is probable that at least some of these uncertainties will remain on conclusion of Stage 1 and that they will require specifically targetted field investigations. Most of these potential investigations are aimed at increasing knowledge of groundwater/surface water interaction:

- Variations in runoff and infiltration in Drift covered areas and across the Drift/Chalk boundary. This may require 2 to 3 months small channel and stream gauging at carefully selected locations**;
- Surface water channel/groundwater relationships may require temporary shallow piezometer and gaugeboard installation at selected locations and continuous monitoring of levels for a period of a few months. This work may be appropriate at specific locations to assess the relationship between groundwater and surface water in the Broads or in the drained marshland system;
- Calibration of suspect long term monitoring installations;
- discharges to inter-tidal marshes and mudflats;
- evaporation in coastal areas.

Monitoring installations and one years monitoring: Current main hydrometric datasets exhibit reasonable spatial and temporal coverage, although there are some gaps. The ongoing asset survey and the Stage 1 activities will identify the relative importance of filling these gaps in relation to development of understanding of the system. With the current state of knowledge, the possibility of extension of this network by construction of further semi-permanent surface or groundwater monitoring installations cannot be ruled out. The most probable types of monitoring to be required again relate to the interaction of groundwater and surface water, but could also consider the relationship of groundwater in different geological formations, especially the Crag and the Chalk around the limit of the Lower London Tertiaries.

Should such installations be required two aspects will have significant programme impacts:

- The time required for access and land acquisition and the time required for contractual procurement of the work;
- The need to ensure that monitoring is carried out over a minimum 12-month period to provide data for all stages of the seasonal cycle.

Although the full benefit of such monitoring data may not be derived for 12 months, it is unlikely that the project would need to come to a complete standstill whilst these data were collected. It is most probable that the project would proceed, and that the 'new' data would be assimilated later.

Monitoring installations and more than one years monitoring: Depending on the nature of any data/knowledge gaps identified, it is possible that extended monitoring at 'new' locations may be required before the project can progress in a meaningful way. It is probable that Stage 3 could progress after one years monitoring, but with the intention of reviewing and revising model development at subsequent times as more data become available. (This would sensibly happen anyway as part of on-going review of model performance during 'tactical use' that would follow Stages 4/5).

Should extended monitoring become necessary before proceeding with Stage 3, then the overall programme implications will require detailed evaluation, particularly with respect to the timescale for compliance with the Habitats Directive. If an extended timescale for monitoring is unavoidable for the 'regional' project, then the possibility of linking model development (Stage 3) for two or more of the sub-areas of the East Anglian Chalk Basin should be evaluated.

Extensive field surveys: This option for Stage 2 is a remote possibility, which if required would cast doubt over the overall project feasibility. If the limits of understanding derived from Stage 1 are sufficiently poorly developed that there are gross uncertainties remaining that affect compilation of meaningful water balances and development of sensible conceptual models, then there a need could be identified for extensive field surveys, significant new monitoring installations ad a long period of data collection and analysis. If this is the case, then it may be necessary to reconsider not just this Project but the complete Strategy for Groundwater Investigations and Modelling.

From the current perspective the most likely requirements for Stage 2 activities are the combination of:

- Habitats Directive/AMP3 investigations;
- Limited further desk study;
- Some new monitoring installations;
- Specific local studies.

Estimates of inputs and time requirements are extremely speculative. A total time period of around 24 months is scheduled for the bulk of Stage 2 (see Figure 6.1), but with considerable overlap with Stages 1 and 3. Towards the end of Stage 2, the Stage 1 report would be updated.

At a suitable point within Stage 2, to be determined by an assessment of the adequacy of new data collection, a revised PID for Stage 3 will be produced, such that model construction, if appropriate, can commence without jeopardising overall project completion timescales.

9.3 Stages 3, 4 and 5

The ultimate deliverables from the Yare North & North Norfolk Project are:

- A distributed groundwater model which can be used with confidence as a predictive and management tool;
- A report detailing the results derived from use of the model in the assessment of an agreed range of future scenarios;
- A detailed manual explaining model operation, such that the model can be used in future by staff unfamiliar with its development.

The options pertaining after Stage 2 to reach these deliverables are summarised in Figure 9.2. In order to optimise the project timescale, it is expected that preparations for, and commencement of the initial parts of, Stage 3 can begin during the latter part of Stage 2.

The risks of failing to achieve the expected deliverable products are effectively managed by the continuous process of review and reappraisal through Stages 1 and 2 and the contractual flexibility afford by the Framework Consultancy Agreement to increase, reduce or terminate the work at any stage. A potential option is to terminate the project without undertaking numerical model development (Stage 3). Although a decision will ultimately depend on the outcome of Stages 1 and 2, it is anticipated that this is unlikely to be the preferred option, since many of the project benefits are significantly enhanced by the development of a numerical model.

At this stage the positive options for Stage 3 are to:

- Develop a single distributed groundwater model for the area which is sufficiently detailed to examine most local issues;
- Develop a single model of the area designed to accommodate detailed local models of areas of specific interest within it, particularly wetland sites.

Based on present estimates (Figure 6.1) these options will be assessed in late 2001/early 2002. It would therefore be premature to identify a preference at this stage as developments in computer hardware and software may open new options. Based on currently available computer facilities and experience elsewhere it is estimated that the time required for the development and calibration of an acceptable groundwater flow model of the Yare & North Norfolk area is likely to be in the order of 100 staff-weeks. In order to achieve ultimate project deadlines, it is anticipated that this work will be undertaken over a period of 15-21 months.

Within this period of model construction and development, it will be essential that time is allowed for consideration and evaluation of preliminary model output and the implications that it may have for modification of aspects of the conceptual understanding. One of the principal benefits that will emerge from model development is the imposition of discipline and rigour on conceptual thinking, which might be slightly 'fuzzy' around the edges. There must be adequate iteration between numerical and conceptual model development.

In the latter stages of model development it will be extremely important that stakeholder consultation is maintained. Ultimately confidence in model predictions can only be derived from satisfactory simulation of historically recorded responses of the flow system to accurate representation of the climate and surface water inputs. Agreement of satisfactory simulation can only be achieved by consultation.

While there must always be a real risk that satisfactory matching of data and output will not be achieved, control and review of Stages 1 and 2 will minimise this risk. The final part of Stage 3 will be the agreement of the future management and natural scenarios which the model should address, together with the development of efficient protocols for updating the model with appropriate data as it is collected, 'tactical use' of the model, and on-going review of the conceptual understanding of system behaviour.

Proposed scenarios for examination under Stage 4 are preliminarily identified on Figure 9.2. By the time that these scenarios are investigated (mid-2003), this list may well have been superseded by other issues. The principals of resource management in an area of conflicting resource demands are, however, unlikely to alter. The requirement for the development of a practical tool to support the scientifically robust, efficient and equitable future management of the water resources of the Yare & North Norfolk Area must guide and constrain all stages of the Project.

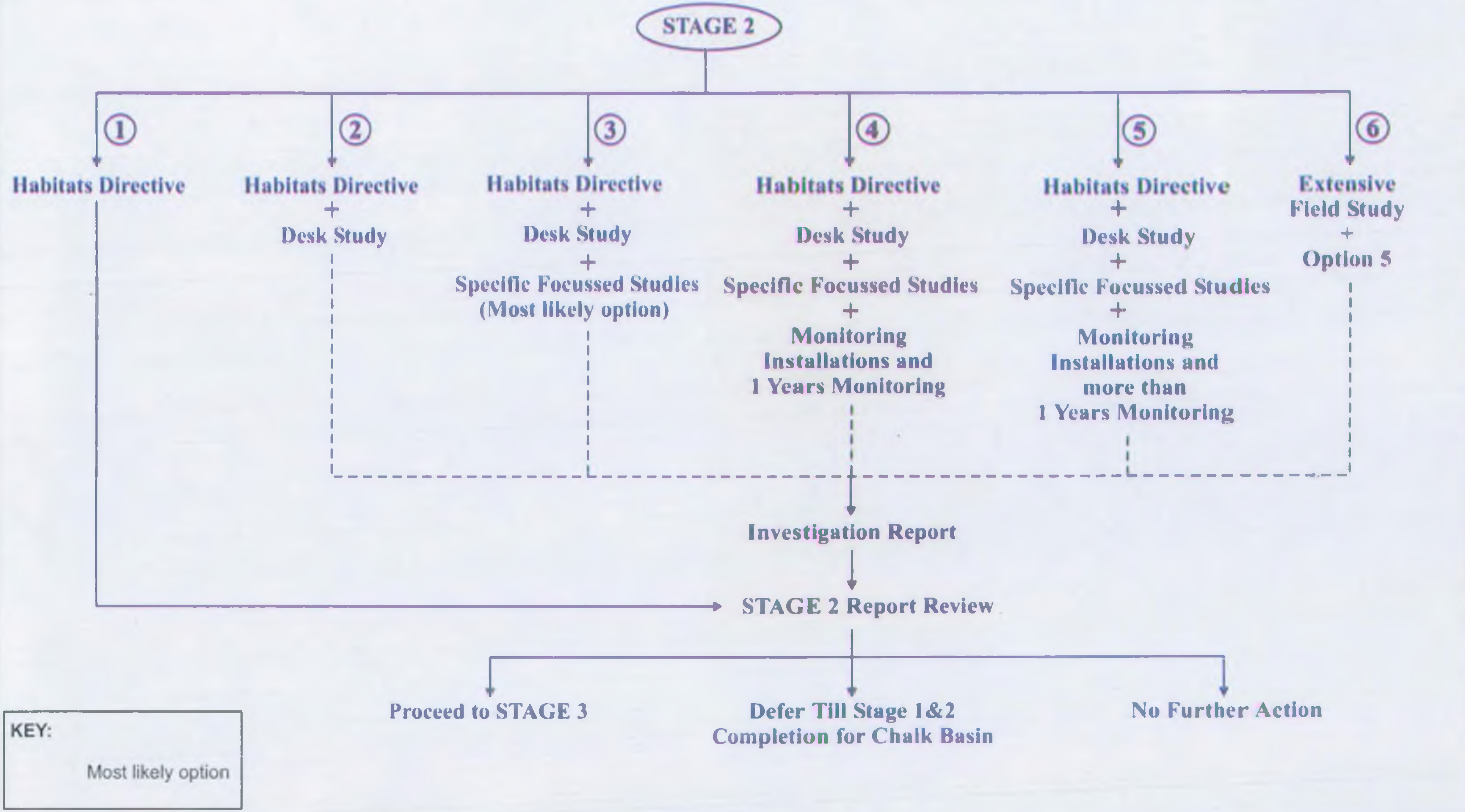

FIGURE 9.1 YARE & NORTH NORFOLK PROJECT: STAGE 2 OPTIONS

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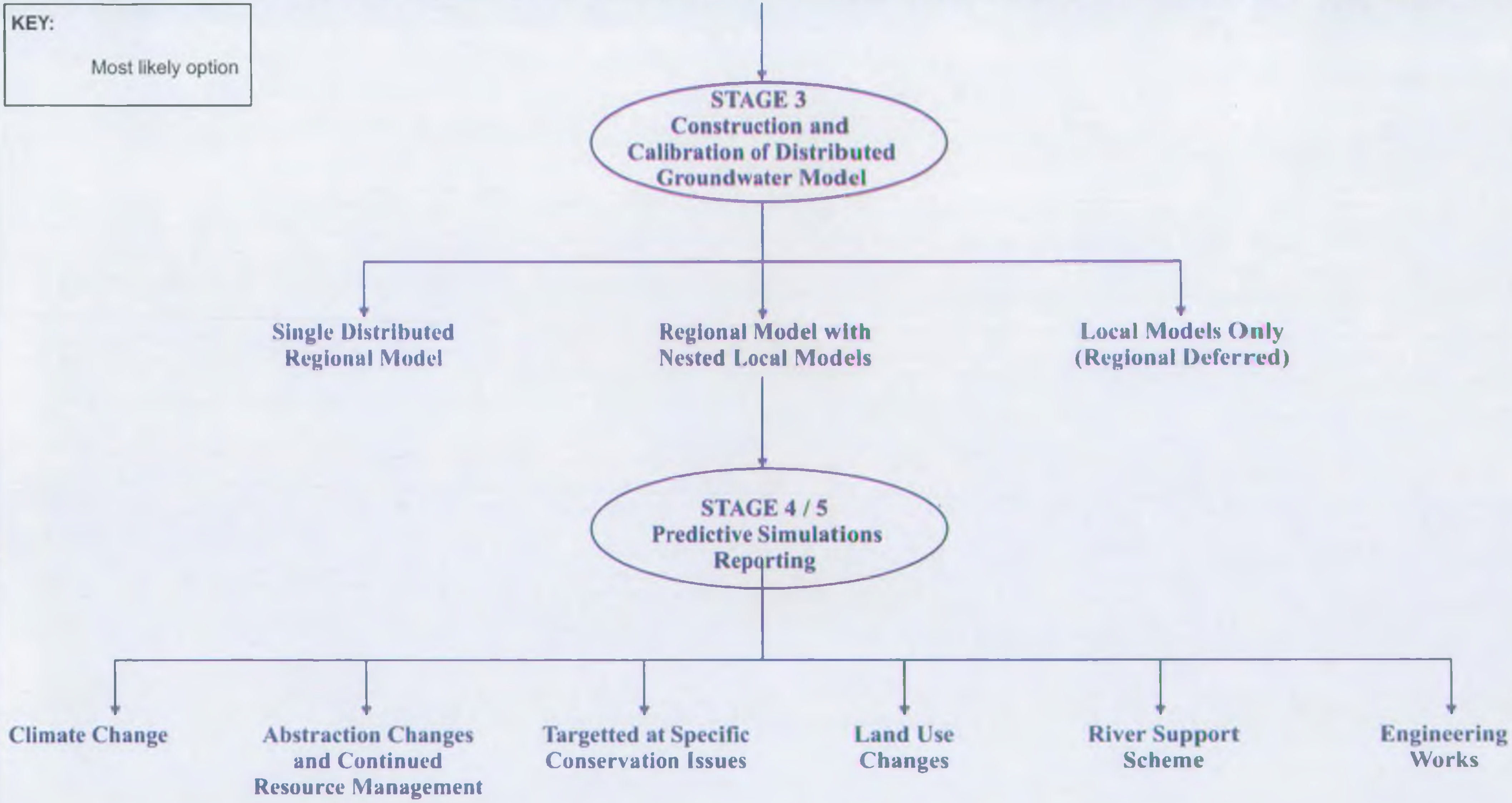

FIGURE 9.2 YARE & NORTH NORFOLK PROJECT: OPTIONS FOR STAGES 3, 4 AND 5

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10. Summary of Recommendations

10.1 Stage 1

The discussions presented in this report have identified a preferred option for Stage 1 of the Yare & North Norfolk Project. Table 10.1 summarises the Tasks and approximate staff-days input estimated for this option.

It is proposed that these activities will take place over a period of approximately 17 months, including a 3 month review period at the end of the Stage. The total estimated input for the preferred option is 1306 staff-days, of which 237 will need to be provided by Agency Staff or their External Advisors. The Agency inputs will principally be directed at project management and review but at an early stage the transfer of field-based knowledge will be important and during interpretation the contributions of Agency area staff will be critical. This option and input estimate is carried forward to the PID and costs and benefits are compared with the groupings of Stage 1 options discussed in Section 8.

10.2 Stage 2

The extent of Stage 2 work represents the greatest range of potential costs of this stage and is unlikely to be quantifiable in detail until Stage 1 activities are well advanced.

It is intended that the PID for this project will be revised to support the recommended Stage 2 tasks. It is possible that this PID will also cover the subsequent project stages. At this stage the most likely Stage 2 activities are probably:

- new monitoring installations at Habitats Directive sites (piezometers, weirs, gaugeboards, possibly weather stations, to be equipped where possible with data loggers);
- further assessment of land use patterns (from LANDSAT) and geological records;
- Stream flow gauging and accretion profiling, especially at boundaries of poorly permeable superficial deposits;
- ADCP surveys in tidal reaches of rivers;
- some semi-permanent river gauging structures;
- Piezometric observation of river groundwater interaction.

Table 10.1 Stage 1 Preferred Option Summary

Activity	**Task**		**Summary and Estimated Input (man-days)**
Management, Review Consensus	1.	Project Meetings	c. Monthly project team meetings, 3 stakeholder meetings, Two Interim Review Stages (192)
Collation	2.	Data Assembly (10)	Include distributed data sets and selected historic information (118)
	3.	Geology	Agency and some BGS and NCC Data (85)
	4.	Land Use, Soils and Drainage	Spatially distributed: ITE map, Land Utilisation surveys, soil association maps, include derivation/confirmation of digital drainage network (61)
	5.	Local Studies	Compliance with Habitats Directive and integration of wetlands information (284)
	6.	Literature Review	Continues through Stage 1 (33)
	7.	Data Catalogue	Complete and present (23)
Analysis	8.	Rainfall Distribution	Discretised on 1 km square, derived form gauged readings and Met Office monthly Long Term Average, also including long historic records (20)
	9.	Groundwater Head	Hydrographs and abstraction of simple pumping test parameters (62)
	10.	Hydrochemistry	Regional assessment without archive surface quality data (44)
	11.	River Flows	Include consideration of interaction wit drainage networks (83)
	12.	Effective Rainfall	Spatially distributed (64)
Interpretation	13.	Water Balances	Whole area including tidal areas (45)
	14.	Conceptual Model	Discussion and graphical representation (57)
	15.	Numerical Model	Specification (14)
	16.	Stage 2 Investigation	Specify in detail (12)
	17.	Comprehensive Report	Complete comprehensive document (79)
	18.	Stage 2 PID	Revised business case and project plan for Stage 2 (30)

10.3 Risk Management

Throughout the project risk will be managed by a process combining:

- Regular progress and task review;
- Clearly defined task briefs;
- Identification of, and in depth review on completion of, tasks within a specific activity;
- Regular stakeholder consultation;
- Regular participation of recognised peer reviewers;
- Flexible contractual arrangements (Term Contract).

10.4 Benefits

The benefits which will accrue from successful project completion fall into three broad categories:

- supporting the Agency in compliance with its statutory and regulatory duties;
- improved technical and conceptual understanding of the area supporting sustainable resource management and resolution of local issues;
- tangible benefits from improved efficiency in performance of regular operations (e.g. Licence Review and Determination) and resultant cost savings and resource optimisation.

These benefits will accrue incrementally during Stages 1 and 2 of the Project but they will only be fully realised on development and acceptance of the calibrated distributed groundwater model as a credible and practical tool for provision of technical support to resource management decisions.

Appendix A
Data Listing and Condition

53 Pages

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Data Listing and Condition

1. Introduction

This document summarises the data available for groundwater modelling in the North Norfolk and Yare North Area (Hydrometric Areas 34/01 to 34/15) which represents the catchment of the rivers listed in Table 1. The area under consideration is shown on Figure A1, on which the hydrometric boundaries and main rivers are also shown.

Table 1 **Hydrometric Areas in North Norfolk and the Yare North Study Area**

Catchment	River Name
34/01	River Hun & Coast
34/02	River Burn
34/03	River Stiffkey
34/04	River Glaven
34/05	River Mun
34/06	River Bure
34/07	Spixworth Beck
34/08	River Ant and Honing Lock
34/09	River Bure below Horstead and River Ant below Honing Lock to Ant confluence
34/10	Hickling Broad
34/11	River Wensum
34/12	River Tud
34/13	River Yare
34/14	River Tas
34/15	Tidal River Yare

The primary source of data reviewed is that held by the Environment Agency but other potentially useful data sources are identified. Most of the data sets were identified during visits to the Environment Agency offices in Ipswich on 28 and 29 April (Tim Lewis) and more detail was obtained during a subsequent visit between 1 and 4 June 1999 (Ben Fretwell). During this second visit, the Agency staff listed below provided much valuable assistance and their help is gratefully acknowledged.

- Marion Martin, Water Resources
- Adrian Green, Water Resources

- David Seccombe, Water Resources
- Victoria Williams, Water Resources
- Andrew Baker, Hydrometry
- Ken McCulloch, Hydrometry
- Simon Wood, Environmental Planning
- Lucy Carter, Hydrometry
- Liz Mullins, Water Resources
- Fiona Ireland, Water Resources
- Jenny Waterworth, Planning
- Graham Robertson, Water Resources

The assistance of Peter Fountain and Chris Gardner on the Public Register in Peterborough and Steve Cook in Hydrology is also acknowledged.

The data collected is reviewed in five sections below.

2. Meteorology

2.1 Available Rainfall Data

The available meteorological data can be divided into rainfall data, collected at numerous sites throughout the area and other meteorological data, collected at only a limited number of sites. Rain gauge data available from Environment Agency records are tabulated in Table 2a (derived from the RAINARK database at Peterborough), and the length of the records illustrated. The table includes gauges currently monitored by the Environment Agency (which have a reference number of the form 34/xx/xx or an alphanumeric reference) and other Meteorological Office gauges (6-figure numeric reference). Note that there are some duplicate entries on Table 2a.

Rain gauge locations are shown on Figure A2. A limited number of gauges record rainfall intensity and these are indicated in Table 2 and on Figure A2. Records for individual raingauges contain gaps in the record and these can occasionally be for extended periods of time. In addition, some of the data is available only as monthly total rainfall.

The Section 14 report produced by Norfolk and Suffolk Rivers Division (1971) contains reference to a number of long term raingauge records: the commencement dates do not always agree with that shown on the RAINARK listing. Gauges for which data for periods earlier than shown on RAINARK may exist are shown on Table 2b.

Table 2a Rain Gauge Data held on RAINARK Environment Agency Peterborough

EA Ref	MO Ref	Station Name	Grid Ref		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
215751	215751	ACLE	TG403103																																		■	■	■	■	■	■		
34/10/04 .	215751	ACLE	TG403103	No Record																																								
34/11/06	207954	ATTLEBRIDGE	TG139157	No Record																																								
207954	207954	ATTLEBRIDGE, OLD HAL	TG139157																					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/06/03	213519	AYLSHAM BANKFIELD HO	TG195273																																			■	■	■	■	■	■	■
213519	213519	AYLSHAM, BANKFIELD H	TG195273								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
213523	213523	AYLSHAM, BANNINGHAM	TG200270			■	■	■	■	■	■	■	■	■	■	■																												
213530	213530	AYLSHAM, DORMIK	TG193268					■	■	■	■	■																																
213520	213520	AYLSHAM, MILL HOUSE	TG198273			■	■	■	■																																			
213518	213518	AYLSHAM, THE MOUNT	TG189270			■	■	■	■	■																																		
213517	213517	AYLSHAM, WILDERNESS	TG190272	No Record																																								
203353	203353	BACONSTHORPE CASTLE	TG121381								■	■	■	■	■	■	■	■	■	■																								
204052	204052	BACTON	TG332347												■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
204062	204082	BACTON	TG339344			■	■	■	■	■	■	■	■	■	■																													
34/05/02		bacton (T)	TG332347	No Record																																								
202802	202802	BARNEY	TF996324							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
34/03/01	202804	barney (T)	TF906324	No Record																																								
202804	202804	BARNEY, BENAYR HOUSE	TF993323																													■	■	■	■	■	■							
215049	215049	BARTON HALL	TG354221			■	■	■	■																																			
215050	215050	BARTON HALL	TG354223																						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/09/02	215050	BARTON HALL	TG354223	No Record																																								
215056	215056	BARTON TURF	TG353217						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																			
BEETLR		BEETLEY	TF988189																																	■	■	■	■	■	■	■	■	
BEETLRC		BEETLY CHECK	TF988189																																		■	■	■	■	■	■	■	
208751	208751	BERGH APTON	TG300021										■	■	■																													
213475	213475	BLICKLING RECTORY	TG179284	No Record																																								
213635	213635	BRAMPTON	TG223240					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																			
202116	202116	BRANCASTER	TF772451																													■	■	■	■	■								
34/01/02		BRANCASTER	TF772451																																			■	■	■	■	■	■	■
202115	202115	BRANCASTER	TF775438			■	■	■	■	■	■	■	■	■	■																													
34/01/02A	202115	brancaster (T)	TF775438	No Record																																								
34/01/02B	202116	brancaster 2 (T)	TF772451	No Record																																								
203553	203553	BRINTON GRANGE	TG039358			■	■	■	■	■	■	■																																
204583	204583	BROWICK HALL	TG130015	1908	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/13/02	204583	BROWICK HALL	TG130015	No Record																																								
215227	215227	BURLINGHAM	TG373101			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																							
202550	202550	BURNHAM MARKET	TF833422	No Record																																								
34/02/03	202611	BURNHAM MARKET	TF836421																														■	■	■	■	■	■	■	■	■	■	■	■
202611	202611	BURNHAM MARKET, CRAB	TF836421																														■	■	■	■	■	■	■	■	■	■		
202521	202521	BURNHAM MARKET, SCHO	TF837420			■	■	■																																				
214033	214033	BUXTON	TG233227	No Record																																								
34/06/06	214018	BUXTON DUDWICK COTT.	TG 222222	No Record																																								
214021	214021	BUXTON, DUDWICK	TG224222	No Record																																								
214018	214018	BUXTON, DUDWICK COTT	TG222222																																				■	■	■	■		
216111	216111	CAISTER HALL	TG503121			■	■	■	■																																			
208928	208928	CANTLEY	TG381048										■	■	■	■	■	■	■	■	■	■																						
34/15/02	208908	cantley oaks (T)	TG380044	No Record																																								
208940	208940	CANTLEY, MANOR HOUSE	TG383051																			■	■	■	■																			
208908	208908	CANTLEY, THE OAKS	TG380044																						■	■	■	■	■	■	■	■	■	■	■	■	■	■						
205960	205960	CARROW ABBEY GARDENS	TG242072	No Record																																								
207818	207818	CAWSTON	TG136238			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																					
209170	209170	CHEDGRAVE MANOR	TM359993	No Record																																								
203699	203699	CLEY S.WKS	TG047424							■	■	■	■	■	■	■	■	■	■																									
203269	203269	COCKTHORPE, THE OLD	TF983422	No Record																																								
34/11/09		COLKIRK	TF924268	No Record																																								
206518	206518	COLKIRK HALL	TF924268			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
214042	214042	COLTISHALL MET.OFFIC	TG287229			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
214043	214043	COLTISHALL SAMOS	TG282220																																					■	■	■		
208033	208033	COSTESSEY	TG176121															■	■	■	■																							
204304	204304	CRANWORTH	TF986036										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
205068	205068	CRINGEFORD	TG192066	No Record																																								
203878	203878	CROMER	TG208422	1920	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
203878	203878	CROMER	TG212424																																				■	■	■	■		
203875	203875	CROMER, HOLT RD	TG207421	No Record																																								

Table 2a Rain Gauge Data held on RAINARK Environment Agency Peterborough

EA Ref	MO Ref	Station Name	Grid Ref	
203884	203884	CROMER, NEWHAVEN COU	TG220416	
213038	213038	CROPTON HALL	TG107284	
208070	208070	DRAYTON, KESWICK COL	TG201131	No Record
206388	206388	DUNTON	TF882291	
207208	207208	EAST BILNEY HALL	TF948196	No Record
207039	207039	EAST DEREHAM	TF990128	
207040	207040	EAST DEREHAM LABORAT	TF994132	
207041	207041	EAST DEREHAM, NEATHE	TG001132	
207044	207044	EAST DEREHAM, SWANTO	TF994138	
208256	208256	EAST TUDDENHAM	TG079113	
34/12/01	208256	EAST TUDDENHAM	TG079113	No Record
214722	214722	EDINGTHORPE	TG304311	
34/11/01	206497	FAKENHAM	TF923207	No Record
206497	206497	FAKENHAM	TF924208	1955
FAKENR		FAKENHAM	TF927303	
FAKENRCK		FAKENHAM (CHECK)	TF927303	
206480	206480	FAKENHAM, WELLS RD	TF917298	No Record
203168	203168	FIELD DALLING	TG008388	
203160	203160	FIELD DALLING, MANOR	TG008384	
205719	205719	FLORDON COMMON	TM182973	
205348	205348	FORNCETT	TM127948	No Record
206784	206784	FOULSHAM	TG028238	
206769	206769	FOULSHAM	TG031252	
34/11/02	206784	FOULSHAM	TG031252	No Record
34/15/04		FRAMINGHAM (LOGGER)	TG272030	No Record
208737	208737	FRAMINGHAM EARL	TG272030	
34/15/01	208737	FRAMINGHAM EARL	TG272030	No Record
214188	214188	FRETTENHAM, THE GRAV	TG238165	
202799	202799	FULMODESTONE	TF993309	
216507	216507	GORLESTON	TG529037	1916
206903	206903	GREAT FRANSHAM	TF898132	
206225	206225	GREAT MASSINGHAM	TF797234	No Record
216151	216151	GREAT YARMOUTH RACEC	TG527099	
204131	204131	GREAT YARMOUTH, CHUR	TG527088	
207132	207132	GRESSENHALL	TF078163	
214298	214298	HAINFORD	TG232177	
213333	213333	HANWORTH RECTORY	TG203340	No Record
209465	209465	HAPTON	TM170960	No Record
204394	204394	HARDINGHAM HALL	TG047037	No Record
34/11/10		HEIGHAM (LOGGER)	TG211095	No Record
HEIGHR		heigham (t)	TG211095	
HEIGHC		HEIGHAM CHECK	TG211095	
205624	205624	HEMPNALL	TM234949	No Record
34/10/05	215803	HEMSBY MET OFF	TG493162	No Record
215803	215803	HEMSBY MET.OFFICE	TG493162	
215804	215804	HEMSBY MET.OFFICE SS	TG493162	
215805	215805	HEMSBY SAMOS	TG493162	
HETHER		HETHERSETT	TG147052	
205107	205107	HETHERSETT	TG178052	
HETHERCK		HETHERSETT CHECK	TG147052	
205083	205083	HETHERSETT SCHOOL	TG157050	
205118	205118	HETHERSETT, THICKTHO	TG168056	
213939	213939	HEVINGHAM	TG172204	
34/06/04	213939	hevingham(T)	TG172204	No Record
214010	214010	HEVINGHAM, RIPPON HA	TG210225	No Record
34/11/05	207568	HEYDON	TG106266	No Record
207568	207568	HEYDON	TG107266	
215516	215518	HICKLING	TG413228	
34/10/02	215435	HICKLING	TG427222	No Record
215435	215435	HICKLING BROAD, NATU	TG427222	
215541	215541	HICKLING, OLD RECTOR	TG408237	No Record
203398	203398	HIGH KELLING	TG103402	
34/06/01	212884	HINDOLVESTON	TG038295	
212884	212884	HINDOLVESTON, HOPE H	TG039298	1955

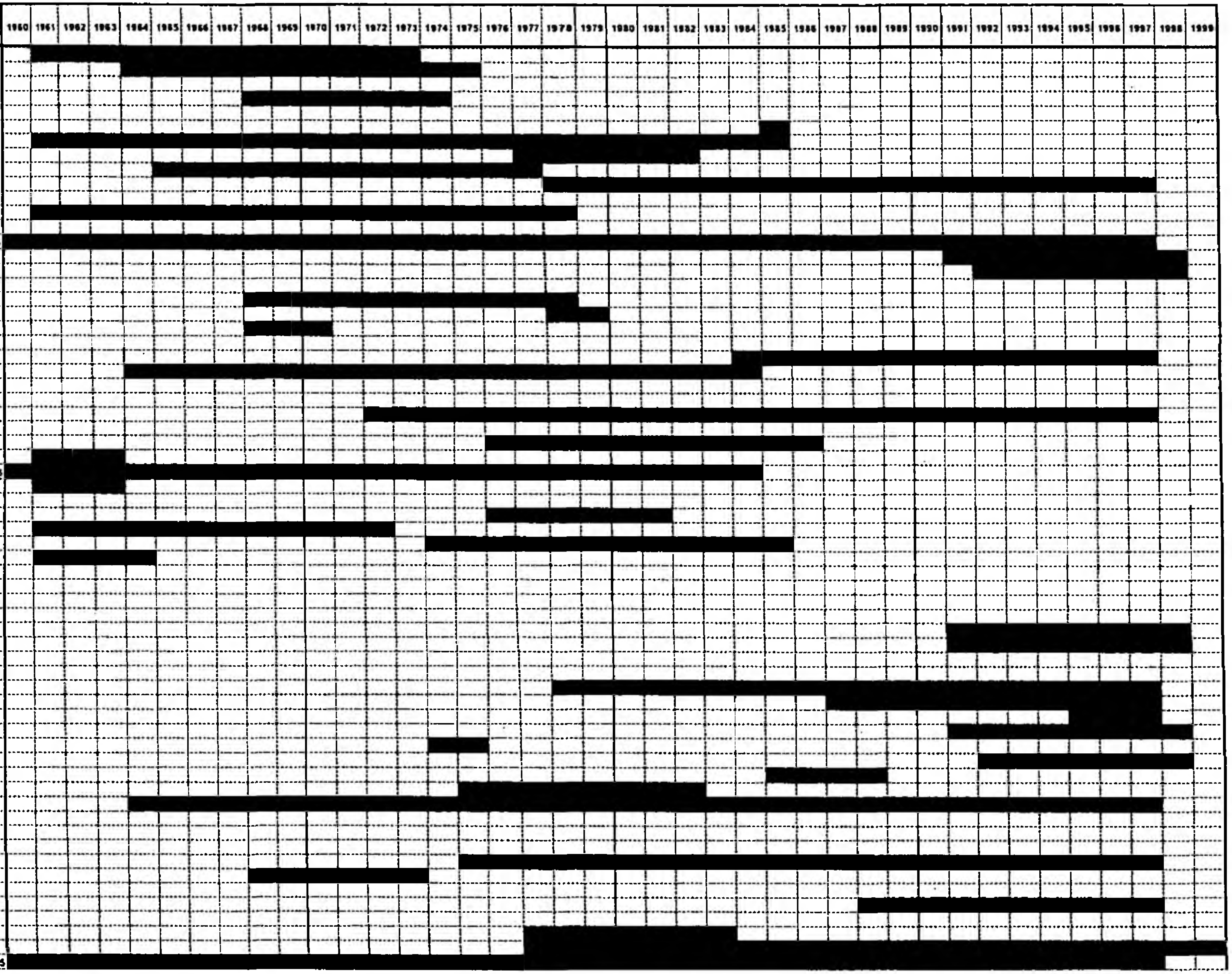

Table 2a Rain Gauge Data held on RAINARK Environment Agency Peterborough

EA Ref	MO Ref	Station Name	Grid Ref		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
212885	212885	HINDOLVESTON, SCHOOL	TG038293	No Record																																								
202034	202034	HOLME HOUSE	TF701435			■	■	■	■	■																																		
34/01/04	202034	holme house(T)	TF701435	No Record																																								
202037	202037	HOLME-NEXT-THE-SEA	TF702435								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/01/01	202037	holme-next-the-sea(T	TF702435																																								■	■
203415	203415	HOLT LODGE	TG079378	No Record																																								
208282	208282	HONINGHAM	TG102108										■	■	■	■	■	■	■	■	■	■																						
34/19/04		hopton on sea(T)	TM 530997	No Record																																								
214578	214578	HORNING P.STA.	TG359165			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
34/09/01	214578	horning(T)	TG358164	No Record																																								
208422	208422	HORSHAM ST FAITH, ME	TG220131	No Record																																								
214475	214475	HOVETON HOME FARM	TG317178	No Record																																								
214480	214480	HOVETON HOUSE	TG319177	No Record																																								
214431	214431	HOVETON SEC SCH	TG307167							■	■	■	■	■																														
202002	202002	HUNSTANTON	TF678416	No Record																																								
202011	202011	HUNSTANTON	TF679423																														■	■	■	■	■	■	■	■	■	■		
34/01/03	202011	HUNSTANTON	TF670423																														■	■	■	■	■	■	■	■	■	■	■	■
34/10/03		ingham(T)	TG400272	No Record																																								
205175	205175	KETTERINGHAM	TG164025	No Record																																								
206563	206563	KETTLESTONE RECTORY	TF965318	No Record																																								
203135	203135	LANGHAM	TG008412	No Record																																								
34/04/01	203134	LANGHAM	TG009418																														■	■	■	■	■	■	■	■	■	■	■	■
203134	203134	LANGHAM, HOLLOW LANE	TG009412																														■	■	■	■	■	■	■	■	■	■		
215758	215758	LINGWOOD, STRUMPSHAW	TG359071																																				■	■	■	■		
34/15/06	215758	LINGWOOD STRUMP HILL	TG 359071	No Record																																								
209230	209230	LODDON	TM375988																				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
34/15/03	209230	loddon (T)	TM375988	No Record																																								
205383	205383	LONG STRATTON	TM193909	No Record																																								
207086	207086	LONGHAM	TF934150													■	■																											
207087	207087	LONGHAM	TF934152	No Record																																								
205579	205579	LUNDY GREEN	TM238024								■	■	■	■	■	■	■	■	■	■	■																							
207479	207479	LYNG	TG087161																					■	■	■	■	■	■	■														
204969	204969	MARLINGFORD HALL	TG126081			■	■	■	■	■	■	■	■	■	■	■																												
208208	208208	MATTISHALL, MILL ST	TG053109														■	■	■	■	■	■	■	■	■	■	■	■	■															
204472	204472	MATTISHALL, WELBORNE	TG053094						■	■	■	■	■	■	■	■	■																											
203478	203478	MELTON CONSTABLE	TG050330											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/03/02	203478	MELTON CONSTABLE	TG050330											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
203354	203354	MELTON CONSTABLE	TG070335																																			■	■	■	■	■		
212947	212947	MELTON CONSTABLE PAR	TG030320	No Record																																								
214715	214715	MELTON CONSTABLE PAR	TG300320	No Record																																								
213292	213292	METTON P.STA.	TG198375																		■	■	■	■	■																			
207185	207185	MILEHAM	TF921195						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
204710	204710	MORLEY ST BOTOLPH	TM061996										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/13/03		MORLEY ST. BOTOLPH	TM061090	No Record																																								
34/13/04		MORLEY ST.B (LOGGER)	TM061996	No Record																																								
205737	205737	NEWTON FLOTMAN	TM198979										■	■	■	■	■	■																										
202347	202347	NORTH CREAKE	TF854371							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/02/02	202347	NORTH CREAKE	TF854371							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
34/02/04		NORTH CREAKE(LOGGER)	TF854371																																								■	■
34/11/03	206859	NORTH ELMHAM	TF987218	No Record																																								
206848	206848	NORTH ELMHAM	TF988231										■	■	■	■	■	■	■																									
206885	206885	NORTH ELMHAM PARK	TF983217																■	■	■	■	■																					
206859	206859	NORTH ELMHAM, TOWER	TF986219																							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
214713	214713	NORTH WALSHAM	TG285305					■	■	■	■	■	■	■	■	■	■	■																										
NWALSR		NORTH WALSHAM	TG296307																																						■	■	■	
NWALSRCK		NORTH WALSHAM(CHECK)	TG296307																																						■	■	■	
NWASLRT		north walsham(T)	TG296307																																	■	■	■	■	■	■			
214628	214628	NORTH WALSHAM, THE P	TG280299							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
214630	214830	NORTH WALSHAM, THE P	TG281302	No Record																																								
214631	214631	NORTH WALSHAM, THE P	TG283301																								■	■	■	■	■	■												
213645	213645	NORTH WALSHAM, WORST	TG287309	No Record																																								
203931	203931	NORTHREPPS HALL	TG231309			■	■	■	■	■	■																																	
214287	214287	NORWICH AIRPORT MTER	TG228138	No Record																																								
208400	208400	NORWICH CEMETERY	TG212066			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■													

Table 2a Rain Gauge Data held on RAINARK Environment Agency Peterborough

EA Ref	MO Ref	Station Name	Grid Ref		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
208389	208389	NORWICH W WKS	TG211095	1956	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
208467	208467	NORWICH WEATHER CENT	TG233082																																		■	■	■	■	■	■		
208468	208468	NORWICH WEATHER CENT	TG233082																																						■	■	■		
34/11/07		nrwch wwks chk(T)	TG212096	No Record																																								
208034	208034	OLD COSTESSEY	TG175122																												■	■	■	■	■	■								
205231	205231	OLD LAKENHAM	TG235069														■	■	■	■	■	■	■	■	■	■	■																		
205232	205232	OLD LAKENHAM	TG236063												■	■	■	■																											
34/10/01	215823	ORMESBY ST MICHAEL	TG468152	No Record																																								
215822	215822	ORMESBY ST MICHAEL	TG488154						■	■																																		
215823	215823	ORMESBY ST MICHAEL W	TG488152	1901	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
207059	207059	QUEBEC HALL	TF985145						■	■																																		
34/15/05		RAVENHAM HALL	TM399905	No Record																																								
209272	209272	RAVENINGHAM HALL	TM399965			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
34/13/01	204433	RUNHALL	TG051077	No Record																																								
204435	204435	RUNHALL	TG054078										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																
204433	204433	RUNHALL, BEECH HOUSE	TG051078																										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
207611	207611	SALL	TG127243	No Record																																								
SALLER		SALLE	TG126244																																	■	■	■	■	■	■	■	■	
SALLERCK		SALLE(CHECK)	TG126244																																							■	■	■	
204100	204100	SCRATBY	TG514155	No Record																																								
206078	206078	SCULTHORPE MET OFFIC	TF856317																					■	■																				
203818	203818	SHERINGHAM	TG150424																■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/05/01	203816	SHERINGHAM	TG150424																																				■	■	■	■	■	■
203810	203810	SHERINGHAM HALL	TG133423	No Record																																								
203830	203830	SHERINGHAM HOUSE	TG155423	No Record																																								
203837	203837	SHERINGHAM, PINE GRO	TG163427			■	■	■	■	■	■	■	■	■	■	■	■																											
203829	203829	SHERINGHAM, ST NICHO	TG155434	No Record																																								
204254	204254	SHIPDHAM	TF959074						■	■																																		
204253	204253	SHIPDHAM SCHOOL	TF965074																■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
34/13/05		SHIPDHAM STW (CHECK)	TF958060	No Record																																								
34/13/06		SHIPDHAM STW(LOGGER)	TF958060	No Record																																								
205830	205830	SHOTESHAM, ALL SAINT	TM258072														■	■	■	■	■	■	■																					
206303	206303	SOUTH RAYNHAM	TF876228																														■	■	■	■	■	■	■	■	■		
204339	204339	SOUTHBURGH	TG003054	No Record																																								
34/08/01	214658	SOUTHREPPS	TG257358	No Record																																								
214658	214658	SOUTHREPPS	TG258357										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
208418	208418	SOUTHWELL LODGE	TG226072	No Record																																								
207484	207484	SPARHAM HALL	TG071186			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
34/11/08		SPARHAM HALL	TG071186	No Record																																								
214324	214324	SPROWSTON	TG251123	1924	■	■	■	■	■	■	■	■	■	■																														
208480	208480	SPROWSTON, OAK LODGE	TG245128	No Record																																								
34/10/08	215023	STALHAM	TG375251	No Record																																								
208724	208724	SURLINGHAM	TG323059							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																			
214709	214709	SWAFIELD RECTORY	TG292327	No Record																																								
207909	207909	SWANNINGTON	TG131193							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
207890	207890	SWANNINGTON, HEATH H	TG132185	No Record																																								
207351	207351	SWANTON MORLEY RECTO	TG015174	No Record																																								
205161	205181	SWARDESTON	TG203028							■	■	■	■	■	■	■																												
202235	202235	SYDERSTONE	TF849329										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/02/01	202235	SYDERSTONE	TF849329																																						■	■	■
202231	202231	SYDERSTONE RECTORY	TF833327	No Record																																								
209445	209445	TACOLNESTON HALL	TM137955	No Record																																								
205443	205443	TACOLNESTON HALL	TM138955																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
34/14/01	205443	tacolneston hall(T)	TM138955	No Record																																								
207969	207969	TAVERHAM	TG149156			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																				
205471	205471	THARSTON	TM183960																											■	■	■	■	■	■	■	■	■	■	■	■	■	■		
205472	205472	THARSTON, VALLEY FAR	TM184960														■	■	■	■	■	■	■	■	■	■	■	■	■	■														
208478	208478	THORPE HAMLET	TG250085	No Record																																								
208485	208485	THORPE ST ANDREW	TG254088	No Record																																								
213322	213322	THURGARTON HALL	TG179360							■	■	■	■	■	■	■	■																											
205379	205379	WACTON HALL	TM180903						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
202980	202980	WALSINGHAM	TF940377	No Record																																								
202987	202987	WALSINGHAM, HILL HOU	TF950359							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																		
202277	202277	WATERDEN HOUSE FARM	TF887381												■	■	■	■	■	■	■																							

Table 2a Rain Gauge Data held on RAINARK Environment Agency Peterborough

EA Ref	MO Ref	Station Name	Grid Ref		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
202697	202697	WELLS S.WKS	TF912440			■	■	■	■	■	■	■	■	■	■	■	■	■	■																									
202701	202701	WELLS-NEXT-THE-SEA	TF917428																			■	■	■	■	■	■	■	■	■	■	■	■	■	■									
206950	206950	WENDLING, ASHNESS	TF927128																		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
206958	206958	WENDLING, CLEAR VIEW	TF930128																	■	■																							
206978	206978	WENDLING, GRANGE FAR	TF940136																■	■																								
34/11/04	206950	WENDLING,ASHNESS	TF928127	No Record																																								
206015	206015	WEST RAYNHAM MET.OFF	TF844250	No Record																																								
206273	206273	WEST RAYNHAM MET.OFF	TF847245			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																							
203846	203848	WEST RUNTON	TG178429																	■	■	■																						
203769	203769	WEYBOURNE 'B'	TG100437																															■	■	■	■	■	■	■	■	■		
203770	203770	WEYBOURNE SAWS	TG099437																																		■	■	■	■	■	■		
203700	203700	WIVETON, GLAVEN CORN	TG042426	No Record																																								
213200	213200	WOLTERTON PARK	TG165317	1950	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
34/06/02	213200	WOLTERTON PARK	TG165318																																■	■	■	■	■	■	■	■	■	■
34/06/05	213598	WOODGATE HOUSE	TG 181260	No Record																																								
213598	213598	WOODGATE HOUSE	TG181260	1906	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
214782	214782	WORSTEAD	TG312265	No Record																																								
214435	214435	WROXHAM	TG306174					■	■	■	■	■																																
204688	204688	WYMONDHAM COLLEGE	TM074984										■	■	■	■	■	■	■	■	■	■																						

Raingauges identified by a sequence of letters (e.g. NWALSR) are tipping bucket recorders on the Agency telemetry system.

Table 2b Additional Historic Rainfall Records (from Section 14 report, 1971)

Station	Grid Ref. (where given)	Met. Office Ref.	Environment Agency Ref.	Years of Record (Section 14)	Years of Record (Rainark)
Fakenham (Pensthorpe)				1886-1907	n/a
West Rudham				1896-1910	n/a
East Rudham				1910-1919	n/a
Fakenham (Kettlestone Rectory)				1938-1941	n/a
Fakenham (Wells Road)	TF 917 298	206480		1945-1953	n/a
Fakenham (Sapelli)	TF 922 296	206497	34/11/01	1955-1968	1955-1999
Cromer (Northrepps Hall)	TG 231 399	203931		1884-1968	1962-1965
Cawston	TG 133 238	207616		1880-1968	1961-1978
Worstead (Lyngate Cottage)		214782		1888-1957	
Edingthorpe	TG 304 311	214722		1957-1968	1961-1978
Sprowston (Oak Lodge)	TG 245 128	208480		1880-1956	
Sprowston (Norfolk Agricultural Station)	TG 251 123	214324		1951-1968	1924-1969
Wymondham	TG 130 015		34/12/02	1890-1968	1908-1999
Ormesby St. Michael	TG 468 152	215823	34/10/01	1900-1968	1901-1999
Geldeston				1880-1919	
Raveningham Hall	TM 399 965	209272	34/15/05	1898-1968	1961-1999
Norwich Cemetery	TG 210 090	208400		1885-1986	1961-1986

2.2 Other Meteorological Data

Additional weather parameters are recorded at various stations maintained by the Met. Office. The Agency have rainfall records only from three of these sites at Hunstanton (just outside the project area), Morley St. Botolph and Hemsby (see Figure A2).. Met. Office sites in or adjacent to the project area include:

- Norwich Weather Centre ('synoptic'): daily and hourly data available, opened 1989
- Hemsby ('SAWS' automatic site): daily and hourly, 1979
- Coltishall ('SAWS' automatic site): daily and hourly, 1963
- Weybourne ('SAWS' automatic site): daily and hourly, 1989
- Morley St. Botolph ('Agro-Met station'): daily, 1969
- Melton Constable ('Climatological'): daily, 1993
- South Raynham ('Climatological'): daily, 1989
- West Raynham ('Climatological'): daily 1957-1969
- Ditchingham ('Climatological'): daily, 1992
- Cromer ('Health Resort'): daily, 1959
- Hunstanton('Health Resort'): daily, 1988
- Lowestoft('Health Resort'): daily, 1959
- Gorleston ('Hourly Wind Station'), daily 1931-1985, some hourly 1957-1975, anemograph since 1970.

The terms in brackets are Met. Office nomenclature: according to the Met. Office, synoptic stations 'usually record a full range of weather elements, available in real-time', climatological stations have 'daily records, some with sunshine and mean wind speed', and SAWS sites are 'automatic sites, both daily ad hourly, real-time if needed'.

2.3 MORECS data

The Agency retain end of week (weekly) MORECS data for the relevant squares (120, 121, 130 and 131) for the following parameters.

Rainfall
Soil Moisture Deficit (SMD)
Potential Evaporation (PE)
Actual Evaporation (AE)
Effective Precipitation for grass and for actual land use (EP)
MORECS data is currently held for the period 1961 to 1998. Data for 1999 will be obtained when available.

2.4 Data Quality

Rainfall data is passed to the Meteorological Office for quality assurance. Other meteorological parameters would, if required, be taken directly from the Met. Office.

3. Hydrology

3.1 River Gauging

River flows have been recorded at the stations given in Table 3 for the lengths of time shown. The location of gauging stations is shown in Figure A3. In addition a number of sites are used for repeat (or occasionally 'one-off') current meter gauging and these are listed in Table 4. Some of the current meter sites serve as checks for gauging stations. Current meter results have been entered onto the GAUGEMAN database for records obtained since 1994. The SPRING database was used to store current meter readings prior to the introduction of GAUGEMAN. Current metered flow records from SPRING and GAUGEMAN have now been amalgamated onto the 'SPOTFLOW' database. The locations of current metering sites for which data are held on SPOTFLOW are shown on Figure A3. Some additional ad hoc flow information may be available within the license determination files.

Not all of these structures were purpose built and therefore do not necessarily conform to British Standards. Many of the structures are adopted weirs, some of which contain sluice gates. The accuracy of these structures is questionable, particularly at high flows.

As asset survey of surface water hydrometric sites was undertaken for the Agency by HR Wallingford in 1995. This produced an assessment of the accuracy of measurement at various flow conditions. The findings for the gauging stations in the Yare & North Norfolk area are summarised in Table 5.

Entec understand that re-calibration of the adopted structures at high flow is proposed for the near future, although details of this programme have not been finalised. The re-rating exercise should permit re-interpretation of historical data. The presence of gates presents a significant difficulty as these are opened and closed to permit river flow depending upon flow regime. In recent years, the flow record contains an indication of whether gates are open or closed, but the structures are not necessarily rated for all positions of the gates.

Table 3 HYDROLOG. Flow Data Summary, Environment Agency Ipswich

EA Ref	Station Name	Location Desc	Grid Ref	
034001	Colney	Yare	TG18200820	1950
034002	Shotesham	Tas	TM22609940	1957
034003	Ingworth	Bure	TG19202960	1959
034004	Costessey Mill	Wensum	TG17701280	
034005	Costessey Park	Tud	TG17001130	
034006	Needham Combined	Waveney	TM22958115	1900
034007	Oakley Park	Dove	TM17407720	
034008	Horning Lock	Ant	TG33102700	
034010	Billingford	Waveney	TM16807820	1900
034011	Fakenham	Wensum	TF91902940	
034012	Burnham	Burn	TF84204280	
034013	Ellington Combined	Waveney	TM36405170	1900
034014	Swanton Morley Combined	Wensum	TG02001840	
034016	Bayfield	Glaven	TG05553055	
034018	Warham	Stiffkey	TF94404140	
034019	Horstead	Bure	TG26701940	
034020	Lt. Walsingham	Stiffkey	TF93503600	
034021	Mundesley Hospital	Mun	TG29803640	
034022	Briston Stw (T)	Bure	TG07243140	
034023	Small Hopes Farm (T)	Bure	TG08583048	
034024	Hall Farm (T)	Tugby Watercourse	TG07782852	
034025	Hollies Farm	Edgefield Watercourse	TG09653154	
034026	Aslacton Ford (T)		TM15109180	
034027	Broome Bridge(T)	Waveney	TM34909720	1900
034028	Mundesley Rookery			
034029	Aldborough College			
034030	Aldborough Footbridge			
034031	Roughton Temp			
034032	South Repps			
034033	Ellingham Ultrasonic	Waveney	TM36450175	1900
034040	Denton			
[illegible]	[illegible]	Waveney	[illegible]	1900
034113	Ellingham Mill	Waveney	TM36409170	1900
034114	Swanton Morley 2 Arc	Wensum	TG02001840	
034206	Needham Weir	Waveney	TM22958115	1900
034213	Ellington Mill	Waveney	TM36405170	1900
034214	Swanton Morley 3 Arc	Wensum	TG02001840	
034322	R. Dove, Abbey Bridge		TM15107380	1900
034323	R Dove, Brandwell Green		TM13007020	1900
034324	Finningham w/c, Stoke Ash		TM11107070	1900
034325	Yaxley w/c Eye		TM14607410	1900
034326	Thorndon W/C Catbridge		TM13807070	1900
034331	R. Wensum City New Mills		TG22600930	
G340901	East Ruston 1A			1900
G340902	East Ruston 1B			1900
G340903	East Ruston 2A			1900
G340904	East Ruston 2B			1900
G340905	East Ruston 2C			1900
G340906	East Ruston 4A			1900
G340907	East Ruston 4B			1900
G340908	East Ruston 5A			1900
G340909	East Ruston 5B			1900
G340910	East Ruston 5C			1900
G340911	East Ruston 6A			1900
G340912	East Ruston 6B			1900
G340913	East Ruston 8A			1900
G340914	East Ruston P2			1900
G340915	East Ruston P5			1900
G340916	East Ruston P7			1900
G340917	East Ruston OD1			1900
G340918	East Ruston OD2			1900
M340501	Mundesley Wind	Mundesley Water Twr	TG307365	1900
M341701	Wickham Skeith	River req Bore	TM092698	1900
T340301	Wells Tide Site	Coastal	TF91654415	
T340501	Cromer Tide Site			
T340901	Hoveton Broad T S	Bure Tidal	TG31651685	
T340902	Ranworth Broad T S	Bure Tidal	TG35051465	
T340903	Barton Broad T S	Ant Tidal	TG35052105	
T340904	Wayford Bridge T S	Ant Tidal	TG34852485	
T341001	Hickling Broad T S	Thurne Tidal	TG41352255	
T341002	Acle Bridge T S	Bure Tidal	TG41451175	
T341003	Repps Tide Site	Thurne Tidal	TL41451755	
T341501	Carrow Bridge Tide S	Yare Tidal	TG23950775	
T341502	Cantley Tide Site	Yare Tidal	TG38350345	
T341503	Rockland Broad T S	Yare Tidal	TG32950475	
T341504	Great Yarmouth T S	Coastal		
T341505	Brundall		TG326072	
T341901	Beccles Quay Tide St	Waveney Tidal	TM42250115	1900
T341902	Burgh St Peter Tide	Waveney Tidal	TM49350345	1900
T341903	Haddiscoe T S	Waveney Tidal	TM45859875	1900
T341904	Burgh Castle	Tidal Waveney	TG474039	1900
T341905	Ellingham Tide	Sluice	TM36409170	1900
L340201	South Creake			1900
L340601	Roughton Lagoon			1900
L341101	New Mills	Wensum	TG22650905	
L341401	Shotesham Bypass Chs	Tas	TM22649945	
L341901	Flodon		TL84654725	1900

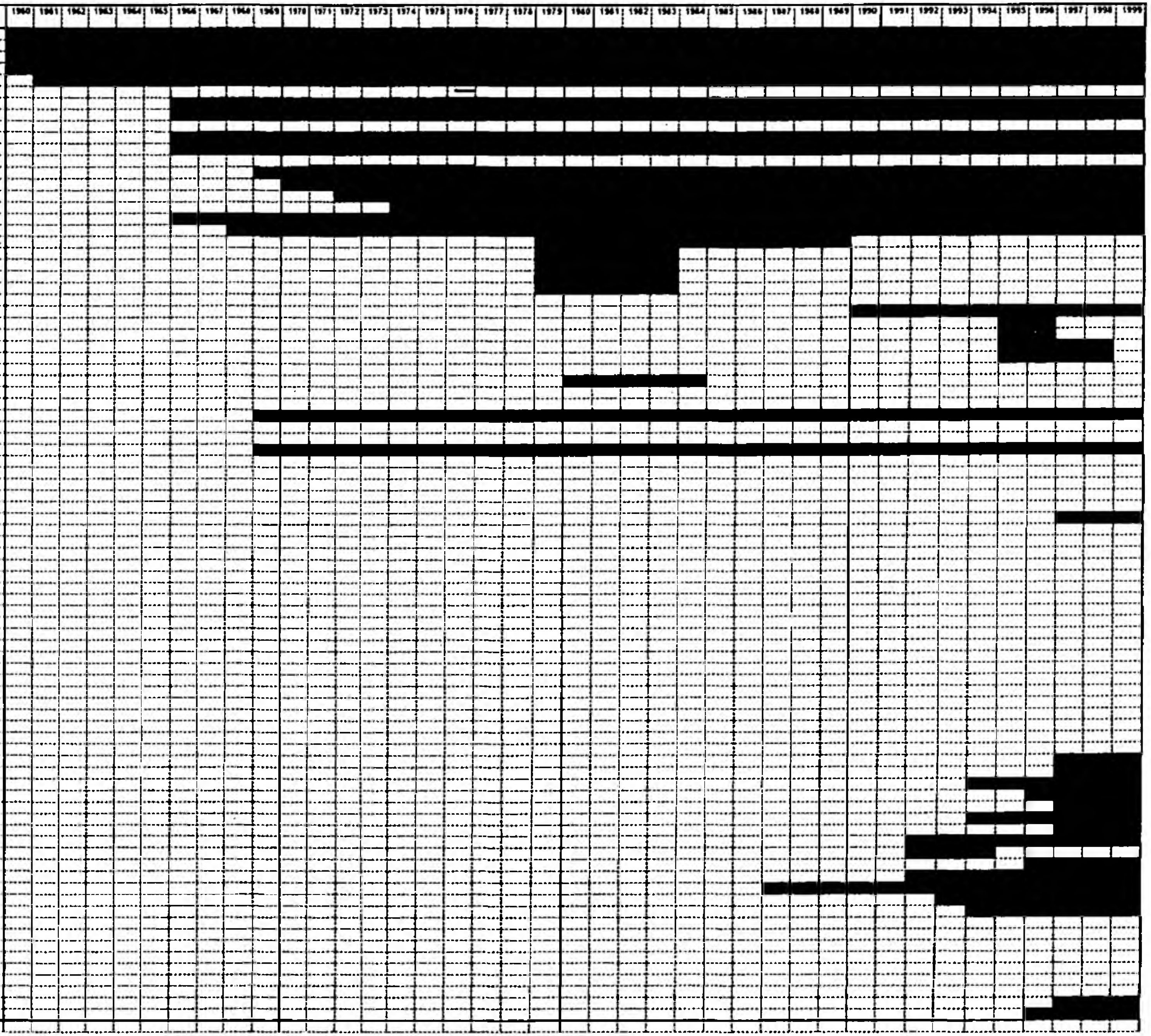

Table 4 Location of Current Meter Flow Monitoring Sites

STATTION REF	STATION NAME	LOCATION DESCRIPTION	NGR EASTIN	NGR NORTHIN	START DATE	END DATE	NO. OF RECORDS
CM340634	ACLE	ACLE LANDSPRING	640700	310400	21/05/96	23/09/99	32
CM340907	HOVETON	ASHMANHAUGH WATERCOURSE	632500	319300	23/07/97	23/09/99	18
CM340622	LITTLE BARNINGHAM	BARNINGHAM STREAM	614000	333800	26/09/38	03/11/83	63
CM340623	LITTLE BARNINGHAM	BARNINGHAM STREAM	613800	333100	26/09/38	03/11/83	63
CM341306	WYMONDHAM	BAYS RIVER	610800	300900	12/10/66	05/02/78	8
CM341309	WYMONDHAM	BAYS RIVER	610900	300900	12/10/66	05/02/78	8
CM341310	WYMONDHAM	BAYS RIVER	610900	301000	12/10/66	05/02/78	8
CM340302	FIELD DALLING	BINHAM STREAM	602200	339500	30/04/84	30/04/84	1
CM340304	LANGHAM	BINHAM STREAM	599900	341000	30/04/84	21/07/99	100
CM340306	BINHAM	BINHAM STREAM	598500	340100	30/11/87	14/12/87	4
CM340307	BINHAM A	BINHAM STREAM	597800	340300	10/07/87	24/09/87	2
CM340308	BINHAM B	BINHAM STREAM	596700	340800	30/11/87	14/12/87	4
CM340631	TUTTINGTON	BLACKWATER BECK	623000	327100	08/09/89	27/04/99	38
CM340602	THURNING	BLACKWATER RIVER	608900	330200	27/11/80	19/08/92	68
CM340629	BLACKWATER BRIDGE	BLACKWATER RIVER	609000	330200	08/03/95	21/07/99	44
CM341123	HOE	BLACKWATER RIVER	599900	317700	16/08/90	16/08/90	1
CM341133	REEPHAM	BLACKWATER RIVER	610800	322800	22/06/67	11/08/92	5
CM341134	REEPHAM	BLACKWATER RIVER	609500	321300	22/06/67	11/08/92	5
CM341135	REEPHAM	BLACKWATER RIVER	609200	322700	22/06/67	11/08/92	5
CM341165	GRESSENHALL	BLACKWATER RIVER	595800	315200	21/10/65	19/07/99	56
CM341301	CRANWORTH	BLACKWATER RIVER	598700	303900	19/07/67	20/07/99	36
CM341302	HARDINGHAM	BLACKWATER RIVER	603400	305000	12/10/66	30/08/91	3
CM341326	HARDINGHAM	BLACKWATER RIVER	602100	305000	12/10/66	30/08/91	3
CM341336	CRANWORTH	BLACKWATER RIVER	698800	303900	19/07/67	20/07/99	36
CM341327	GREAT MELTON	BOW HILL SPRING	613000	307900	12/10/66	16/01/92	4
CM340619	BUXTON WITH LAMM	CAMPING BECK	623400	322600	04/08/89	03/01/91	9
CM340633	BUXTON	CAMPING BECK	622900	322100	21/08/95	30/09/99	36
CM341502	THURTON	CARLETON BECK	633400	301200	14/05/79	23/10/79	68
CM341506	THURTON	CARLETON BECK	633400	301100	14/05/79	23/10/79	68
CM341507	THURTON	CARLETON BECK	633700	301600	14/05/79	23/10/79	68
CM341514	CARLETON ST PETERS	CARLETON BECK	633600	302300	02/10/95	22/09/99	39
CM340912	DILHAM	DILHAM STREAM	631700	324800	21/08/95	27/04/99	37
CM340703	CROSTWICK	DOBBS BECK	626800	315500	27/08/76	09/01/91	63
CM340902	EAST RUSTON	EAST RUSTON STREAM	633900	327900	26/08/71	30/06/92	23
CM340625	EDGEFIELD	EDGEFIELD STREAM	609500	333700	04/05/81	24/06/81	44
CM340626	BRISTON	EDGEFIELD STREAM	609700	331500	14/04/81	03/01/91	86
CM341323	DEOPHAM	FIELD DRAIN	604700	301600	16/09/61	07/11/69	8
CM341324	DEOPHAM	FIELD DRAIN	605100	301500	16/09/61	07/11/69	8
CM341325	DEOPHAM	FIELD DRAIN	605600	301700	16/09/61	07/11/69	8
CM340914	PANXWORTH	FLEET DYKE	635200	313000	15/03/96	23/09/99	34
CM341114	FOULSHAM	FOULSHAM BECK	602900	324300	22/06/67	20/07/99	39
CM341115	TWYFORD	FOULSHAM BECK	601600	324500	22/06/67	22/06/67	1
CM341167	FOULSHAM	FOULSHAM BECK	603600	324800	22/06/67	20/07/99	39
CM340910	WORSTEAD	FRANKFORT STREAM	630500	324600	11/08/67	13/10/67	21
CM341329	LITTLE MELTON	GRANGE FARM SPRING	614900	306700	16/01/92	16/01/92	2
CM341509	HOLVERTON	HELLINGTON BECK	630000	303600	05/07/91	05/07/91	1
CM341510	HELLINGTON	HELLINGTON BECK	631000	303400	05/07/91	22/09/99	39
CM341511	HELLINGTON	HELLINGTON BECK	632000	303700	05/07/91	22/09/99	39
CM340807	HONING	HONING STREAM	632800	327300	14/10/68	01/03/79	41
CM340604	ITTERINGHAM	ITTERINGHAM STREAM	614400	331800	14/06/69	19/08/92	60
CM340605	ITTERINGHAM	ITTERINGHAM STREAM	614600	330700	14/06/69	19/08/92	60
CM341320	KETTERINGHAM	KETTERINGHAM STREAM	617400	329000	06/07/67	08/07/67	1
CM341321	KESWICK	KETTERINGHAM STREAM	618900	303500	21/07/67	19/05/70	12
CM341322	KESWICK	KETTERINGHAM STREAM	619900	304400	21/07/67	19/05/70	12
CM341422	LONG STRATTON	LONG STRATTON WATERCOURSE	619400	394100	02/10/95	22/09/99	40
CM341317	GREAT MELTON	MELTON BECK	614100	305600	12/10/66	16/01/92	4
CM341319	GREAT MELTON	MELTON BECK	614100	307600	12/10/66	16/01/92	4
CM340610	CAWSTON	MERMAID STREAM	616500	325100	27/10/91	20/01/92	38
CM340611	CAWSTON	MERMAID STREAM	617000	324800	27/10/91	20/01/92	38
CM340612	BRAMPTON	MERMAID STREAM	621200	324500	04/08/89	30/09/99	47
CM340632	BRAMPTON	MERMAID STREAM	621500	324700	04/08/89	30/09/99	47
CM340501	NORTH REPPS	MUN BECK	625300	338300	25/04/68	21/10/68	85
CM340502	SOUTH REPPS	MUN BECK	626400	337900	03/05/68	21/10/68	85
CM341154	LYNG	NORTH DRAIN	607200	317900	16/08/90	19/10/92	41
CM341508	THURLTON	NORTON BECK	641400	298500	08/07/75	08/07/75	1
CM341001	HEMBLINGTON	PANXWORTH RUN	633800	312400	19/03/96	19/03/96	2
CM341002	HEMBLINGTON	PANXWORTH RUN	634300	312400	19/03/96	19/03/96	2
CM341166	SWANTON MORLEY	PENNY SPOT BROOK	603600	317000	01/08/55	20/07/99	98
CM341328	LITTLE MELTON	POND OUTFALL	615000	370000	16/01/92	16/01/92	2
CG034008	HONING LOCK	RIVER ANT	633100	327000	13/05/60	20/11/68	125
CM340801	NORTH WALSHAM	RIVER ANT	627400	332000	14/10/68	30/05/91	39
CM340802	SWAFIELD	RIVER ANT	628600	331900	10/08/68	27/04/99	121
CM340803	NORTH WALSHAM	RIVER ANT	629700	331400	14/10/68	30/05/91	39
CM340804	NORTH WALSHAM	RIVER ANT	629900	330500	14/10/68	30/05/91	39
CM340851	HONING LOCK	RIVER ANT	633100	327000	13/05/60	20/11/68	125
CM340903	HONING	RIVER ANT	633100	327000	14/10/68	01/03/79	41
CG034003	INGWORTH	RIVER BURE	619200	329600	01/08/55	20/01/98	26
CM340601	BRISTON	RIVER BURE	608500	330500	14/04/81	03/01/91	86
CM340603	CORPUSTY	RIVER BURE	609900	331200	26/07/89	19/08/92	11
CM340627	CORPUSTY (LITTLE LONDON)	RIVER BURE	610800	330500	02/02/94	21/07/99	54
CM340628	ALDBOROUGH	RIVER BURE	618600	333700	29/04/69	21/07/99	54

Table 4 Location of Current Meter Flow Monitoring Sites

STATTION REF	STATION NAME	LOCATION DESCRIPTION	NGR EASTIN	NGR NORTHIN	START DATE	END DATE	NO. OF RECORDS
CM340651	INGWORTH	RIVER BURE	619200	329600	01/08/55	20/01/98	26
CG034050	SOUTH CREAKE	RIVER BURN	586600	335500	24/08/82	29/11/95	2
CM340201	SOUTH CREAKE	RIVER BURN	586800	334900	24/08/82	29/11/95	2
CM340202	SOUTH CREAKE	RIVER BURN	586600	335500	24/08/82	29/11/95	2
CM340204	NORTH CREAKE	RIVER BURN	585600	339400	13/10/77	13/10/77	1
CM340205	BURNHAM THORPE	RIVER BURN	585700	340500	07/10/77	15/06/79	118
CM340206	BURNHAM THORPE	RIVER BURN	585300	341500	07/10/77	15/06/79	118
CM340207	BURNHAM THORPE	RIVER BURN	585100	341700	07/10/77	15/06/79	118
CM340208	BURNHAM THORPE	RIVER BURN	584800	342100	07/10/77	15/06/79	118
CM340209	LEICESTER SQUARE FARM	RIVER BURN	586700	335200	17/02/93	25/10/99	85
CM340210	FORGE HOUSE	RIVER BURN	586300	335500	17/02/93	25/10/99	83
CM340211	EASTER CORNHILL	RIVER BURN	585700	336300	28/03/78	25/10/99	72
CM340212	SLYS FARM	RIVER BURN	583500	337400	17/03/93	25/10/99	71
CM340213	NORTH CREAKE CROSSROADS	RIVER BURN	585400	338200	25/02/93	25/10/99	69
CM340214	ABBEY MEADOWS	RIVER BURN	585500	338500	07/10/77	03/07/97	42
CM340215	ABBEY FARM	RIVER BURN	585500	339500	17/02/93	25/10/99	75
CM340216	MORLEYS FARM	RIVER BURN	585800	335900	28/05/97	28/09/99	29
CM340251	BURNHAM OVERY	RIVER BURN	584200	342700	03/05/56	12/05/65	127
CM340252	BURNHAM OVERY	RIVER BURN	583600	343600	03/05/56	12/05/65	127
CM341530	WASHINGFORD FARM	RIVER CHET	633300	399400	26/10/93	22/09/99	60
CM340401	THORNAGE	RIVER GLAVEN	605100	336000	03/06/77	21/07/99	229
CM340402	HOLT	RIVER GLAVEN	607800	340800	20/03/79	21/07/99	48
CM340403	LETHERINGSETT	RIVER GLAVEN	605500	339500	26/07/56	11/08/65	13
CM340404	LETHERINGSETT	RIVER GLAVEN	604700	340600	26/07/56	11/08/65	13
CM340405	BAYFIELD	RIVER GLAVEN	605600	339500	03/05/56	08/02/95	181
CM340406	THORNAGE	RIVER GLAVEN	605700	337600	03/06/77	21/07/99	229
CM340407	GLANFORD	RIVER GLAVEN	604500	341600	05/05/95	31/05/95	2
CM340451	BAYFIELD	RIVER GLAVEN	605700	257900	03/05/56	08/02/95	181
CM340452	LETHINGSETT BRIDGE	RIVER GLAVEN	606200	338800	28/06/56	27/12/62	45
CM340453	GLANDFORD MILL	RIVER GLAVEN	604500	341500	05/05/95	21/07/99	34
CM340456	HOLT	RIVER GLAVEN	608600	336400	20/03/79	21/07/99	48
CM340101	HOLME NEXT THE SEA	RIVER HUN	569900	343600	10/03/69	01/11/89	19
CM340102	HOLME NEXT THE SEA	RIVER HUN	569900	343600	10/03/69	01/11/89	19
CM340103	HUNSTANTON	RIVER HUN	568900	342400	14/08/95	28/09/99	41
CM340104	BRANCASTER MARSH 1	RIVER HUN	577530	344340	30/04/99	30/04/99	1
CM340105	BRANCASTER MARSH 2	RIVER HUN	577760	344370	19/05/99	19/05/99	1
CM340106	BRANCASTER MARSH 3	RIVER HUN	577760	344390	30/04/99	30/04/99	1
CM340107	BRANCASTER MARSH 4	RIVER HUN	578030	344390	30/04/99	30/04/99	1
CM340108	BRANCASTER MARSH 5	RIVER HUN	579210	344520	30/04/99	30/04/99	1
CM340109	BRANCASTER MARSH 6	RIVER HUN	579220	344610	30/04/99	30/04/99	1
CM340110	BRANCASTER MARSH 7	RIVER HUN	579910	344570	30/04/99	30/04/99	1
CM340111	BRANCASTER MARSH 8	RIVER HUN	580060	344530	30/04/99	30/04/99	1
CG034021	MUNDESLEY HOSPITAL	RIVER MUN	629600	336400	19/10/64	17/07/97	39
CM340504	GIMINGHAM	RIVER MUN	626600	336900	05/10/64	10/03/93	8
CM340507	MUNDESLEY GOLF COURSE	RIVER MUN	630400	336200	30/07/92	10/03/93	3
CM340508	MUNDESLEY ROOKERY	RIVER MUN	631500	336400	30/07/92	10/03/93	2
CM340509	TRIMINGHAM (HARRIS)	RIVER MUN	627100	337400	19/01/93	30/07/93	2
CM340510	TRIMINGHAM	RIVER MUN	626900	337900	05/10/64	24/09/99	47
CM340511	MUNDESLEY HOSPITAL	RIVER MUN	629600	336400	19/10/64	17/07/97	39
CM340301	HOUGHTON ST. GILE	RIVER STIFFKEY	592200	335300	21/05/71	12/10/71	140
CM340303	LANGHAM	RIVER STIFFKEY	600700	340900	30/04/84	21/07/99	100
CM340309	STIFFKEY	RIVER STIFFKEY	596500	343400	10/06/69	10/06/69	1
CM340310	WELLS NEXT SEA	RIVER STIFFKEY	593600	343100	10/12/64	18/01/65	40
CM340311	EAST BARSHAM	RIVER STIFFKEY	591700	334000	07/09/64	16/06/65	40
CM340312	THORPLAND HALL	RIVER STIFFKEY	593800	332200	07/09/64	16/06/65	40
CM340313	HINDERINGHAM	RIVER STIFFKEY	596300	337600	21/09/79	07/12/79	13
CM340314	THURSFORD	RIVER STIFFKEY	597700	333000	29/06/95	19/07/99	39
CM340351	STIFFKEY VILLAGE	RIVER STIFFKEY	597200	343000	03/05/56	28/06/56	4
CM340352	WALSINGHAM	RIVER STIFFKEY	593400	336500	28/06/56	27/08/99	363
CG034002	SHOTESHAM	RIVER TAS	622600	299400	01/08/55	22/09/99	55
CM341401	ASLACTON	RIVER TAS	615100	291600	05/05/80	10/11/82	64
CM341402	BUNWELL	RIVER TAS	614500	292700	04/12/79	04/12/79	1
CM341404	FORNCETT	RIVER TAS	616300	292400	25/09/64	11/07/67	2
CM341405	FORNCETT	RIVER TAS	616500	293400	25/09/64	11/07/67	2
CM341406	THARSTON	RIVER TAS	619200	293400	06/01/65	11/07/67	4
CM341408	THARSTON	RIVER TAS	619400	294100	06/01/65	11/07/67	4
CM341409	THARSTON	RIVER TAS	619400	294000	06/01/65	11/07/67	4
CM341410	THARSTON	RIVER TAS	619200	295800	06/01/65	11/07/67	4
CM341411	HEMPNALL	RIVER TAS	623600	294400	13/09/67	22/09/99	39
CM341412	BRACON ASH	RIVER TAS	617400	299300	11/10/66	11/10/66	1
CM341413	WRENINGHAM	RIVER TAS	616500	298000	11/10/66	13/09/67	2
CM341414	WRENINGHAM	RIVER TAS	616500	298100	11/10/66	13/09/67	2
CM341415	FLORDON	RIVER TAS	617700	297500	11/10/66	11/10/66	1
CM341417	CAISTER ST. EDMOND	RIVER TAS	623700	303800	13/06/67	13/06/67	1
CM341418	SHOTESHAM	RIVER TAS	622600	299400	01/08/55	22/09/99	55
CM341420	BIXLEY	RIVER TAS	623500	305700	13/07/92	29/09/92	38
CM341421	HEMPNALL	RIVER TAS	621600	394700	13/09/67	22/09/99	39
CM341423	TROWSE NEWTON	RIVER TAS	623500	305700	30/10/95	23/09/99	33
CM341451	SHOTESHAM	RIVER TAS	622600	299400	01/08/55	22/09/99	55
CM341101	EAST RUDHAM	RIVER TATT	583600	330900	06/06/80	15/06/81	94
CM341102	EAST RUDHAM	RIVER TATT	583900	330400	06/06/80	15/06/81	94

Table 4 Location of Current Meter Flow Monitoring Sites

STATTION REF	STATION NAME	LOCATION DESCRIPTION	NGR EASTING	NGR NORTHING	START DATE	END DATE	NO. OF RECORDS
CM341106	TATTERSETT	RIVER TATT	586700	328000	16/08/90	16/08/90	1
CM341163	COXFORD	RIVER TATT	584700	329400	18/07/67	19/07/99	216
CM341307	WYMONDHAM	RIVER TIFFEY	611000	301100	12/10/66	05/02/78	8
CM341308	WYMONDHAM	RIVER TIFFEY	610900	301100	12/10/66	05/02/78	8
CM341311	WYMONDHAM	RIVER TIFFEY	611400	301100	12/10/66	05/02/78	8
CM341312	WYMONDHAM	RIVER TIFFEY	609400	302700	12/10/66	05/02/78	8
CM341313	WYMONDHAM	RIVER TIFFEY	609500	302800	12/10/66	05/02/78	8
CM341315	BARFORD	RIVER TIFFEY	611900	307500	07/08/76	29/07/92	3
CM341316	BARFORD	RIVER TIFFEY	612000	307600	07/08/76	29/07/92	3
CM341330	WYMONDHAM (U/S STW)	RIVER TIFFEY	609400	302600	23/05/44	20/07/99	52
CM341332	WYMONDHAM (D/S STW)	RIVER TIFFEY	609400	302600	05/04/95	20/07/99	38
CM341203	EAST TUDDENHAM	RIVER TUD	607400	311800	05/01/72	10/01/73	28
CM341204	HOCKERING	RIVER TUD	606600	312800	28/06/95	20/07/99	37
CG034011	FAKENHAM	RIVER WENSUM	591900	329400	16/08/67	16/08/67	1
CG034114	SWANTON MORLEY 2 ARCH	RIVER WENSUM	602000	318400	16/04/98	16/04/99	3
CM341107	RAYNHAM	RIVER WENSUM	588500	324100	18/07/67	16/08/90	2
CM341109	HEMPTON	RIVER WENSUM	591200	329500	12/09/67	12/09/67	1
CM341110	FAKENHAM	RIVER WENSUM	591900	329400	16/08/67	16/08/67	1
CM341111	RYBURGH	RIVER WENSUM	596400	327000	16/08/67	16/08/67	1
CM341112	GUIST	RIVER WENSUM	598700	325000	16/08/90	30/07/91	3
CM341113	GUIST	RIVER WENSUM	599700	325000	16/08/90	30/07/91	3
CM341116	BILLINGFORD	RIVER WENSUM	600400	320300	22/06/67	16/08/90	2
CM341124	BILLINGFORD	RIVER WENSUM	602200	320500	22/06/67	16/08/90	2
CM341127	ELSING	RIVER WENSUM	605100	317800	16/08/90	16/08/90	1
CM341128	LYNG	RIVER WENSUM	607200	317700	16/08/90	19/10/92	41
CM341129	GREAT WITCHINGHAM	RIVER WENSUM	610300	318300	16/08/90	16/08/90	2
CM341143	ALDERFORD	RIVER WENSUM	612700	318600	09/09/75	16/10/92	11
CM341144	ATTLEBRIDGE	RIVER WENSUM	612800	316700	16/08/80	24/07/92	5
CM341145	RINGLAND	RIVER WENSUM	614200	313700	16/08/90	19/10/92	14
CM341146	COSTESSEY	RIVER WENSUM	617700	312800	16/08/90	16/08/90	1
CM341148	KETTLESTONE	RIVER WENSUM	596800	331600	11/05/76	03/06/76	21
CM341149	NORTH ELMHAM	RIVER WENSUM	598700	321200	30/06/67	19/10/92	37
CM341151	FAKENHAM MILL	RIVER WENSUM	591900	329300	01/06/62	01/06/62	1
CM341152	SWANTON MORLEY	RIVER WENSUM	602100	318500	01/08/55	20/07/99	98
CM341153	MILL STREET	RIVER WENSUM	605100	317800	10/08/92	19/10/92	13
CM341156	LYNG	RIVER WENSUM	607200	317700	16/08/90	19/10/92	41
CM341158	ALDERFORD	RIVER WENSUM	612700	318500	09/09/75	16/10/92	11
CM341159	ATTLEBRIDGE	RIVER WENSUM	612800	316700	16/08/80	24/07/92	5
CM341160	RINGLAND	RIVER WENSUM	614100	313700	16/08/90	19/10/92	14
CM341162	NORTH ELMHAM	RIVER WENSUM	599200	322800	30/06/67	19/10/92	37
CM341164	WEST RAYNHAM	RIVER WENSUM	587800	325500	19/07/95	19/07/99	37
CG034001	COLNEY	RIVER YARE	618200	308200	09/05/58	23/03/99	7
CM341303	GARVESTONE	RIVER YARE	603300	307300	07/08/76	07/08/76	1
CM341304	HARDINGHAM	RIVER YARE	604800	306200	12/10/66	30/08/91	3
CM341305	BARFORD	RIVER YARE	612400	308400	07/08/76	29/07/92	3
CM341331	BARNHAM BROOM	RIVER YARE	607500	307500	26/10/93	20/07/99	52
CM341351	COLNEY	RIVER YARE	618200	308200	09/05/58	23/03/99	7
CM341352	CRINGLEFORD BRIDGE	RIVER YARE	619900	205900	01/08/55	29/05/57	11
CM341503	BRUNDALL	RUN DYKE	633600	308400	21/10/77	21/10/77	2
CM341130	SALLE	SALLE BECK	612500	325000	11/08/77	11/08/92	5
CM341131	SALLE	SALLE BECK	612600	324200	11/08/77	11/08/92	5
CM341132	REEPHAM	SALLE BECK	611600	321300	22/06/67	11/08/92	5
CM341147	SALLE	SALLE BECK	612800	325500	11/08/77	11/08/92	5
CM340606	AYLMERTON	SCARROW BECK	618600	339600	27/05/68	31/05/95	102
CM340607	HANWORTH	SCARROW BECK	619300	335900	23/08/89	25/08/89	3
CM340608	ERPINGHAM	SCARROW BECK	618700	331800	28/07/89	09/01/91	18
CM340609	ERPINGHAM	SCARROW BECK	618200	330900	28/07/89	09/01/91	18
CM340620	EAST BECKHAM	SCARROW BECK	615900	339900	10/04/84	21/05/84	66
CM340621	EAST BECKHAM	SCARROW BECK	616200	339800	10/04/84	21/05/84	66
CM340628	ALDBOROUGH	SCARROW BECK	618630	363370	29/04/69	21/07/99	54
CM341419	SHOTESHAM	SHOTESHAM STREAM	624600	209900	01/08/55	22/09/99	55
CM341155	LYNG	SOUTH DRAIN	607100	317800	16/08/90	19/10/92	41
CM340701	CROSTWICK	SPIXWORTH BECK	625500	316200	27/08/76	09/01/91	63
CM340702	CROSTWICK	SPIXWORTH BECK	626500	316600	27/08/76	09/01/91	63
CM340704	HAINFORD	SPIXWORTH BECK	621400	318300	22/08/95	23/09/99	40
CM340705	HORSHAM ST. FAITH	SPIXWORTH BECK	622700	316000	22/08/95	23/09/99	39
CM340706	SPIXWORTH	SPIXWORTH BECK	623900	316500	22/08/95	23/09/99	41
CM341170	BEETLEY	SPONG BECK	598200	319200	14/08/95	19/07/99	36
CM340630	SKEYTON	STAKEBRIDGE BECK	625100	324300	04/10/73	30/09/99	74
CM341103	PENSTHORPE	STIBBARD WATERCOURSE	596100	329300	15/07/97	19/07/99	18
CM340408	STODY	STODY WATERCOURSE	606100	335300	15/07/97	21/07/99	17
CM341533	STUSTON	STUSTON BROOK	999999	999999	08/06/99	08/06/99	1
CM340614	ROUGHTON	SUFFIELD BECK	622300	335600	07/09/89	07/09/89	1
CM340616	SKEYTON	SUFFIELD BECK	624600	327300	04/10/73	30/09/99	74
CM340617	SKEYTON	SUFFIELD BECK	623700	325300	04/10/73	30/09/99	74
CM340618	SKEYTON	SUFFIELD BECK	624200	325500	04/10/73	30/09/99	74
CM340904	CATFIELD	SUTTON BROAD	637300	322600	11/05/78	25/05/78	15
CM341140	FELTHORPE	SWANNINGTON BROOK	616400	319200	09/09/73	09/09/75	2
CM341141	FELTHORPE	SWANNINGTON BROOK	615800	318400	09/09/73	09/09/75	2
CM341142	SWANNINGTON	SWANNINGTON BROOK	613500	319000	09/09/75	09/09/75	1
CM341513	HELLINGTON	THE BECK	631300	303500	05/07/91	22/09/99	39

Table 4 Location of Current Meter Flow Monitoring Sites

STATTION REF	STATION NAME	LOCATION DESCRIPTION	NGR EASTIN	NGR NORTHIN	START DATE	END DATE	NO. OF RECORDS
CM340905	TUNSTEAD	TUNSTEAD STREAM	629100	322000	05/10/85	28/11/85	80
CM340906	TUNSTEAD	TUNSTEAD STREAM	629100	321700	05/10/85	28/11/85	80
CM340624	THURNING	TYBY WATERCOURSE	607800	328500	27/11/80	19/08/92	68
CM340909	WORSTEAD	UPPER STREET STREAM	630900	324500	11/08/67	13/10/67	21
CM341403	GREAT MOULTON	WACTON STREAM	616900	291500	13/06/67	13/06/67	1
CM341117	WENDLING	WENDLING BECK	593300	312700	22/08/67	22/08/67	1
CM341118	EAST DEREHAM	WENDLING BECK	598500	313400	22/09/67	22/09/67	1
CM341119	GRESSENHALL	WENDLING BECK	597400	313400	21/10/65	19/07/99	56
CM341120	GRESSENHALL	WENDLING BECK	597500	313400	21/10/65	19/07/99	56
CM341121	GRESSENHALL	WENDLING BECK	597500	313700	21/10/65	19/07/99	56
CM341122	GRESSENHALL	WENDLING BECK	595600	315800	21/10/65	19/07/99	56
CM341161	WORTHING	WENDLING BECK	599700	320100	26/06/92	28/05/99	53
CM341165	GRESSENHALL	WENDLING BECK	596810	381520	21/10/65	19/07/99	56
CM340808	SWANTON ABBOTT	WESTWICK WATERCOURSE	626700	325100	11/08/67	25/09/67	9
CM341136	SPARHAM	WHITEWATER RIVER	608600	320300	22/06/67	16/08/90	2
CM341137	SPARHAM	WHITEWATER RIVER	608300	320300	22/06/67	16/08/90	2
CM341138	REEPHAM	WHITEWATER RIVER	608200	320200	22/06/67	11/08/92	5
CM341139	GREAT WITCHINGHAM	WHITEWATER RIVER	609800	318900	16/08/90	16/08/90	2
CM341168	FOXFORD	WHITEWATER RIVER	609800	318900	26/06/92	20/07/99	48
CM341318	WICKLEWOOD	WICKLEWOOD STREAM	608300	303300	12/10/66	12/10/66	1
CM341504	BRUNDALL	WITTON RUN	633300	308800	21/10/77	21/10/77	2
CM341505	BLOFIELD	WITTON RUN	632500	309500	21/10/77	23/09/99	37
CM341532	BLOFIELD	WITTON RUN	633200	308900	21/10/77	23/09/99	37
CM340901	WITTON	WITTON WATERCOURSE	634400	331700	23/07/81	30/07/81	2
CM340911	WORSTEAD	WORSTEAD STREAM	630100	325200	11/08/67	13/10/67	21
CM341171	WORTHING	WORTHING WATERCOURSE	600400	320000	26/06/92	28/05/99	53

Table 5 **Assessment of Accuracy of Flow Gauging Stations (from Hydraulics Research (1995)**

		Q_{95}	Q_{MEAN}	Q_{MAF}	Q_{FULL}	Comments (by Hydraulics Research)
034001	Colney	1	1	-	3	Weir is laboratory model tested. Approach is not straight (bank erosion). Assessed on NRA/HR modular ratings.
034002	Shotesham	1	1	-	4	Upstream approach too short. By-pass causes structure to drown. Accurate rating must include calibrated by-pass. HR rating assumes no by-pass flow.
034003	Ingworth	-	-	-	-	Assessment not valid as structure was model tested.
034004	Costessey Mill	-	-	-	-	Assessment not valid as structure was model tested. NRA rating equation data from 1979 but structure rebuilt in 1988.
034005	Costessey Park	3	2	2	3	Dam boards in 2 outer arches assumed to be out. Flumes can only be accurately assessed to top of trap section, which is near modular limit. Model tested by NRA.
034008	Honing Lock	1	1	-	4	Non-standard structure (rated as standard). Rating limit assessed on non-modular ratings. Heavy siltation and weed. Non-modular only at extreme range.
034011	Fakenham (Sluice Open)	1	3	4	4	Assessment made for modular range only. Heavy silt in upstream and downstream channels. NRA equations refer to head over RH Crump.
	Fakenham (Sluice Closed)	2	1	3	4	NRA equations refer to head over RH Crump. Drowns at about 0.8m head. Heavy silt upstream and downstream.
034012	Burnham Overy	2	4	-	3	MAF discharge above rating limit.
034014	Swanton Morley (2 Arch)	-	-	-	1	Drowns at very low heads (i.e. below Q95). Needs further investigation. Could not be assessed at Q95, mean or MAF. Assessed only0on non-modular rating.
	Swanton Morley (3 Arch)	-	-	-	4	(as above)
034016	Bayfield					(Not included in HR assessment)
034018	Warham	3	3	3	3	HR assessment suggests modular throughout range (NRA estimate early drowning from 1975 study).
034019	Horstead (Sluice Open)	1	1	-	1	NRA equation 3 is wrong. Multiplier is given as 0, no stilling well levels obtained. No gauge boards.
	Horstead (Sluice Closed)	1	1	-	3	Assessed on modular ratings. No stilling well levels obtained. No gauge boards. Some crest level errors apparent.
034020	Lt. Walsingham					(Not included in HR assessment)
034021	Mundesley Hospital	-	-	-	1	No tailwater possible because of very low flows. V-notch plate is standard but installed wrong way round. Assessment made only at rating limit.

Q_{95}: flow exceeded 95% of the time
Q_{MEAN}: average daily flow
Q_{MAF}: mean annual flood
Q_{FULL}: full range

Assessed Accuracy ratings

Class	Error
1	< 3.0%
2	3.1-5.0%
3	5.1-10.0%
4	> 10.1%

3.2 Tidal Gauging

At a number of sites the surface elevation response to tidal effects is recorded, and these are shown on Figure A3. These do not record flow. For a number of these locations, given in Table 6, some data has not been converted from chart records and these are held in the archive storage area at Ipswich.

3.3 Surface Water Abstractions

The model area contains some 142 licensed surface water only abstractions and 79 combined surface and groundwater abstractions. The location of these is shown on Figure A4. Spray irrigation accounts for the largest number of abstractions. Only a small number of surface water abstraction licences have been granted since 1963, although a recent trend has been increased numbers of winter only abstraction licences for storage of water to be used for spray irrigation in summer.

Table 6 Location of Chart Only Tidal Sites

Site	NGR	Start Date	End Date
Acle Bridge		1973	1991
Cattaway Bridge		1984	-
Haddiscoe Depot		1969	1991
Beccles Quay		1970	1993
Ellingham Sluice		1978	1993
Great Yarmouth		1982	-
Carrow Bridge		1974	1974
Wells-next-the-Sea		1979	1986
Cantley		?	?
Burgh St Peter		1974	1983
Hoveton Broad		1978	1986
Rockland Broad		1987	-
Burgh Castle		1987	-

Available historical records of license returns are largely in digital form and consist of monthly returns for abstractions greater than 20 m^3/d. These returns cover the period 1988 to the present day. Prior to this monthly returns were provided for abstractions greater than 5 thousand cubic metres per annum (tcma), and smaller abstractions provided annual returns only. These records date back to 1968. Historical records were added to the database in 1988 and therefore any paper records that were not available at that time may have been lost.

In addition to these sites, a number of wetlands incorporate monitoring of surface water levels using gaugeboards.

3.4 Surface Water Quality

Surface water quality data is held on the Public Register in Peterborough. Sites currently being monitored are shown on Figure A5. These records date back to 1985, and occasionally 1980. Records prior to this are held on microfiche and are not readily available for use. Surface water quality monitoring by the Agency is generally on a monthly basis and consists of a basic suite of

Total Oxidised Nitrogen
Dissolved Oxygen
Phosphate
Ammonia
BOD
COD
Temperature

Additional parameters may be measured for sensitive sites.

3.5 Accretion Profiles

A compilation of available accretion profiles was made in 1997 (the 'Glory File'). Accretion profiles are available for 1997 for the Bure (34/6), Wensum (34/11), and Yare (34/13 and 34/15). This report also refers to accretion profiles undertaken on the Bure by 'Biology' in 1993, Wensum (Mott MacDonald, 1990) and the Yare (Simon Hydrotechnica, 1991).

3.6 Discharges

Details of consented discharges are held on the Public Register in Peterborough (contact Peter Fountain, Water Quality). Locations of all discharge consents are shown on Figure A6. (A listing is available, but is voluminous and therefore not repeated here). There are around 3000 discharge consents currently in force in the study area. Discharges are dominantly small, consented discharges which do not have specified maximum flow rates: these account for around 20% of all discharges. Only 6% of consented discharges are in excess of 100 m^3/d dry weather flow (Figure A6). Sewage treatment works (STWs) account for almost all of these larger discharges.

Discharge consents may be subject to water quality monitoring. Determinands used for water quality monitoring are dependant upon the nature of the discharge.

3.7 River Bed Profiles

The Norwich Office holds a set of 1:1250 maps on which are indicated the locations of surveyed river cross-sections: these are nominally at 100 m intervals along all main river channels. Longitudinal profiles are also available.

In addition, as part of the Broadlands Flood Alleviation Strategy (BFAS) project, cross-sections for the tidal reaches are also available on CD. These are presented as digital drawings (and not as spreadsheets for example), so it would be necessary to extract the elevation information manually for use elsewhere.

3.8 Other Sources of Hydrological Data

Reports on River Burn

Water level measurements on Hickling Broad at Ormesby St. Michael by Essex and Suffolk Water (Graham Robertson / Joanne Pitt).

Short-term river gauging data may be held in pump test files for larger abstraction licences close to rivers.

Water Level Management Plans are either available or are in the process of production for the sites listed in Table 7.

Table 7 Location and Status of WLMPs

Site No	Site Name	Authority Responsible for Plan	Status
476	Alderfen Broad	Smallburgh IDB	Plan finalised and agreed with EN
028a	Alderford Common	River Wensum IDB	Draft with EN
477	Ant Broads and Marshes	Smallburgh IDB	Plan in preparation
478	Aslacton Parish Land	Upper Yare & Tas IDB	Plan in preparation
479	Badley Moor, Dereham	River Wensum IDB	Plan required, but no action yet taken
480	Beetley & Hoe Meadows	River Wensum IDB	Plan not required and agreed with EN
481	Booton Common	River Wensum IDB	Draft with EN
483	Breydon Water	Lower Bure, Halvergate & Acle, Burgh Castle, Langley Chadgrave & Toft Monks IDBs	Plan in preparation (part of Halvergate WLMP)
484	Broad Fen, Dilham	Smallburgh IDB	Plan in preparation
485	Bryant's Heath	Upper Bure IDB	Draft with EN
486	Bure Broads and Marshes	Middle Bure IDB	Plan required, but no action yet taken
487	Burgh Common & Muckfleet Marshes	Muckfleet & South Flegg IDB	Plan in preparation
488	Buxton Heath	Upper Bure IDB	Draft with EN
489	Calthorpe Broad	Smallburgh IDB	Plan in preparation
494	Crostwick Marsh	Middle Bure IDB	Plan required, but no action yet taken
495	Damgate Marshes, Acle	Lower Bure, Halvergate & Acle IDBs	Plan finalised (part of Halvergate WLMP)
496	Decoy Carr, Acle	Lower Bure, Halvergate & Acle IDBs	Plan finalised (part of Halvergate WLMP)
	Dillington Carr, Gressenhall	Environment Agency	Interim Management Statement prepared
501	Ducan's Marsh, Claxton	Lower Yare Second IDB	Interim Management Statement in preparation
503	East Ruston Common	Smallburgh IDB	Plan in preparation
505	Flordon Common	Upper Yare & Tas IDB	Draft with EN

Table 7 (continued) **Location and Status of WLMPs**

Site No	Site Name	Authority Responsible for Plan	Status
506	Forncett Meadows	Upper Yare & Tas IDB	Plan required, but no action yet taken
511	Hall Farm Fen, Hemsby	Muckfleet & South Flegg IDB	Plan in preparation
512	Halvergate Marshes	Lower Bure, Halvergate & Acle IDBs	Plan in preparation
513	Hardley Flood	Lower Yare Second IDB	Interim Management Statement in preparation
518	Limpenhoe Meadows	Limpenhoe & Reedham IDB	Plan in preparation
519	Ludham-Potter Heigham Marsh	Smallburgh IDB	Plan in preparation
	North Norfolk Coast: Blakeney Freshes	Environment Agency	Endorsed
	North Norfolk Coast: Brancaster	Environment Agency	Endorsed
	North Norfolk Coast: Burnham Norton	Environment Agency	Endorsed
	North Norfolk Coast: Burnham Overy Marshes	Environment Agency	Endorsed
	North Norfolk Coast: Cley/Salthouse Marshes	Environment Agency	Endorsed
	North Norfolk Coast: Holme	Environment Agency	Endorsed
	North Norfolk Coast: Wells West Bank	Environment Agency	Endorsed
523	Poplar Farm Meadows, Langley	Lower Yare Second IDB	Interim Management Statement in preparation
524	Potter & Scarning Fens	River Wensum IDB	Draft with EN
525	Priory Meadows	Smallburgh IDB	Plan in preparation
	River Wensum	Environment Agency	Interim Management Statement prepared
530	Sea Mere Hingham	Upper Yare & Tas IDB	Draft with EN
531	Shallam Dyke Marshes	Repps, Martham & Thurne IDB	Plan in preparation
533	Smallburgh Fen	Smallburgh IDB	Plan in preparation
534	Southrepps Common	Smallburgh IDB	Draft with EN
536a	Swannington Upgate Common	River Wensum IDB	Draft with EN
487a	Trinity Broads	Muckfleet & South Flegg IDB	Plan required, but no action yet taken
539	Upper Thurne Broads and Marshes	Smallburgh & Happisburgh IDBs	Plan in preparation
540	Upton Broad & Marshes	Middle Bure IDB	Plan finalised (part of Halvergate WLMP)
542	Whitwell Common	River Wensum IDB	Draft with EN
543	Winterton to Horsey Dunes	Happisburgh-Winterton IDB	IMS in preparation
545	Yare Broads and Marshes	Lower Yare First & Lower Yare Fourth IDBs	Plan in preparation

4. Geology

4.1 Agency Held Information

The geology of the area can be found on the relevant 1:50 000 scale geological maps (Sheets 130 to 132, 146 to 148, 160 to 162 and 174 to 175), although sheets 130, 131 and 147 are not yet available. The Agency's Ipswich Office also has copies of the 1:10 560 scale surveyor's maps for the areas indicated in Figure A7. BGS are currently undertaking surveying work in North Norfolk, which will lead to issue of the 'missing' maps over the next four years.

The Agency are considering licensing digital 1:50 000 geological maps from BGS. These will shortly be available for all currently published map areas.

The Agency also have a complete copy of the BGS well catalogue as it was in 1992, which has subsequently been updated by abstraction licensing staff with logs from recent applications. The location of wells is shown on 1:10 560 scale maps held in Ipswich, and the logs are organised into files for each 10 km grid square. The quality of well records is highly variable, many consisting of nothing more than a drillers log.

An indication of the coverage of geological borehole logs is given on Figure A8, which is a screen dump from the BGS Borehole Catalogue: the figure differentiates between boreholes shallower than 30 m and deeper holes.

4.2 Other Information

There are many potential sources of geological information: those that are readily accessible through Agency records are listed below.

Sand and Gravel Assessment Reports. These are available for the areas indicated below:

- Assessment of Sand and Gravel Resources. Attlebridge Norfolk. IGS Report No 73/5.
- Assessment of Sand and Gravel Resources. Heathersett, Norfolk. IGS Report No 73/4
- Assessment of Sand and Gravel Resources. Country Southeast of Norwich. IGS Report No 71/20.

The Hydrogeological Maps for East Anglia show an interpretation of the shallow geology

Site Investigation reports: The agency holds numerous site investigation reports containing borehole logs. Principal sources might be landfill monitoring wells, geotechnical site investigations, wetland investigations, contaminated land investigations. Many of these boreholes are likely to be shallow.

Deep investigation boreholes. The coastal areas of Norfolk have been investigated by Oil Exploration companies and a number of borehole logs from these investigations are held in the licensing files (in the general geology section).

Norfolk County Council also hold many geological borehole logs, which are available for inspection, although the majority of these boreholes are very shallow.

5. Hydrogeology

The main aquifer in the area is the Chalk, the extent of which is shown on Figure A9. In the east the Crag has only been developed for groundwater abstraction to any extent following the introduction of geotextile screens in the 1970's due to problems with fines blocking coarser screens. Groundwater in the crag can still experience water quality problems due to high iron content. In some areas significant sand and gravel deposits also exist.

5.1 Groundwater Levels

The Environment Agency maintains a record of water levels at the locations shown on Figure A9. The length of these monitoring records is shown on Table 8.

Recent additions to the monitoring records are available from two sources, the first is the wetland monitoring programme and the second is the Bacton to Great Yarmouth gas pipeline groundwater monitoring scheme. The wetland monitoring points are included on Table 8, and the observation boreholes associated with the pipeline are listed in Table 9. Both data set locations are included on Figure A9. Monitoring began on wetlands in 1996 and continues at a monthly frequency. Monitoring of the pipeline started in 1997 and continues to the present day.

An assessment of the completeness of the record has been made by dividing the number of records available by the number of months of the record (see 'Ratio' column on Table 8). Values of this ratio in excess of unity indicate either data gaps or an infrequent monitoring. Values greatly below unity show that data loggers have been used for at least part of the record period.

In addition to these formal groundwater monitoring systems a number of other sources of groundwater level can be found. These are:

- 1969 map of groundwater elevation issued by Water Resources Board – source data not indicated.
- Landfill monitoring wells: a number of landfills have monitoring regimes dating back several years (see Table 10).
- RAF Sculthorpe. Long-term monitoring at RAF Sculthorpe to investigate contamination has been undertaken both by the Agency and by consultants (Geraghty and Miller).
- The 'Hydrogeology of Northern East Anglia' map shows water table elevations for 1976.

5.2 Aquifer Parameters

Aquifer parameters (Transmissivity, T and Storativity, S) are principally available from pumping tests associated with licence applications. Nearly all groundwater licence applications are accompanied by a pump test. Prior to c1989 these tests were nearly always conducted by staff from the predecessor organisations to Agency (National Rivers Authority, Anglian Water Authority, Norwich Rivers Division). Since that time the onus has been on applicants to conduct pumping tests. In recent years (last 2 years) applications have been accompanied by an Environmental Statement detailing impacts on the water environment. Values of T and S have previously been compiled by BGS for use in the Aquifer Properties Manual. The locations of the pumping tests included in the Aquifer Properties Manual are shown on Figure A10a, which also indicates the magnitude of the interpreted transmissivity. Figure A10b shows the locations of those tests for which storage values have been derived.

The majority of the information contained within the Aquifer Properties Manual is derived from 'successful' boreholes that yielded adequate supplies of water. Of equal importance in trying to develop an understanding of the regional hydrogeology are the poor-yielding boreholes. Details of pumping tests that produced insufficient quantities of water for the applicant's purposes are held in the 'Not Proceeded With' file at the Agency office in Ipswich.

5.3 Groundwater Quality

The Agency maintains a network of monitoring wells from which groundwater samples are taken for quality analysis and these are shown on Figure A11. Groundwater quality has only been monitored since 1993 or 1994 at a frequency of one or two samples per year. Recently a cut in the available budget will mean a reduction in either the number of wells sampled or the frequency of sampling.

The Agency also hold water quality data from Anglia water PWS wells dating back to 1985.. Data from before this date may exist in paper form. The sampling frequency for this data varies depending upon the use of the data, it may be at a weekly frequency for wells providing water directly to public supply. Water quality samples may be taken following blending of water from several wells rather than from the well head and therefore may not directly represent groundwater quality.

Table 8 HYDROGAT Groundwater Monitoring Sites

Grid Sq	REF	LOCATION	NGR	BGS	DATUM	DATLE	AQUIFER	AQ UNIT	GEOLOGY	RECORDS	RATIO
TF71	NTF7136G1	East Walton Common - Gaugeboard	TF 7273 1647		17.700	s		Gaugeboard	SURFACE	15	1.47
TF71	NTF7136G2	East Walton Common - Gaugeboard	TF 7230 1630		0.000			Gaugeboard	SURFACE	9	-1.00
TF71	NTF7136P1	East Walton Common - Deep	TF 7274 1648		19.370	s				79	1.12
TF71	NTF7136P2	East Walton Common - Shallow	TF 7274 1648		19.710	s				79	1.12
TF72	TF72/820	Great Massingham	TF 7980 2780	145/158	92.560	s	CH	Upper Chalk	CHALK	276	1.09
TF73	TF73/868	Sutton Farm, Stanhoe	TF 7963 3489	130/12	65.850	s	CH	Upper Chalk	CHALK	540	1.06
TF74	TF74/325	Thornham Farm Obs - Beacon Hill	TF 7354 4239		0.000					22	1.09
TF74	TF74/439	Thornham Marsh Obs Borehole	TF 7490 4380		0.000					291	0.15
TF74	TF74/745	Whitelodge, Brancaster	TF 7757 4404	130/93	31.790	s	CH	Upper Chalk	CHALK	572	1.04
TF82	TF82/362	Rudham House Farm, East Rudham	TF 8122 2808	146/124	49.000	s	CH	Upper Chalk	CHALK	297	1.01
TF82	TF82/870	Valley Farm, Helhoughton	TF 8604 2792	146/182	49.070	s	CH	Upper Chalk	CHALK	473	1.16
TF83	NTF8331E1	Syderstone Common - HW 7	TF 8344 3152		0.000					18	1.17
TF83	NTF8331G1	Syderstone Common - Gaugeboard	TF 8353 3149		0.000			Gaugeboard	SURFACE	3	0.67
TF83	NTF8331G2	Syderstone Common - Gaugeboard	TF 8344 3155		46.530	s		Gaugeboard	SURFACE	3	0.67
TF83	NTF8331G3	Syderstone Common - Gaugeboard	TF 8330 3158		49.970	s		Gaugeboard	SURFACE	3	0.67
TF83	NTF8331G4	Syderstone Common - Gaugeboard	TF 8304 3168		0.000			Gaugeboard	SURFACE	0	-1.00
TF83	NTF8331P1	Syderstone Common - Deep Pz 1	TF 8344 3152		47.790	s	CH	Upper Chalk	CHALK	79	1.12
TF83	NTF8331P2	Syderstone Common - Deep Pz 2	TF 8304 3167		49.070	s				79	1.12
TF83	NTF8331P3	Syderstone Common - Shallow	TF 8304 3167		48.740	s				70	1.45
TF83	NTF8331P4	Syderstone Common - Shallow	TF 8344 3152		48.760	s				1	0.00
TF83	TF83/323	School Canteen, Syderstone	TF 8331 3250	146/259	65.580	s	CH	Upper Chalk	CHALK	374	0.93
TF83	TF83/560	South Creake - Observation Borehole	TF 8584 3824		24.200		CH	Upper Chalk	CHALK	685	0.08
TF83	TF83/560A	South Creake - Gravel Piezometer	TF 8584 3824		24.190		GD	Drift	Q & Recent	436	0.12
TF83	TF83/566	Manor Farm, South Creake	TF 8587 3840		22.790	s	CH	Upper Chalk	CHALK	309	0.22
TF83	TF83/567	South Creake School	TF 8578 3806	130/216	23.410	s	CH	Upper Chalk	CHALK	1295	0.44
TF83	TF83/570	North Creake - Observation Borehole	TF 8531 3779		18.170		CH	Upper Chalk	CHALK	893	0.08
TF83	TF83/570A	North Creake - Gravel Piezometer	TF 8531 3770		18.240		GD	Drift	Q & Recent	568	0.15
TF84	TF84/317	Creake Road, Burnham Market	TF 8371 4172	130/63	10.520	s	CH	Upper Chalk	CHALK	91	0.98
TF84	TF84/850	Meole House, Holkham	TF 8807 4570	130/254	4.530	s	CH	Upper Chalk	CHALK	384	1.09
TF90	TF90/819	Shipdham Airfield	TF 9803 0707	161/241a	87.240	s	CH	Upper Chalk	CHALK	544	1.03
TF91	NTF9133P1	Holly Farm Meadow - Deep	TF 9382 1317		53.910	s				74	1.17
TF91	NTF9133P2	Holly Farm Meadow - Shallow	TF 9382 1317		53.740	s				75	1.18
TF91	NTF9133PA	Holly Farm Meadow - Existing Pz	TF 9381 1304		49.630	s				77	1.32
TF91	NTF9133PB	Holly Farm Meadow - Existing Pz	TF 9368 1300		48.790	s				19	1.53
TF91	NTF9186P2	Hoe Meadow - Shallow	TF 9791 1889		31.540	s				78	1.12
TF91	NTF9162E1	Potter & Scarning Fen - Existing Pz	TF 9815 1210		0.000					10	1.00
TF91	NTF9162E2	Potter & Scarning Fen - Existing Pz	TF 9814 1209		0.000					5	0.80
TF91	NTF9162P1	Potter & Scarning Fen - Deep	TF 9812 1222		47.800	s				75	1.12
TF91	NTF9162P2	Potter & Scarning Fen - Shallow	TF 9812 1222		47.820	s				78	1.12
TF91	NTF9162P3	Potter & Scarning Fen - Shallow	TF 9814 1219		43.080	s				75	1.19
TF91	NTF9186P1	Hoe Meadow - Deep	TF 9803 1895		31.100	s				9	-1.00
TF91	NTF9186P3	Hoe Meadow - Shallow	TF 9803 1894		0.000					0	-1.00
TF91	NTF9187P1	Beetley Meadow - Deep	TF 9827 1755		0.000					5	0.80
TF91	NTF9187P2	Beetley Meadow - Shallow	TF 9827 1755		0.000					5	0.80
TF91	NTF9187P3	Beetley Meadow - Shallow	TF 9819 1730		0.000					5	0.80
TF91	NW/TF913A	Holly Farm Meadow - Dipwell A	TF 9380 1319		0.000		VO	See Soil Log		18	0.94
TF91	NW/TF913B	Holly Farm Meadow - Dipwell B	TF 9380 1319		0.000		VO	See Soil Log		18	0.94
TF91	NW/TF918A	Beetley & Hoe Meadows - Dipwell A	TF 9820 1740		0.000		VO	See Soil Log		0	-1.00
TF91	NW/TF918B	Beetley & Hoe Meadows - Dipwell B	TF 9820 1740		0.000		VO	See Soil Log		0	-1.00
TF91	TF91/822	Hillfield Farm, Scarning	TF 9622 1249	160/131	53.270	s	CH	Upper Chalk	CHALK	300	1.00
TF91	TF91/751	Drift Farm, Dillington	TF 9716 1579	147/265	40.780	s	CH	Upper Chalk	CHALK	541	1.04
TF91	TF91/774	Beech House, Gressenhall	TF 9747 1705	146/262	41.310	s	CH	Upper Chalk	CHALK	544	1.03
TF91	TF91/864	Gorgate Crossroads - Borehole	TF 9849 1676		45.980	s	CH	Upper Chalk	CHALK	141	0.97
TF91	TF91/864A	Gorgate Crossroads - Piez 1	TF 9849 1676		48.030	s	GD	Boulder Clay	Q & RECENT	137	1.00
TF91	TF91/864B	Gorgate Crossroads - Piez 2	TF 9849 1676		48.030	s	GD	Sand & Gravel	Q & Recent	138	1.01
TF91	TF91/888	Beetley Common - Borehole	TF 9887 1863		30.720	s	CH	Upper Chalk	CHALK	140	0.94
TF91	TF91/888A	Beetley Common - Piez	TF 9887 1863		30.570	s	GD	Drift	Q & Recent	140	0.94
TF92	TF92/790	Newmans Yard, Fakenham	TF 9203 2987		42.880		GD	Sand & Gravel	Q & Recent	65	1.03
TF92	TF92/423	Barracuda Brickyard - Bore	TF 9433 2220	146/418	58.800	s	CH	Upper Chalk	CHALK	532	1.05
TF92	TF92/423A	Barracuda Brickyard - Well	TF 9433 2220	146/418	58.800	s	GD	Drift	Q & Recent	241	1.00
TF92	TF92/671	School, Great Ryburgh	TF 9615 2734	146/298	33.230	s	CH	Upper Chalk	CHALK	537	1.04
TF92	TF92/810	Tower Hills, P.S. North Elmham	TF 9889 2183	146/275	48.380	s	CH	Upper Chalk	CHALK	294	1.07
TF93	TF93/011	Grove House Farm, Sculthorpe	TF 9014 3107	146/122	41.370	s	CH	Upper Chalk	CHALK	318	1.09
TF93	TF93/089A	Egmere P.S. - Bore A	TF 9093 3898	130/153a	63.780	s	CH	Upper Chalk	CHALK	290	1.04
TF93	TF93/089B	Egmere P.S. - Bore B	TF 9093 3898	130/153b	63.640	s	CH	Upper Chalk	CHALK	172	1.01
TF93	TF93/707	Fakenham Depot	TF 9271 3031	146/58	54.000	s	CH	Upper Chalk	CHALK	294	1.02
TF93	TF93/762	The Old Station, Little Walsingham	TF 9322 3660		31.300	s	CH	Upper Chalk	CHALK	86	1.02
TF93	TF93/763	Little Walsingham	TF 9335 3669	130/215	25.880	s	CH	Upper Chalk	CHALK	503	1.11
TF93	TF93/919	Kettlestone / Little Ryburgh Common	TF 9095 3180		0.000					32	0.59
TF94	TF94/118	Cuckoo Lodge, Wells	TF 9189 4133	130/130	47.170	s	CH	Upper Chalk	CHALK	529	1.08
TG00	TG00/088	Church Road, Whinburgh	TG 0083 0891	161/341	54.420	s	CH	Upper Chalk	CHALK	170	1.01
TG00	TG00/480	Thuxton House, Thuxton	TG 0409 0822	161/238	38.420	s	CH	Upper Chalk	CHALK	538	1.04
TG00	TG00/837	Kimberley P.S. - Bore	TG 0870 0330	161/434	33.910	s	CH	Upper Chalk	CHALK	137	1.11
TG01	NTG0111P1	Badley Moor - Deep	TG 0176 1184		37.690	s				0	-1.00
TG01	NTG0111P2	Badley Moor - Shallow	TG 0176 1184		37.710	s				26	1.12
TG01	NTG0111P3	Badley Moor - Shallow	TG 0172 1182		38.430	s				73	1.22
TG01	NTG0111P4	Badley Moor - Existing Pz	TG 0118 1162		0.000					13	1.46
TG01	TG01/138	Etling Green, Dereham	TG 0102 1390	161/	58.170	s	CH	Upper Chalk	CHALK	296	1.00
TG01	TG01/738	Council House, Hockering	TG 0762 1330	161/359	43.010	s	CH	Upper Chalk	CHALK	301	0.99
TG01	TG01/787	Sparham Hill, Lyng	TG 0770 1690		45.000	s	CH	Upper Chalk	CHALK	137	0.99
TG01	TG01/990	Blackwater Farm, Great Witchingham	TG 0906 1993	147/218	37.800	s	CH	Upper Chalk	CHALK	545	1.03
TG02	TG02/341	Main Street, Foulsham	TG 0317 2416	147/151	35.370	s	CH	Upper Chalk	CHALK	363	1.04
TG02	TG02/494	Hindolveston - Borehole	TG 0449 2981		58.400	s	CH	Upper Chalk	CHALK	177	0.99
TG02	TG02/494A	Hindolveston - Piez	TG 0449 2981		58.390	s	GD	Sand & Gravel	Q & Recent	175	1.01
TG02	TG02/575	Abbey Farm, Guestwick	TG 0532 2758	147/275	57.210	s	CH	Upper Chalk	CHALK	539	1.04
TG02	TG02/778	Tyby - Borehole	TG 0765 2712		42.390	s	CH	Upper Chalk	CHALK	198	1.08
TG02	TG02/778A	Tyby - Piez 1	TG 0765 2712		42.450	s	GD	Sand & Gravel	Q & Recent	189	1.04
TG02	TG02/778B	Tyby - Piez 2	TG 0765 2712		42.430	s	GD	Sand & Gravel	Q & Recent	172	1.02
TG03	NTG0387G1	Holt Lowes - Gaugeboard	TG 0871 3718		0.000			Gaugeboard	SURFACE	21	1.14
TG03	NTG0387P1	Holt Lowes - Deep	TG 0847 3725		53.530	s				79	1.12
TG03	NTG0387PA	Holt Lowes - Existing Pz	TG 0846 3727		49.630	s				75	1.12
TG03	NTG0387PB	Holt Lowes - Existing Pz	TG 0837 3721		48.780	s				78	1.12
TG03	NW/TG038A	Holt Lowes - Dipwell #1	TG 0880 3740		0.000		VO	See Soil Log		86	0.49
TG03	NW/TG038B	Holt Lowes - Dipwell #2	TG 0880 3740		0.000		VO	See Soil Log		86	0.49
TG03	TG03/253	The Hall, Brinton	TG 0380 3561	113/1449	43.200	s	CH	Upper Chalk	CHALK	570	1.05
TG03	TG03/421	Melton Constable Industrial Estate	TG 0410 3290	147/15	82.170	s	CH	Upper Chalk	CHALK	247	1.15
TG03	TG03/511	Redlands, Briston - Bore	TG 0510 3150		64.140	s	CH	Upper Chalk	CHALK	144	0.99
TG03	TG03/511A	Redlands, Briston - Well	TG 0510 3150		64.800	s	UK	Unknown	Unknown	143	1.00
TG03	TG03/644	Old Lodge, Dody - Bore	TG 0640 3430		57.570	s	CH	Upper Chalk	Unknown	1215	0.17

Table 6 HYDRODAT Groundwater Monitoring Sites

Grid Sq	REF	LOCATION	NGR	BGS	DATUM	DATLE	AQUIFER	AQ UNIT	GEOLOGY	RECORDS	RATIO
TG03	TG03/844A	Old Lodge, Stody - Well	TG 0640 3420	131/20	97.510	s	CH	Upper Chalk	Unknown	181	1.09
TG03	TG03/712	Briston STW - Bore	TG 0724 3147		44.330	s	CH	Upper Chalk	Unknown	145	1.10
TG03	TG03/712A	Briston STW - Piezometer	TG 0724 3143		0.000		CR	Crag	CRAG	51	1.12
TG03	TG03/915	Holly Farm, Briston	TG 0950 3181	147/212	40.120	s	CH	Upper Chalk	CHALK	259	1.05
TG03	TG03/934	Street Farm, Edgefield (Abs. Bore)	TG 0944 3373		80.080	s	CH	Upper Chalk	CHALK	173	1.07
TG03	TG03/934A	Street Farm, Edgefield (Obs. Bore)	TG 0951 3369		87.230	s	CH	Upper Chalk	CHALK	171	1.03
TG03	TG03/934B	Edgefield Piez. 1	TG 0951 3361		87.300	s	CR	Crag	CRAG	174	1.01
TG03	TG03/934C	Edgefield Piez. 2	TG 0951 3361		87.319	s	CR	Crag	CRAG	174	1.01
TG03	TG03/934D	Edgefield Piez. 3	TG 0951 3362		87.212	s	CR	Crag	CRAG	172	1.02
TG04	TG04/239	Miranda, Little Lane, Blakeney	TG 0751 4382	131/120	19.970	s	CH	Upper Chalk	CHALK	383	1.03
TG04	TG04/433	Glaven Bridge, Cley Obs. Bore	TG 0430 4380		3.810	s	CH	Upper Chalk	CHALK	256	1.01
TG04	TG04/808	Gardeners Bungalow, Kelling	TG 0642 4062	131/720	81.070	s	CH	Upper Chalk	CHALK	834	0.71
TG10	TG10/871	Ketteringham, School Wood	TG 1611 0298	161/247	30.170	s	CH	Upper Chalk	CHALK	231	1.00
TG10	TG10/824	Ketteringham Hall	TG 1645 0252	161/198	41.930	s	CH	Upper Chalk	CHALK	308	1.05
TG10	TG10/7730	Netherall Lane, Colney	TG 1751 0783		30.870	s	CH	Upper Chalk	CHALK	308	0.19
TG10	TG10/981	Colney P.W.S.	TG 1619 0810		8.370		CH	Upper Chalk	CHALK	447	0.08
TG10	TG10/985	Colney Marshes	TG 1830 0800		8.960		CH	Upper Chalk	CHALK	904	0.08
TG11	NTG114P1	Swannington Upgate Common - Deep	TG 1437 1922		71.000	s				75	1.16
TG11	NTG114P2	Swannington Upgate Common - Shallow	TG 1498 1902		73.480	s				78	1.17
TG11	NTG114PA	Swannington Upgate Common - Existing Pz	TG 1495 1810		0.000					10	2.90
TG11	NTG115PB	Swannington Upgate Common - Existing Pz	TG 1502 1812		0.000					12	2.50
TG11	NW/TG115A	Swannington Upgate Common - Dipwell #1	TG 1500 1810		0.000		UO	See Soil Log		9	0.78
TG11	NW/TG115B	Swannington Upgate Common - Dipwell #2	TG 1509 1810		0.000		UO	See Soil Log		29	0.79
TG11	TG11/151	Weston Longville	TG 1115 1575	147/540	49.790	s	CH	Upper Chalk	CHALK	298	1.00
TG11	TG11/541	Beech Farm, Taverham	TG 1515 1476	161/340	40.140	s	CH	Upper Chalk	CHALK	537	1.04
TG11	TG11/619	The Spinney, Costessey	TG 1881 1101	161/221	17.970	s	CH	Upper Chalk	CHALK	344	1.03
TG11	TG11/942	Glebe Farm, Horsford - Bore	TG 1975 1478		33.240	s	CH	Upper Chalk	CHALK	62	1.02
TG11	TG11/942A	Glebe Farm, Horsford - Piez	TG 1975 1478		33.240	s	CH	Upper Chalk	CHALK	7	1.00
TG12	NTG1212P1	Buxton Common - Deep	TG 1114 2792		75.950	s				8	3.00
TG12	NTG1212P2	Buxton Common - Shallow	TG 1114 2792		74.430	s				75	1.16
TG12	NTG1212P3	Buxton Common - Shallow	TG 1119 2798		73.830	s				75	1.15
TG12	NTG1212P4	Buxton Common - Shallow	TG 1149 2804		74.890	s				4	1.50
TG12	NTG1212P5	Buxton Common - Deep	TG 1114 2792		75.790	s				24	1.17
TG12	NTG1212P9	Buxton Common - Deep	TG 1113 2289		0.000					0	-1.00
TG12	NTG1212V1	Buxton Common - V Notch Weir	TG 1106 2794		0.000					1	0.00
TG12	NTG1271E1	Buxton Heath - English Nature	TG 1736 2197		0.000					0	-1.00
TG12	NTG1271E2	Buxton Heath - English Nature	TG 1736 2197		0.000					0	-1.00
TG12	NTG1271P1	Buxton Heath - Deep	TG 1772 2193		33.080	s				78	1.12
TG12	NTG1271P2	Buxton Heath - Deep	TG 1772 2153		33.250	s				78	1.12
TG12	NTG1271P3	Buxton Heath - Shallow	TG 1772 2153		31.060	s				78	1.17
TG12	NTG1271P4	Buxton Heath - Shallow	TG 1704 2184		31.890	s				75	1.16
TG12	NTG1271P5	Buxton Heath - Shallow	TG 1736 2198		29.660	s				75	1.13
TG12	NTG1271V1	Buxton Heath - V Notch Weir	TG 1792 2173		0.000					0	-1.00
TG12	TG12/172	Haydon P.S.	TG 1178 2772	147/530	44.900	s	CH	Upper Chalk	CHALK	291	1.03
TG12	TG12/194	Corpusty Foot Verge - Bore	TG 1149 2982		21.330	s	CH	Upper Chalk	CHALK	164	1.12
TG12	TG12/194A	Corpusty Foot Verge - Piez	TG 1149 2982		21.340	s	GO	Sand & Gravel	Q & Recent	73	1.01
TG12	TG12/198	Corpusty STW - Obs Bore	TG 1182 2983		29.020	s	CH	Upper Chalk	CHALK	108	1.09
TG12	TG12/198A	Corpusty STW - Piez No 2	TG 1182 2983		28.110	s	GO	Sand & Gravel	Q & Recent	105	1.10
TG12	TG12/577	Longlands P.S., Oulton	TG 1577 2773	147/143b	48.430	s	CH	Upper Chalk	CHALK	240	1.08
TG12	TG12/788	Blickling Hall	TG 1781 2849	147/143c	24.710	s	CH	Upper Chalk	CHALK	84	1.13
TG13	TG13/031	Blackhall Farm, Edgefield	TG 1011 3317		64.480	s	CH	Upper Chalk	CHALK	294	1.02
TG13	TG13/108	Thwaite, Saxthorpe	TG 1180 3050	147/240	33.480	s	CH	Upper Chalk	CHALK	83	1.06
TG13	TG13/151	Hole Farm, Hempstead - Borehole	TG 1118 3573		88.780	s	CH	Upper Chalk	CHALK	173	1.03
TG13	TG13/151A	Hole Farm, Hempstead - Piez 1	TG 1118 3573		88.750	s	CH	Upper Chalk	CHALK	164	1.16
TG13	TG13/151B	Hole Farm, Hempstead - Piez 2	TG 1118 3578		88.270	s	CH	Upper Chalk	CHALK	148	1.21
TG13	TG13/320	Barningham - Borehole	TG 1304 3219		47.080	s	CH	Upper Chalk	CHALK	175	1.01
TG13	TG13/320A	Barningham - Piez 1	TG 1304 3219		47.070	s	GO	Sand & Gravel	Q & Recent	174	1.03
TG13	TG13/320B	Barningham - Piez 2	TG 1304 3219		47.870	s	GO	Sand & Gravel	Q & Recent	151	1.15
TG13	TG13/349	Bodham Hill, West Beckham	TG 1790 3880		93.430	s	CH	Upper Chalk	CHALK	174	1.03
TG13	TG13/754	Lime Kiln Farm	TG 1743 356	131/175	47.810	s	CH	Upper Chalk	CHALK	125	1.25
TG13	TG13/754A	Field House	TG 1747 3375		47.910	s	UK	Unknown	Unknown	62	1.11
TG13	TG13/765	Thurgarton Old Hall - Bore	TG 1730 3890		40.200	s	CH	Upper Chalk	CHALK	171	1.03
TG13	TG13/765A	Thurgarton Old Hall - Well	TG 1730 3890		40.420	s	CH	Upper Chalk	CHALK	171	1.03
TG14	NTG1462P1	Beeston Regis Common - Shallow	TG 1665 4254		29.380	s				37	0.78
TG14	NTG1462PA	Beeston Regis Common - Existing Pz	TG 1648 4243		0.000					179	0.31
TG14	NW/TG148	Sheringham and Beeston Regis Common	TG 1640 4243		0.000		UO	See Soil Log		0	-1.00
TG14	TG14/410	The Dales, Upper Sheringham (Old Bore)	TG 1609 4188	131/138	50.140	s	CH	Upper Chalk	CHALK	528	1.06
TG14	TG14/410A	The Dales, Upper Sheringham (New Bore)	TG 1611 4188		50.580	s	GO	Sand	Q & Recent	275	0.99
TG14	TG14/414	All Saints Church, Upper Sheringham	TG 1444 4191		34.430	s	GO	Sand	Q & Recent	62	1.00
TG20	NTG2030P4	Shotesham Common - Shallow	TG 2135 0079		0.000					75	1.16
TG20	NTG2030V2	Shotesham Common - V Notch Weir	TG 2135 0034		0.000					8	1.75
TG20	TG20/322	Stoke Holy Cross	TG 2327 0200		8.040	s	CH	Upper Chalk	CHALK	200	1.01
TG20	TG20/478	Eastern Gas, Thorpe (Norwich)	TG 2480 0780		2.340		CH	Upper Chalk	CHALK	780	0.08
TG20	TG20/557	Bixley, Demolished Cottage	TG 2513 0584	161/10	34.770	s	CH	Upper Chalk	CHALK	1217	0.48
TG20	TG20/801	Brooke Gravel Pit	TG 2818 0081	161/43	28.500	s	GO	Gravel	Q & Recent	533	1.03
TG21	NTG2188O1	Crostwick Marsh - Shallow	TG 2631 1862		0.000					4	1.00
TG21	NTG2188P1	Crostwick Marsh - Deep	TG 2677 1864		3.590	s				78	1.17
TG21	NTG2188PA	Crostwick Marsh - Existing Pz	TG 2633 1867		0.000					19	1.53
TG21	NTG2188PB	Crostwick Marsh - Existing Pz	TG 2678 1863		2.290	s				22	1.27
TG21	NW/TG218A	Crostwick Marsh - Dipwell #1	TG 2630 1650		0.000		UO	See Soil Log		2	0.50
TG21	NW/TG218B	Crostwick Marsh - Dipwell #2	TG 2630 1650		0.000		UO	See Soil Log		2	0.50
TG21	TG21/331	Rope Lodge	TG 2314 1324	161/97	35.710	s	CH	Upper Chalk	CHALK	279	1.05
TG21	TG21/480	Frettenham Depot	TG 2409 1857	147/770	6.730	s	CH	Upper Chalk	CHALK	526	1.09
TG21	TG21/619	Orange Farm, Spixworth	TG 2881 1140	161/322	35.010	s	CH	Upper Chalk	CHALK	533	1.05
TG22	NTG2259P1	Bryants Heath - Deep	TG 2588 2919		25.900	s				75	1.16
TG22	NTG2259P2	Bryants Heath - Shallow	TG 2580 2933		21.740	s				15	1.57
TG22	NTG2259P3	Bryants Heath - Shallow	TG 2587 2918		21.220	s				24	1.21
TG22	NTG2260PB	Bryants Heath - Existing Pz	TG 2600 2919		0.000					0	-1.00
TG22	NW/TG225A	Bryants Heath - Dipwell #1	TG 2590 2940		0.000		UO	See Soil Log		0	-1.00
TG22	NW/TG225B	Bryants Heath - Dipwell #2	TG 2590 2940		0.000		UO	See Soil Log		0	-1.00
TG22	TG22/080	Scotts Green, Aylsham	TG 2001 2610	147/736	24.950	s	CH	Upper Chalk	CHALK	531	1.05
TG22	TG22/713	Brook Farm, Westwick	TG 2714 2530	147/117b	14.970	s	CH	Upper Chalk	CHALK	289	1.02
TG22	TG22/901	Hengate Cottage, Coltishall - Bore	TG 2810 2070	148/112	4.310	s	CH	Upper Chalk	CHALK	278	1.06
TG22	TG22/901A	Hengate Cottage, Coltishall - Well	TG 2810 2070	148/112	4.310	s	OO	Drift	Q & Recent	282	1.05
TG23	NW/TG238	Southrepps Common	TG 2610 3500		0.000		UO	See Soil Log		0	-1.00
TG23	TG23/070	Hall Farm, Melton	TG 2000 3150		41.280		OO	Drift	Q & Recent	98	1.07
TG23	TG23/186	Jones Farm, Roughton	TG 2183 3849	131/99	89.090	s	CH	Upper Chalk	CHALK	528	1.06
TG23	TG23/214	Manor Farm, Colby	TG 2243 3134	147/84	18.720	s	CH	Upper Chalk	CHALK	329	1.12

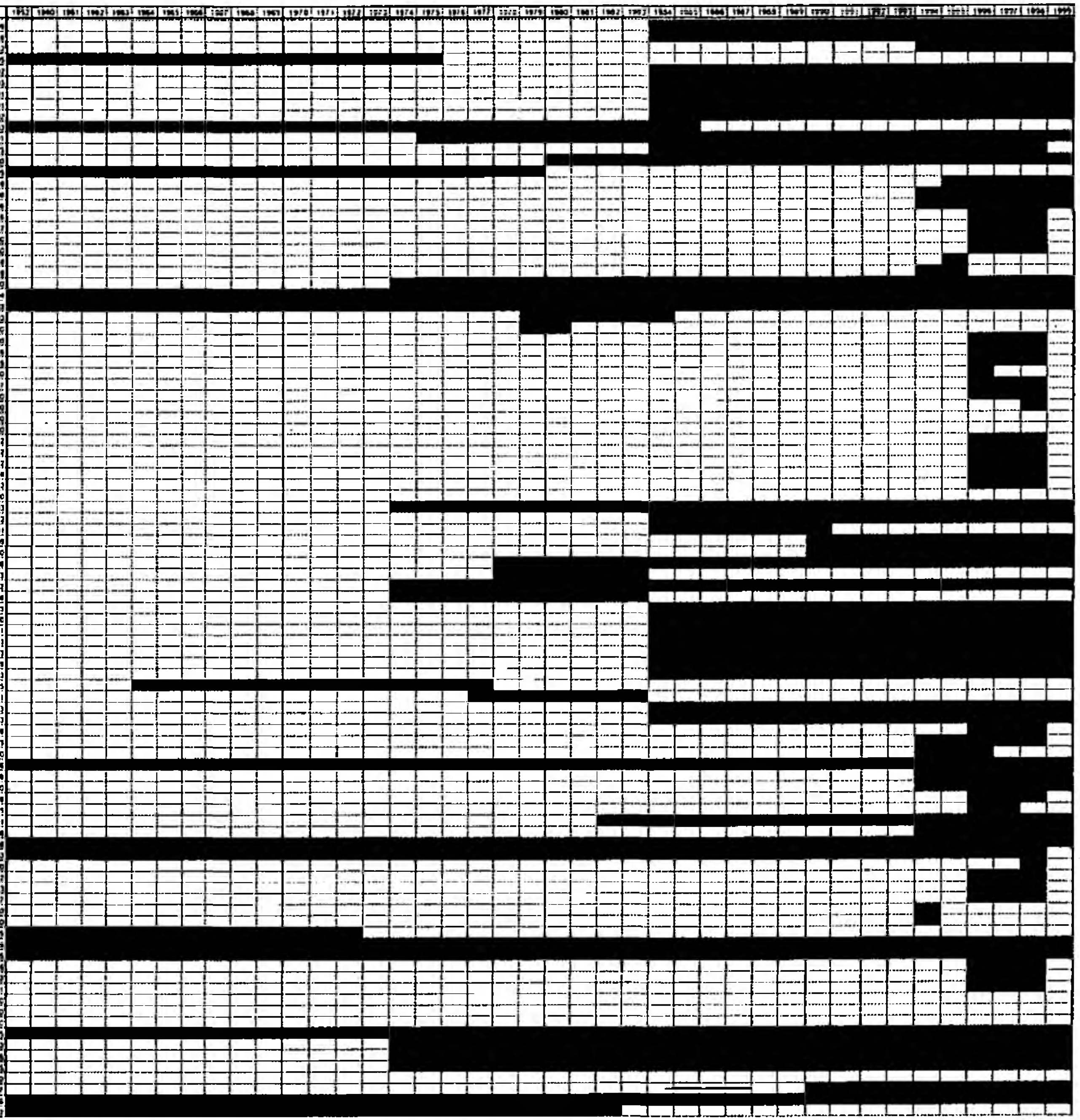

Table 5 HYDRODAT Groundwater Monitoring Sites

Grid Sq	REF	LOCATION	NGR	BGS	DATUM	DATLE	AQUIFER	AQ UNIT	GEOLOGY	RECORDS	RATIO
TG23	TG23/013	[illegible]	TG 2113 2181	146/80	17.180	r	CH	Upper Chalk	CHALK	290	1.01
TG30	NTG3013G1	Duncans Marsh GB-1	TG 3782 0170		1.922	r				3	1.00
TG30	NTG3013P1	Duncans Marsh PZ-1	TG 3772 0172		3.611	r	CH			0	-1.00
TG30	NTG3013P2	Duncans Marsh PZ-2	TG 3772 0170		3.634	r	OO			3	1.00
TG30	NTG3013P3	Duncans Marsh PZ-3	TG 3790 0177		3.449	r	OO			3	1.00
TG30	NTG3082G1	Poplar Farm Meadows - Gaugeboard	TG 3695 0209		-0.991	r		Gaugeboard	SURFACE	5	0.80
TG30	NTG3082PA	Poplar Farm Meadows - PZ-A	TG 3695 0215		0.000		VS			0	-1.00
TG30	NTG3082PB	Poplar Farm Meadows PZ-B	TG 3698 0214		0.000		VS			0	-1.00
TG30	NTG3072P1	Poplar Farm Meadows PZ-1	TG 3700 0204		0.317	r	OO			5	0.80
TG30	NTG3072P2	Poplar Farm Meadows PZ-2	TG 3700 0204		0.379	r	OO			5	0.80
TG30	NTG3092G1	Limpenhoe Meadows - Gaugeboard	TG 3960 0208		1.300	r		Gaugeboard	SURFACE	10	1.33
TG30	NTG3092G2	Limpenhoe Meadows - Gaugeboard	TG 3956 0209		0.000	r		Gaugeboard	SURFACE	19	1.29
TG30	NTG3093P1	Limpenhoe Meadows - Shallow	TG 3976 0322		4.790	r				22	1.32
TG30	NTG3093PA	Limpenhoe Meadows - Existing Pz	TG 3995 0312		0.000					14	1.64
TG30	NTG3093PB	Limpenhoe Meadows - Existing Pz	TG 3993 0313		0.000					17	1.31
TG30	NW/TG304A	Duncans Marsh - Dipwell #1	TG 3400 0190		0.000		VO	See Soil Log		11	1.45
TG30	NW/TG304B	Duncans Marsh - Dipwell #2	TG 3400 0190		0.000		VO	See Soil Log		11	1.43
TG30	NW/TG307A	Poplar Farm Meadows - Dipwell #1	TG 3700 0210		0.000		VO	See Soil Log		0	-1.00
TG30	NW/TG307B	Poplar Farm Meadows - Dipwell #2	TG 3700 0210		0.000		VO	See Soil Log		0	-1.00
TG30	NW/TG309A	Limpenhoe Meadows - Dipwell #1	TG 3990 0310		0.000		VO	See Soil Log		0	-1.00
TG30	NW/TG309B	Limpenhoe Meadows - Dipwell #2	TG 3990 0310		0.000		VO	See Soil Log		0	-1.00
TG30	TG30/010	The Manor, Bergh Apton	TG 3083 0134	152/77	28.980	r	OO	Drift	Q & Recent	315	1.09
TG30	TG30/172	Waste Disposal Site, Strumpshaw	TG 3320 0724	153/100	46.290	r	CH	Upper Chalk	CHALK	205	1.12
TG31	NTG3183E1	Upton Broad - NW1	TG 3831 1350		0.000					18	1.22
TG31	NTG3183E2	Upton Broad - NW1	TG 3840 1389		0.000					14	1.36
TG31	NTG3183E3	Upton Broad - NW1	TG 3840 1389		0.000					10	1.30
TG31	NTG3183E4	Upton Broad - NW1	TG 3840 1389		0.000					10	1.30
TG31	NTG3183G1	Upton Broad - Gaugeboard	TG 3832 1350		1.080	r		Gaugeboard	SURFACE	20	1.20
TG31	NTG3183G3	Upton Broad - Gaugeboard	TG 3809 1383		0.730	r		Gaugeboard	SURFACE	20	1.20
TG31	NTG3183P1	Upton Broad - Deep	TG 3832 1330		1.979	r				25	1.16
TG31	NTG3183P2	Upton Broad - Shallow	TG 3832 1330		1.889	r				25	1.16
TG31	NTG3183P3	Upton Broad - Shallow	TG 3813 1385		1.080	r				24	1.21
TG31	NTG3193G2	Upton Broad - Gaugeboard	TG 3953 1381		-0.650	r		Gaugeboard	SURFACE	15	1.20
TG31	NTG3193P4	Upton Broad - Shallow	TG 3943 1386		0.400	r				25	1.16
TG31	TG31/204	Woodbastwick Hall	TG 3345 1600	149/13	3.140	r	CH	Upper Chalk	CHALK	298	1.02
TG32	ERUS11A	East Ruston Common BH 1A	TG 3419 2780		2.050					21	1.17
TG32	ERUS11B	East Ruston Common BH 1B	TG 3419 2779		2.119					21	1.17
TG32	ERUS12A	East Ruston Common BH 2A	TG 3391 2785		2.500					182	0.17
TG32	ERUS12B	East Ruston Common BH 2B	TG 3391 2786		2.380					186	0.17
TG32	ERUS12C	East Ruston Common BH 2C	TG 3390 2786		2.410					186	0.17
TG32	ERUS13A	East Ruston Common BH 3A	TG 3398 2757		2.530					182	0.15
TG32	ERUS13B	East Ruston Common BH 3B	TG 3398 2757		2.540					184	0.15
TG32	ERUS14A	East Ruston Common BH 4A	TG 3481 2780		0.840					78	0.37
TG32	ERUS14B	East Ruston Common BH 4B	TG 3480 2781		0.870					77	0.38
TG32	ERUS15A	East Ruston Common BH 5A	TG 3402 2796		2.040					156	0.16
TG32	ERUS15B	East Ruston Common BH 5B	TG 3402 2796		2.030					155	0.19
TG32	ERUS15C	East Ruston Common BH 5C	TG 3403 2797		2.380					167	0.17
TG32	ERUS16A	East Ruston Common BH 6A	TG 3438 2872		3.400					24	1.17
TG32	ERUS16B	East Ruston Common BH 6B	TG 3438 2872		3.480					25	1.17
TG32	ERUS17A	East Ruston Common BH 7A	TG 3437 2837		3.150					181	0.38
TG32	ERUS17B	East Ruston Common BH 7B	TG 3437 2837		3.440					182	0.18
TG32	ERUS18A	East Ruston Common BH 8A	TG 3411 2810		1.930					174	0.18
TG32	ERUS18B	East Ruston Common BH 8B	TG 3412 2810		1.890					143	0.20
TG32	ERUS18C	East Ruston Common BH 8C	TG 3411 2818		2.920					185	0.17
TG32	ERUSTGB1	East Ruston Gaugeboard 1	TG 3380 2785		0.000			Gaugeboard	SURFACE	282	0.11
TG32	ERUSTGB2	East Ruston Gaugeboard 2	TG 3411 2810		0.000			Gaugeboard	SURFACE	172	0.14
TG32	ERUSTGB3	East Ruston Gaugeboard 3	TG 3436 2722		0.000			Gaugeboard	SURFACE	189	0.15
TG32	ERUSTP1	East Ruston Common Pz 1	TG 3433 2837		1.980	r	VO	Peat	Q & Recent	15	1.27
TG32	ERUSTP2	East Ruston Common Pz 2	TG 3429 2823		1.380	r	VO	Peat	Q & Recent	15	1.27
TG32	ERUSTP3	East Ruston Common Pz 3	TG 3420 2808		1.480	r	VO	Peat	Q & Recent	14	1.21
TG32	ERUSTP4	East Ruston Common Pz 4	TG 3412 2792		1.980	r	VO	Peat	Q & Recent	15	1.27
TG32	ERUSTP5	East Ruston Common Pz 5	TG 3417 2778		1.080	r	VO	Peat	Q & Recent	15	1.27
TG32	ERUSTP6	East Ruston Common Pz 6	TG 3412 2778		1.380	r	VO	Peat	Q & Recent	15	1.27
TG32	ERUSTP7A	East Ruston Common Pz 7a	TG 3401 2792		1.290	r	VO	Peat	Q & Recent	13	1.31
TG32	ERUSTP7B	East Ruston Common Pz 7b	TG 3401 2792		1.280	r	VO	Peat	Q & Recent	13	1.31
TG32	ERUSTP8	East Ruston Common Pz 8	TG 3438 2840		1.700	r	VO	Peat	Q & Recent	15	1.27
TG32	NTG3224G1	Smallburgh Fen - Gaugeboard	TG 3292 2468		0.000			Gaugeboard	SURFACE	7	1.14
TG32	NTG3224P1	Smallburgh Fen - Deep Chalk	TG 3259 2444		3.990	r				54	0.67
TG32	NTG3224P2	Smallburgh Fen - Deep Crag	TG 3258 2444		3.840	r				248	0.15
TG32	NTG3224PA	Smallburgh Fen - Existing Pz	TG 3270 2458		0.000					295	0.18
TG32	NTG3224PB	Smallburgh Fen - Existing Pz	TG 3271 2458		1.880	r				73	0.48
TG32	NTG3224PC	Smallburgh Fen - Existing Pz	TG 3252 2463		0.000					15	2.73
TG32	NTG3281G1	Catfield Fen - Gaugeboard	TG 3881 2121		1.170	r		Gaugeboard	SURFACE	21	1.14
TG32	NTG3281G2	Catfield Fen - Gaugeboard	TG 3884 2121		1.200	r		Gaugeboard	SURFACE	0	-1.00
TG32	NTG3281G3	Catfield Fen - Gaugeboard	TG 3874 2138		1.180	r		Gaugeboard	SURFACE	21	1.14
TG32	NTG3281P1	Catfield Fen - Deep	TG 3881 2137		2.130	r				25	1.16
TG32	NTG3281P2	Catfield Fen - Shallow	TG 3881 2137		2.130	r				26	1.12
TG32	NTG3281P3	Catfield Fen - Shallow	TG 3875 2131		1.819	r				26	1.12
TG32	NTG3270P4	Catfield Fen PZ-4	TG 3727 2079		2.588	r	OO			4	1.00
TG32	NTG3270P5	Catfield Fen PZ-5	TG 3723 2062		1.990	r	OO			4	1.00
TG32	NW/TG324A	Broad Fen - Dipwell A	TG 3473 2540		1.790		VO	See Licence		2881	0.03
TG32	NW/TG324B	Broad Fen - Dipwell B	TG 3472 2510		1.680		VO	See Licence		1777	0.04
TG32	TG32/209	School Road, Neatishead	TG 3380 2070	148/146	7.310	r	CH	Upper Chalk	CHALK	92	1.00
TG32	TG32/341	Hatfield Estate	TG 3315 2431	148/142	8.780	r	CH	Upper Chalk	CHALK	114	1.01
TG32	TG32/448	Wayford Wood Estate	TG 3485 2498	148/53	8.030	r	CH	Upper Chalk	CHALK	381	1.06
TG32	TG32/780	Brunstead Hall - Borehole	TG 3700 2662		7.980	r	CH	Upper Chalk	CHALK	541	2.08
TG32	TG32/780A	Brunstead Hall - Well	TG 3700 2662	148/99	7.980	r	OO	Crag	CRAG	117	1.01
TG32	TG32/815	Catfield Pez 1	TG 3815 2170		7.070	r	CR	Crag	CRAG	62	1.04
TG32	TG32/815A	Catfield Pez 2	TG 3810 2140		7.410	r	CR	Crag	CRAG	64	1.01
TG32	TG32/815B	Catfield Pez 3	TG 3778 2144		4.519	r	CR	Crag	CRAG	61	1.05
TG32	TG32/815C	Catfield Pez 4	TG 3781 2182		0.750	r	CR	Crag	CRAG	61	1.05
TG32	TG32/815D	Catfield Pez 5	TG 3675 2240		1.930	r	CR	Crag	CRAG	66	1.28
TG32	TG32/815E	Catfield Pez 6	TG 3865 2302		3.179	r	CR	Crag	CRAG	35	1.40
TG32	TG32/816	Catfield Fen Refuge Barn	TG 3840 2180		3.980		OO	Crag	CRAG	55	1.05
TG33	TG33/003	Bristol Close, Knapton	TG 3035 3387	132/30	43.270	r	CH	Upper Chalk	CHALK	113	1.01
TG33	TG33/433	Eden Hall, Barton	TG 3430 3347	149/103	8.700	r	CH	Upper Chalk	CHALK	253	1.11
TG40	NTG4003P2	Limpenhoe Meadows - Deep	TG 4011 0321		0.940	r				19	1.21
TG40	NTG4008P1	Decoy Carr PZ-1	TG 4081 0852		1.811	r	OO			3	1.00

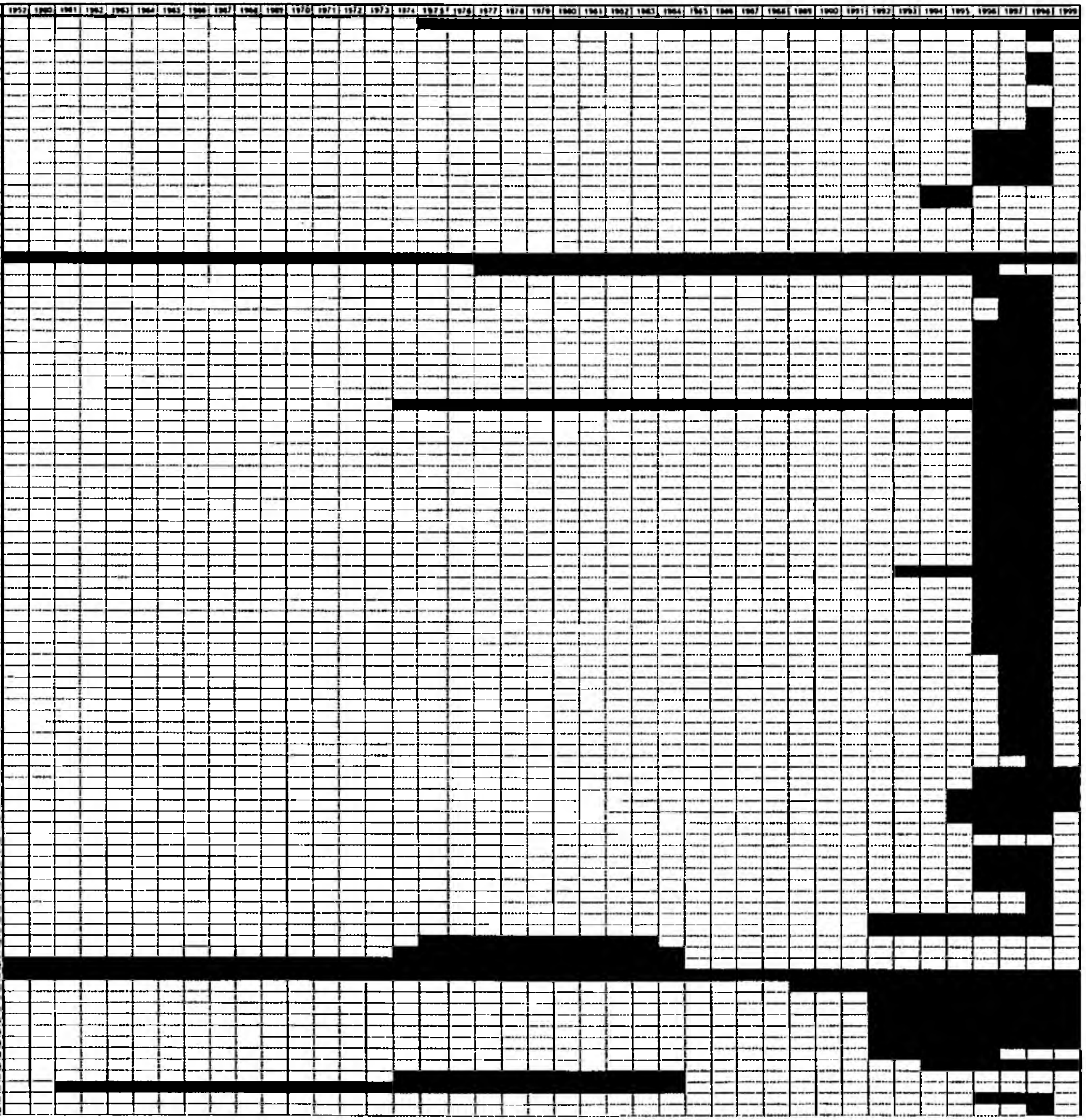

Table 9 HYDRODAT Groundwater Monitoring Sites

Grid Sq	REF	LOCATION	NGR	BGS	DATUM	DATLE	AQUIFER	AQ UNIT	GEOLOGY	RECORDS	RATIO
TG40	NTG4009P2	Deeps Cen PZ-2	TG 4091 9957		1.462 s		OD			2	1.00
TG40	NTG4009P3	Deeps Cen PZ-3	TG 4093 9948		1.539 s		OD			2	1.00
TG41	NW/TG418A	Hall Farm Fen - Dipwell A	TG 4610 1790		0.000		UO	See Bed Log		2774	0.97
TG41	NW/TG418B	Hall Farm Fen - Gaugeboard	TG 4610 1790		0.000		UO	Gaugeboard	SURFACE	82	0.50
TG41	TG41/002	Acle Primary School - Borehole	TG 4021 1043	162/126	4.950 s		CH	Upper Chalk	CHALK	841	1.03
TG41	TG41/002A	Acle Primary School - Well	TG 4021 1043	162/126	4.090 c		OQ	Drift	Q & Recent	321	1.07
TG42	TG42/334	Eastfield Farm, Hickling	TG 4345 2363		3.110		CR	Crag	CRAG	34	1.07
TM19	NTG1962O1	Forncett Meadows	TM 1649 9253		25.370 s		UN			20	1.20
TM19	NTG1962P1	Forncett Meadows - Deep	TM 1650 9290		28.630 s					25	1.15
TM19	NTG1962P2	Forncett Meadows - Shallow	TM 1650 9290		27.490 s					25	1.19
TM19	NTG1962P3	Forncett Meadows - Shallow	TM 1650 9251		27.710 s					25	1.19
TM19	NTG1962P4	Forncett Meadows - Deep	TM 1648 9253		0.000					9	-1.00
TM19	NTM1951P1	Aslacton Parish Land - Deep	TM 1554 9193		34.770 s					25	1.15
TM19	NTM1951P2	Aslacton Parish Land - Shallow	TM 1554 9191		34.690 c					25	1.15
TM19	NTM1951P3	Aslacton Parish Land - Shallow	TM 1558 9178		32.340 s					25	1.19
TM19	NTM1951P4	Aslacton Parish Land - Shallow	TM 1554 9183		34.700 s					25	1.19
TM19	TM19/089	Wighefield	TM 1099 9696	161/284	50.300 s		CH	Upper Chalk	CHALK	211	1.08
TM19	TM19/238	Ashthorpe House	TM 1387 9796	179/307	39.970 s		CH	Upper Chalk	CHALK	84	0.99
TM19	TM19/563	Wreningham	TM 1039 9801	161/532	45.970 s		CH	Upper Chalk	CHALK	294	1.02
TM19	TM19/871	Forncett Saint Peter	TM 1651 9272	179/119	32.490 s		CH	Upper Chalk	CHALK	419	1.03
TM19	TM19/918	St Michael's View	TM 1695 9736	161/553	32.980 s		CH	Upper Chalk	CHALK	33	0.94
TM29	NTM2949O1	Shotesham Common - Gaugeboard	TM 2440 9932		15.700 s			Gaugeboard	SURFACE	20	1.20
TM29	NTM2949P1	Shotesham Common - Deep	TM 2433 9914		17.900 s					25	1.16
TM29	NTM2949P2	Shotesham Common - Shallow	TM 2430 9916		17.280 s					25	1.19
TM29	NTM2949P3	Shotesham Common - Shallow	TM 2431 9932		12.990 s					25	1.19
TM29	NTM2949V1	Shotesham Common - V Notch Weir	TM 2436 9900		0.000					9	1.11
TM29	TM29/216	Bedlam, Bedingham	TM 2790 9744	161/514	25.180 s		CH	Upper Chalk	CHALK	339	1.10
TM49	EW/TM498A	Barnby Marshes - Dipwell #1	TM 4800 9100		0.000		UO	See Bed Log		62	0.47
TM49	EW/TM498B	Barnby Marshes - Dipwell #2	TM 4800 9100		0.000		UO	See Bed Log		62	0.47
TM49	TM49/214	Waveney Hotel	TM 4917 9342	176/134	1.780 s		CH	Upper Chalk	CHALK	224	1.32
TM59	EW/TM590	Oulton Marsh	TM 5050 9290		0.000		UO	See Bed Log		9	-1.00
TM59	EW/TM590A	Sprats Water & Marshes - Dipwell #1	TM 5070 9210		0.000		UO	See Bed Log		17	0.58
TM59	EW/TM590B	Sprats Water & Marshes - Dipwell #2	TM 5070 9210		0.000		UO	See Bed Log		31	0.61

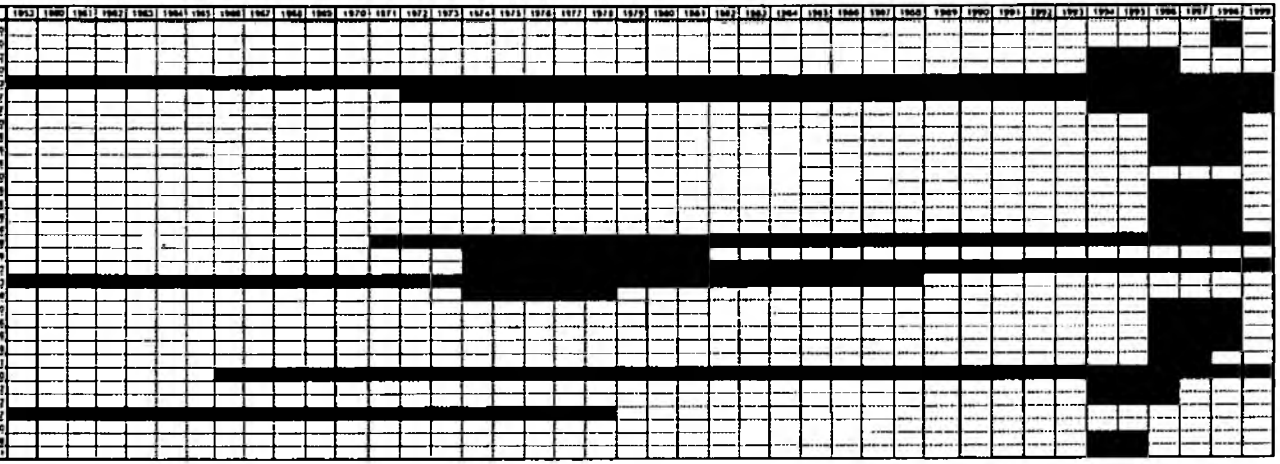

Table 9 Bacton Pipeline Monitoring

Bacton Pipeline Monitoring
Boreholes

Ref.	Location	Easting	Northing	Geology	Borehole Depth	Screened Interval
HDP1	Cobholm Island	651340	307570	Crag;Sand	35	20-24
HA32	Cobholm Island	651340	307570	Breydon Form; Clay, sandy	2	0.7-1.2
HA34	Elm Farm	651600	310260	Breydon Form; Clay/silty	2	1.0-1.5
HDP3	Elm Farm	651600	310260	Crag; Clay, pebbly	35	25-28
HA6	Elm Farm	651350	310560	Breydon Form: Silt/Sandy	3	1.8-1.8
HDP4	Elm Farm	651340	310570	Breydon Form. Silt/Sandy	10	3.5-5.5
HA7	Elm Farm	651220	310720	Breydon Form: Clay, Silty	3	2.0-3.0
HA8	Elm Farm	651170	310940	Breydon Form: Clay sand	3	2.0-3.0
HDP5	Elm Farm	651160	310950	Breydon Form,Peat, clay	10	7.0-9.0
HA9	Elm Farm	651080	311210	Breydon Form; Peat	3	2.0-3.0
HDP6	Ormesby	650820	312600	Corton Form; Sand/Clay	15	11.5-14.5
HA10	Ormesby	650500	313290	Corton Form; Sand silty	3	2.0-3.0
HA11	Ormesby	650730	314370	Lowestoft, Clay, sandy	4	2.6-3.6
HA12	Ormesby	650020	315190	Corton Form; Sand/Clay	5	3.5-4.5
HA13	Ormesby	649300	315920	Lowestoft; Sand.silty	2	1.3-2.2
BH5	Hemsby: Hall Farm	648630	316900	Crag: Sand	11	9.0-10.0
HDP7	Hemsby: Hall Farm	648640	316750	Crag; Sand. Silty	10	7.5-9.5
HA14	Hemsby: Hall Farm	648420	317130	Corton Form;Clay Gravelly	3	2.0-3.0
HDP8	Hemsby: Hall Farm	648420	317130	Crag; Sand	15	10.0-14
HA15	Hemsby: Hall Farm	648300	317230	Corton Form; Sand/Clay	2	0.8-1.8
HDP10	Hemsby: Hall Farm	647690	317490	Crag;Sand pebbly,silty	15	11.5-13.5
HA16	Hall Farm SSSI	648190	317240	Breydon Form; Silt/Sandy	2	1.2 -2.1
HDP9	Hall Farm SSSI	648190	317230	Crg; Sand, fine- course	15	1.5 -14.5
HA17	Hall Farm SSSI	648110	317140	Breydon Form; Sand, Silty	3	1.65 - 2.55
HDP30	Dairy Barn Farm - North of repps	647200	317440	Corton Form; Clay, sandy	5	3.5 -4.5
HDP11	Dairy Barn Farm - North of repps	643390	317160	Crag; Sand gravel	7	4.5 -6.5
HA19	Dairy Barn Farm - North of repps	642290	317190	Corton Form; Clay Sandy	3	2.0 -3.0
HDP12	Repps	641980	317660	Crag; Gravel, sandy	5	2.5 -4.5
HA20	Repps	641910	317760	Crag; Sand, silty	1	0.9 -1.4
HDP13	Repps	641890	317770	Crag; Silt, sandy, gravel	28	23-26
BH7	Potter Heigham and Potter Heigham SS	640920	318430	Crag; Sand	12	8.0-9.0
HA21	Potter Heigham and Potter Heigham SS	641650	317940	Breydon Form; Clay, sandy	2	1.0-2.0
HDP14	Potter Heigham and Potter Heigham SS	641650	317950	Crag; Sand/Gravel	30	14-18
HA22	Potter Heigham and Potter Heigham SS	641360	318220	Breydon Form; Clay silty	2	1.1-2.0
HDP15	Potter Heigham and Potter Heigham SS	641360	318220	Crag; Sand, slightly silty	30	20.5-23.5
HA23	Potter Heigham and Potter Heigham SS	641160	318350	Corton; Clay silty/sandy	2	1.1-2.0
HDP16	Potter Heigham - Catfield	640750	318600	Crag; Sand/Gravel	30	22-25
HA24	Potter Heigham - Catfield	640750	318600	Crag; Sand	6	3.0-6.0
HDP17	Potter Heigham - Catfield	639600	320570	Crag; Sand slightly silty	1	5.5-8.5
HDP29	Potter Heigham - Catfield	639220	321370	Corton; Clay silty/sandy	5	3.5-4.5
HA25	Catfield	639280	321980	Corton; Sand silty/clayey	2	0.8-1.8
HDP19	Catfield	639150	322170	Crag; Sand, silty	10	7.0-9.0
HA26	East Ruston - Hickling	639230	322940	Corton; Sand	1	3.0-4.0
HDP20	East Ruston - Hickling	639200	322120	Crag; Sand/Gravel	10	7.0-9.0
HDP21	East Ruston - Hickling	639310	324350	Corton; Sand, silty	5	3.0-4.0
HDP28	East Ruston - Hickling	639050	324690	Corton; Sand, silty	7	4.5-6.5
HA27	East Ruston - Hickling	638330	325830	Corton; Sand, silty	3	2.1-3.0
HA28	East Ruston - Hickling	637860	327210	Corton; Clay, sandy/silty	3	1.6-2.5
HDP22	East Ruston - Hickling	637730	327490	Corton; Sand silty/clayey	10	7.5-9.5
HA29	East Ruston - Hickling	637390	328280	Crag;Sand	3	2.0-3.0
HDP23	East Ruston - Hickling	636790	329150	Crag; Sand, silty	15	11.83-13.90
HDP27	Mill Common - Walcott	636110	330580	Peat,Gravel, sandy/silty	5	3.67-4.44
HA30	Mill Common - Walcott	634920	332050	Crag; Sand., Slightly silty	2	0.7-1.7
HDP25	Mill Common - Walcott	634830	332180	Chalk	15	13-15
HDP26	Mill Common - Walcott	634010	333260	Crag; Sand, silty	8	5.5-7.5
HA31	Mill Common - Walcott	632640	334050	Crag; Sand Silty	2	1.2-2.25
BH4	Great Yarmouth - racecourse	652910	310210	Blown Sand/ North Denes, Sa	11	9.0-10.0

Dykes with Gaugeboards

TG50/19(04)B	Bure Loop	651540	309380
TG51/11(01)A	Elm Farm	651170	311190
TG51/11(02)A	Elm Farm	651220	311000
TG51/11(10)A	Elm Farm	651580	310260
TG41/87(13)A	Hall Farm Fen	648500	317110
TG41/87(14)A	Hall Farm Fen	648410	317220
TG41/87(13)A	Repps	641740	317810
TG41/87/(14)A	Repps	641890	317690
TG41/18(04)A	Potter Heigham	641220	318290
TG41/18(05)A	Potter Heigham	641050	318440
TG41/18(06)A	Potter Heigham	641550	317990
TG41/18(04)A	Potter Heigham	641710	317930
TG32/92(01)B	Catfield	639340	322170
TG32/93(01)B	Hickling Road	639190	323220
TG33/42(01)A	Mill Common	634800	332150
TG33/42(05)A	Mill Common	634760	332200

Dykes without Gaugeboards

TG50/17(05)B	Cobholm Island	651360	307490
TG51/17(06)B	Cobholm Island	651430	307320
TG50/19(02)B	Bure Loop	651350	309190
TG50/19(03)B	Bure Loop	651440	309280
TG50/19(05)A	Bure Loop	651750	309610
TG50/19(06)A	Bure Loop	651820	309680
TG50/19(07)A	Bure Loop	651890	309760
TG50/19(08)A	Bure Loop	651900	309870
TG50/19(09)A	Bure Loop	651670	310150
TG51/11(03)A	Elm Farm	651270	310810
TG51/11(04)B	Elm Farm	651330	310560
TG41/87(01)C	Hall Farm Fen	648180	317070
TG41/87(02)A	Hall Farm Fen	648190	317170
TG41/87(05)A	Hall Farm Fen	648080	317150
TG41/87(11)B	Hall Farm Fen	648450	317000
TG41/87(12)B	Hall Farm Fen	648430	317070
TG41/17(01)A	Repps	641950	317650
TG41/18(03)B	Potter Heigham	641340	318180
TG41/18(06)C	Potter Heigham	641550	317990
TG41/18(13)A	Potter Heigham	641290	318180
TG32/93(02)B	Hickling Road	639240	322950

Table 10 **Landfill Sites with Groundwater Monitoring Boreholes**

Site	Approximate Grid Reference	No of Boreholes
Attlebridge	TG 145 160	14
Bergh Apton	TG 300 000	9
Beetley	TF 955 190	21
Costessey	TG 160 110	14
Edgefield	TG 085 355	15
Harford Bridge	TG 225 050	7
Hempton	TF 905 285	8
Mayton Wood	TG 245 210	18
Morningthorpe	TM 210 945	7
Rackheath	TG 275 120	6
Strumpshaw	TG 350 070	9

5.4 Groundwater Abstractions

Historically the licensing system was initiated following the 1963 Water Resources Act but until approximately 1980 the system was not standardised and was mainly based on empirical observations. In the mid 1970's it was common practice to run step tests and then move straight into the constant rate test. Modem practice usually requires a minimum 24 hour recovery between these two parts of the test. Since 1980 each test has been accompanied by a test report with the following headings

Abstraction licences are held in files according to the hydrometric area in which they fall. For each hydrometric area a number of general files are held within the system. The files are mainly correspondence. Pump tests are held in separate lever arch files in chronological order. Pump tests were conducted by Agency staff until approximately 1989 since when the applicant has been responsible for conducting pump tests. Requirement for Environmental Assessments introduced in 1995 filtered through to licensing in 1997 as it takes approximately 2 years to process an application. Pump tests have become more sophisticated in design and increasingly incorporate purpose-drilled observation wells (previous tests used the pumping well or nearby pre-existing wells for water level observations).

Details of Public Water Supply (PWS) wells are held separately from the main body of data.

There are currently 1297 licensed groundwater abstractions within the study area and a further 79 licences which are a mixture of groundwater and surface water out of a total of 1519 licensed water abstractions. Individual licences can apply to several sources. Large abstractions are predominantly for public water supply. The largest number of licences is for agricultural purposes. The locations are shown on Figure A12.

Available historical records of license returns are largely in digital form and consist of monthly returns for abstractions greater than 20 m^3/d. These returns cover the period 1988 to the present day. Prior to this monthly returns were provided for abstractions greater than 5 thousand cubic metres per annum (tcma), and smaller abstractions provided annual returns only. These records date back to 1968. Historical records were added to the database in 1988 and therefore any paper records that were not available at that time may have been lost.

Daily abstractions from some major sources are available from Anglian Water Services for the last few years.

5.5 Other Hydrogeological Information

The public water supply wells have been subject to work to delineate groundwater protection zones (GPZs) by Aspinwalls, Geraghty & Miller, Southern Science and some in-house Agency work. Earlier work by Geraghty and Miller assessed nitrate vulnerable zones around some of the PWS wells. The files for GPZs are held by Water Resources in Ipswich and NVZs by Environmental Planning in Ipswich. Copies of both data sets are also held in Peterborough.

Each PWS also has a Source Works file, copies of which are held by Anglian Water: the Ipswich office has copies of some of these.

Wetland dossiers, produced at various times by Birmingham University and HSI, exist for a total of 28 sites within the Yare North & North Norfolk areas, shown on Table 11. The locations of piezometers installed at these sites are included on Figure A9.

6. Soils and Land Use

The Agency have (at the National Centre for Environmental Data and Surveillance at Twerton) the digital 'Land Cover Map of Great Britain' as produced by the Institute of Terrestrial Ecology. This is available in two forms, the most detailed being at 25 m spatial resolution. The information was derived from satellite images for 1990. It is intended that an updated map will be produced for the year 2000.

Detailed (field scale) land use data is available for the Bure catchment for 1995, contained in a report held by the Agency.

The Agency have MAFF super-parish data for 1995. Parish returns for years prior to 1988 would be available from the Public Records Office if needed.

Paper maps produced during the Land Survey of Britain, covering the whole country at 1:63 360 in the 1930s, are available for inspection at King's College London. A sub-set of maps (at 1:25 000) from a similar survey done in the mid-1960s is also available. The only maps published from this survey for East Anglia cover areas around Thetford, Methwold, Loddon and Fakenham. The Loddon and Fakenham sheets are relevant to the Yare & North Norfolk study. Field copies of maps covering the rest of East Anglia are available for inspection via the Survey Co-ordinator in London (Professor Alice Coleman, formerly of King's College).

Distribution of soils catalogued according to the dominant HOST classification is available on a 1 km grid. In addition, the Soil Survey hold digital soil association information on a 100 m grid.

Table 11 Wetland Site Dossiers in Yare North/North Norfolk Study Area

Site Name	NGR	HIS	Birmingham University	AMP3
Ant Broads and Marshes (Catfield Fen)	TG262 213	Y	Y	Y
Aslacton Parish Land	TM156 918	Y	Y	N
Badley Moor, Dereham	TG013 117	Y	Y	N
Beetley & Hoe Meadows	TF982 174	Y	Y	Y
Booton Common	TG113 230	Y	Y	Y
Bryant's Heath	TG259 294	Y	Y	N
Burgh Common & Muckfleet Marshes	TG440 117	N	N	Y
Buxton Heath	TG175 218	Y	Y	N
Coston Fen	TG062 066	N	Y	Y
Crostwick Marsh	TG263 165	Y	Y	N
Decoy Carr, Acle	TG405 090	Y	N	N
Ducan's Marsh, Claxton	TG339 027	Y	Y	N
Forncett Meadows	TM166 926	Y	Y	N
Hall Farm Fen, Hemsby	TG481 170	N	N	Y
Holly Farm Meadow, Wendling	TF936 131	Y	Y	N
Limpenhoe Meadows	TG399 031	Y	N	N
Martham Broad & Marshes	TG458 203	N	Y	N
Poplar Farm Meadows, Langley	TG370 021	Y	Y	N
Potter & Scaming Fens	TF982 120	Y	Y	N
Scoulton Mere	TF985 014	N	N	Y
Sheringham & Beeston Regis	TG164 424	Y	N	Y
Shotesham Common	TM241 998	Y	Y	N
Smallburgh Fen	TG327 246	Y	Y	N
Strumpshaw Fen	TG303 008	N	N	Y
Swannington Upgate Common	TG148 181	Y	Y	N
Syderstone Common	TF834 315	Y	Y	N
Upton Broad & Marshes	TG390 137	Y	Y	N
Whitwell Common	TG088 206	Y	Y	Y

7. GIS

A list of layers in the current Agency GIS is shown on Table 12. It is intended that the project will add to and refine the information on GIS, so that all users at the Agency may benefit.

Table 12 **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
1	Flood risk zones (where warnings are issued). High, medium and low priority.	no	29/08/95	
2	Flow Forecast points (high, medium and low priority)	no	02/03/95	
3	Telemetry sites (existing and proposed). Flow gauging; level &/or tidal;	no	02/03/95	
4	Central Area groundwater resource units	yes	01/04/95	250,000
5	Augmentation boreholes in the Deben Catchment	yes	31/03/95	
6	Sites of Special Scientific Interest and County Wildlife Sites in the Deben	yes	31/03/95	
7	Effluent discharge sites in Deben catchment	yes	31/03/95	
8	Gauging stations, temporary gauging stations and current metering sites in the	yes	31/03/95	
9	Groundwater licences within the Gipping Chalk Groundwater Model Area (plus	yes	30/09/95	
10	Major elements of Regional Water Resources System, eg augmentation boreholes	yes	31/08/94	
11	Regional pesticides database	yes		
12	Dangerous substances LI/LII inventory	yes		
13	Routine Biological sampling points (rivers and canals) - all routine sites	yes	01/10/95	
14	Eutrophic Sensitive Areas/Polluted Waters Database.	yes		
15	1993 chemistry water quality map - colour coded according to National Water		01/05/94	
16	1992/3/4 Biological River Quality Maps - colour coded according to Biological		01/05/95	
17	1993/94 Chemistry Water Quality Map - Colour coded according to General Qualit		01/05/95	
18	Physical Landscape Morphology Map	yes		
19	Backshore/Hinterland Interface Geomorphology	yes		
20	Current Model Site Locations	yes		
21	Bathymetric Contour Map - Admiralty Charts	yes		
22	Current Measurement Sites (MIAS databank of current measurement records and	yes		
23	Measured Water Level Recording Sites	yes		
24	Wave data points	yes		
25	Water Level Model Data Points	yes		
26	Run map for coastal and aerial surveys since 1991.	yes	01/10/95	
27	Bedload Current Vector Arrows			
28	Net current vector arrows.	yes		
29	Suspended Sediment Current Vector Arrows	yes		
30	Location Map for Geological Corridor Sites - British Geological Survey (BGS)	yes		
31	Low Water Lines 1880, 1900, 1950 & 1970	yes		
32	Nearshore Morphology	yes		
33	Map of the Foreshore	yes		
34	Map of the Backshore	yes		
35	Hinterland Morphology	yes		
36	Map of Backshore Beaches	yes		

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
37	Hinterland/Backsmore Interface	yes		
38	Backshore Marsh Morphology	yes		
39	Foreshore Morphology	yes		
40	MOD Coastal Ranges			
41	Mapping of Infrastructure Features	yes		
42	Map showing industrial features	yes		
43	Foreshore Geological Classification	yes		
44	Hinterland Geological Classification	yes		
45	Map of coastal defences	yes		
46	Map of the 4 different levels of estuaries	yes		
47	ADAS Land Classification	yes		63,360
48	Sites of Coastal Amenities and Beach Access Points	yes		
49	Map showing boundaries of conurbations.	yes		
50	Tidal Flood Areas Below Highest Recorded Tide Levels.	yes		
51	High Water Lines, 1880, 1900, 1950 - 1970.	yes		
52	Significant Wave Height Data 1:1, 1:10, 1:100 1:250. Wave roses.	yes		
53	Coastlines around the North Sea and English Channel (UK & Europe)	yes		
54	River Nene/Welland Survey - Condition Survey 1995	yes	01/05/95	
55	Integrated Pollution control database.	yes		
56	Bathing Water Directive Inventory	yes	01/10/95	
57	National Pesticide Database	yes		
58	Consents	yes		
59	Applications For Consent to Discharge AWS + private	no	01/10/95	
60	AWS Continuous Discharges to Tidal Waters	no	31/10/95	
61	AWS STW Register	no	04/09/95	
62	Flow data upstream of AWS STW	no		
63	GQA Stretches & Grades	yes		
64	Water Quality Targets for River stretches.	yes		
65	Compliance with targets (river & effluent)	yes		
66	Freshwater (river) water quality monitoring sites - description.	yes		
67	Saline Water Quality monitoring sites - description.	yes		
68	Sediment water quality monitoring sites - descripton.	yes		
69	Groundwater water quality monitoring sites - description.	yes		
70	Biological water quality monitoring sites- description	yes		
71	Anglian Water Services monitored discharges - description.	yes		
72	Private & Industrial monitored discharges - description.	yes		

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
73	Anglian Water Services raw groundwater quality monitoring sites - description.	yes		
74	River Quality Objective (RQO) Stretches (historic) - description.	yes		
75	Groundwater monitoring information	yes		
76	Flow Gauging Stations - description.	yes		
77	Rainfall monitoring sites - description.	yes		
78	Site File Waste Disposal databases - description.	yes		
79	Conservation sites - description	yes		
80	AA Gazeteer of place names.	yes		
81	NRA Assets	no		
82	Coastline - High - water mark & low water mark for Anglian Region and whole UK	yes		100,000
83	Main River Network (both banks) plus Fluvial and Saline Flood Units	no		10,000
84	Modelled Water Level Return Periods	no		
85	Cross Sectional Data	no		
86	Flood Plain for Fluvial 1:100 and Saline 1:200 year events.	no		10,000
87	Environmentally Sensitive Sites.	no		
88	Non-tidal\Tidal\Estuarine\Coast Interface	no		
89	Road and Rail Communications Network	no		200,000
90	Land Use	no	22/08/94	
91	COPPS Reaches	no		
92	Flooding Problems	no		50,000
93	Observation network - current metering and gw monitoring.	y/n		
94	Low flow database (lists licences with flow/level clauses) useful in drought	no		
95	Flooding locations (classified @ risk yellow, amber, red conditions)	no		
96	Hydrometric network of G/S rain gauges, tide gauges etc	y/n		
97	Abstraction points (licensing/discharge points)	no		
98	Groundwater observation network location	yes		
99	Groundwater Hydrogeological Catchments	yes		250,000
102	Sites of Special Scientific Interest from English Nature	yes	06/03/95	
103	Sites of Special Scientific Interest from English Nature	yes		50,000
104	River Augmentation Boreholes	yes		50,000
105	Groundwater source	yes		50,000
106	Principal industrial discharge	yes		50,000
107	NRA fluvial gauging stations	yes		50,000
108	Other fluvial gauging stations	yes		50,000
109	Fluvial flapped outfalls	yes		50,000
110	Fluvial level stations	yes		50,000

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
111	Groundwater level stations	yes		50,000
112	Locks	yes		50,000
113	Pointing doors	yes		50,000
114	NRA pumping stations	yes		50,000
115	IDB pumping stations	yes		50,000
116	Public water supply intake	yes		50,000
117	Water quality monitoring station	yes		50,000
118	Rain gauges	yes		50,000
119	Sewer/sea outfall	yes		50,000
120	Slackers	yes		50,000
121	NRA fluvial sluices	yes		50,000
122	Other fluvial sluices	yes		50,000
123	Syphons	yes		50,000
124	Tidal control sluices	yes		50,000
125	Tidal flapped outfall	yes		50,000
126	Tidal level stations	yes		50,000
127	Principal surge and gate	yes		50,000
128	NRA weirs	yes		50,000
129	Other weirs	yes		50,000
130	Sewage treatment works	yes		50,000
131	Hydrometric catchments	yes		50,000
132	Internal drainage boards	yes		50,000
133	NRA reservoirs and washlands	yes		50,000
134	Public Water Supply Reservoirs	yes		50,000
135	Main rivers	yes		50,000
136	IDB rivers	yes		50,000
137	AWARD Watercourses	yes		50,000
138	Other Watercourses	yes		50,000
139	Storm tide divisions	yes		50,000
140	Coastal responsibility	yes		50,000
141	Coastal flood area	yes		50,000
142	Fluvial flood area	yes		50,000
143	Bulk transfer systems	yes		50,000
144	NRA regional boundary	yes		50,000
145	NRA catchment boundaries	yes		50,000
146	River quality objectives	yes		50,000

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
147	Exposed aquifer outcrop	yes		50,000
148	Saline limit	yes		50,000
149	Navigation limit	yes		50,000
150	OS data at 1:250,000 scale 'Routemaster sheet 6'	yes		250,000
151	OS data at 1:250,000 scale 'Routemaster sheet 9'	yes		250,000
152	Areas of outstanding natural beauty			
153	The Broads Authority boundary			
154	Coastline	yes		
155	County boundaries (including coastline) with names from Ordnance Survey	yes		10,000
156	Catchment Plan Boundaries with Plan names	yes	28/09/95	50,000
157	Boundaries of 1:50,000 and 1:250,000 scale raster maps with map names	yes	31/03/95	10,000
158	Boundaries of 1:10,000 scale raster maps	yes	17/10/94	10,000
159	Inland waters from Institute of Hydrology.	yes		50,000
160	District council boundaries obtained from Ordnance survey.	yes		10,000
161	NRA logo	yes	20/06/94	
162	Boundaries of the Regional Maps	yes		50,000
163	National Parks	yes	21/09/93	
164	National nature reserves	yes	02/03/94	
165	NRA offices	yes	23/08/95	
166	NRA catchment and area boundaries	yes	11/04/95	50,000
167	Main rivers, IDB rivers and inland waters	yes		50,000
168	Main rivers, IDB rivers, AWARD watercourses and other watercourses with main	yes		50,000
169	Roads (A and B class and motorways)	yes		200,000
170	Main towns	yes		
171	Parish boundaries from DoE, translated from Arc Info	yes	24/11/95	10,000
172	Sites in Anglian Region with electrical equipment			
173	1:50,000 Ordnance Survey digital raster backgrounds. 20km x 20km - b&w with		01/01/96	50,000
174	Catchment boundaries (National coverage). Originally created by WrC &	no		200,000
175	Estuaries (National) originally digitised by Halcrows.	no		10,000
176	NUTS 2 (Nomenclature des Unites Territoriales Statistique) Regions. 172 aeras	no		
177	European rivers and coastline UNEP (United Nations Environment Programme).	yes		
178	National General Quality Maps for Anglian Region	yes		
179	Fluvial flood areas from SoS.	no		10,000
180	Aquifer outcrops	yes		50,000
181	Environment Agency public face boundaries.	yes	01/04/96	10,000
182	Main rivers from Institute of hydrology	yes		50,000

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
183	Bathrooms: access to bath and WC per enumeration district by house and by	no	01/01/91	250,000
184	Hazardous substance authorisations, from Local Authorities (Landmark).		14/04/97	250,000
185	National nature reserves.	yes	08/03/99	10,000
186	Nitrate sensitive areas.	no	10/03/97	25,000
187	Designated Environmentally Sensitive Areas.	no	10/04/97	25,000
188	Nitrate vulnerable zones.	no	10/03/97	25,000
189	Sites of Special Scientific Interest.	yes	08/03/99	10,000
190	Integrated Pollution Control Sites (Environmental Protection Act 1990 (Part A))	no	10/01/97	250,000
191	Set of Greenbelt data from DoE (incomplete).	no	01/03/97	10,000
192	Areas of Outstanding Natural Beauty digitised by FRCA from Countryside	no	01/08/95	50,000
193	Environment Agency Public Face Regional Boundaries with Area and Population	no	01/01/96	250,000
194	Environment Agency Water Management Regional Boundaries with Area and	yes	01/03/96	250,000
195	Air Pollution Consents: Local authority consented discharge to air	no	17/03/97	250,000
196	Car ownership per household per person.	no	01/01/91	250,000
197	Communal establishments (number of); prisons, hospitals, hotels, etc. per	no	01/01/91	250,000
198	Population, broken down into age categories.	no	01/01/91	250,000
199	Socio-Economic Groups by head of household and by gender.	no	01/01/91	250,000
200	Total population per enumeration district.	no	01/01/91	250,000
201	Travel to work: breakdown of means of travel to work per enumeration district.	no	01/01/91	250,000
202	Thames Region Public Face Boundary.	no	01/01/96	250,000
203	Thames Region Water Management Boundary.	no	01/01/96	250,000
204	GQA National Extra Reaches: unmonitored or unclassefied stretches to connect	no	01/10/96	250,000
205	GQA Reaches covering England and Wales, displayed in varying thickness	no	01/10/96	250,000
206	GQA Reaches (biology) covering England & Wales, displayed in varying thickness	no	01/10/96	250,000
207	GQA Reaches (chemistry) covering England & Wales displayed in varying thickne	no	01/10/96	250,000
208	Standard Average Annual Rainfall for the period 1941-1970 obtained from IoH.	no	21/07/97	250,000
209	Rainfall isohyets at 50mm intervals for Great Britain generated from RAIN4170 (Re	no	21/07/97	250,000
210	National Forest boundary, digitised by FRCA.	no	01/01/95	250,000
211	Community forest boundaries digitised by FRCA from Countryside Commission m	no	04/08/97	50,000
212	National Park boundaries digitised by FRCA from Countryside Commission maps,	no	05/08/97	50,000
213	Heritage coast: boundaries of areas subject to Heritage Coast designation,	no	05/08/97	50,000
214	Environment Agency Public Face Area Boundaries for all eight regions.	no	23/07/97	250,000
215	Radioactive Substance Act (1993): locations of nuclear and non-nuclear	no	10/01/97	250,000
216	Water Industry Act Sites: discharges to water of substances prescribed by the	no	10/01/97	250,000
217	Significant reservoirs: extracted from AA's dataset which are considered	no	01/10/96	250,000
218	River Habitat Monitoring Sites.	no	01/10/96	250,000

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
219	1:10,000 scale OS raster tiles.	yes	16/02/98	10,000
220	1:10,000 scale OS raster tiles in b&w with contours.	yes		10,000
222	OS 1:50,000 scale colour raster.	yes		50,000
223	OS grid at 5km,10km and 100km.	yes	26/03/98	
224	OS Boundary line datasets.	yes	01/02/97	10,000
225	IDB rivers from IDB's	yes		50,000
226	AWARD watercourses based upon the Water Act 1973 Section 24(5) Survey modif	yes		50,000
227	Other watercourses	yes		50,000
228	Main rivers from Institute of hydrology	yes		50,000
229	IDB rivers from IDB's	yes		50,000
230	AWARD watercourses based upon the Water Act 1973 Section 24(5) Survey modif	yes		50,000
231	Other watercourses	yes		50,000
232	English Heritage's archaelogical sites data: scheduled ancient monuments.	yes	28/05/98	
233	National Nature Reserves	yes	30/07/98	
234	SPA's	yes	30/07/98	
235	RAMSARS	yes	30/07/98	
236	Local Environment Agency Plans	yes	06/08/98	
237	Inland waters	yes		50,000
238	Landline	no	22/03/99	1,250
239	Groundwater protection zones	no		50,000
240	ITE Landcover map for Anglian Region	no	17/08/97	
241	Waste Sites	no		10,000
242	Waste Sites	no		10,000
243	Integrated Pollution Control sites.	yes		
244	Radioactive Substance Act (1993): locations of nuclear and non-nuclear	no		
245	Terrier: land owned by the Environment Agency.		12/08/94	10,000
246	Fluvial Standards of Service Areas	no		10,000
247	Planning applications	yes		10,000
248	Pre-planning enquiries	yes		10,000
249	District council boundaries, part of the Boundary - Line Series	yes	24/04/99	10,000
250	Electoral divisions (Boundary-Line)	yes	01/02/97	10,000
251	European parliamentary divisions (Boundary-Line)	yes	01/02/97	10,000
252	Foreshore polygons (Boundary-Line)	yes	01/02/97	10,000
253	Non civil boundaries (Boundary-Line)	yes	01/02/97	10,000
254	Parish boundaries (Boundary-Line)	yes	01/02/97	10,000
255	Non-Electoral divisions (Boundary-Line)	yes	01/02/97	10,000

Table 12 (continued) **GIS Data**

Ref	Description	Public domain?	Last updated	Scale 1:
256	Ward Divisions (Boundary-Line)	yes	01/02/97	10,000
257	Westminister divisions (Boundary-Line)	yes	01/02/97	10,000
258	County boundaries (Boundary-Line)	yes	01/02/97	10,000
259	A roads	yes		200,000
260	Rivers	yes		200,000
261	Environment Agency Water Management Area Boundaries	yes		250,000
262	RAMSAR's	yes	08/03/99	10,000
263	Special Protection Areas (SPA's)	Yes	08/03/99	10,000
264	Scheduled Ancient Monuments	yes	21/01/98	250,000
265	Beaches from Automobile Association	yes		200,000
266	Railway lines from Automobile Association	yes		200,000
267	Railway crossings from Automobile Association	yes		200,000
268	Railway Stations from Automobile Association	yes		200,000
270	Special Area of Conservation	yes	08/03/99	10,000
271	Surface water sub catchment boundaries	yes	02/07/98	50,000
272	County boundaries from AA	yes	23/03/99	200,000
273	Surface water hydrometric catchments	yes	24/03/98	50,000
274	Unitary authority boundaries	yes	13/04/99	10,000
275	Farms which fall in Nitrate Vulnerable Zones	yes	23/04/99	
276	Surface water hydrometric sub catchments	yes	24/11/98	250,000
277	Soil types in the Nitrate Vulnerable Zones.	yes	31/03/99	
278	Western boundary of Eocene deposits. Dataset digitized by John Waddingham fro	yes		250,000

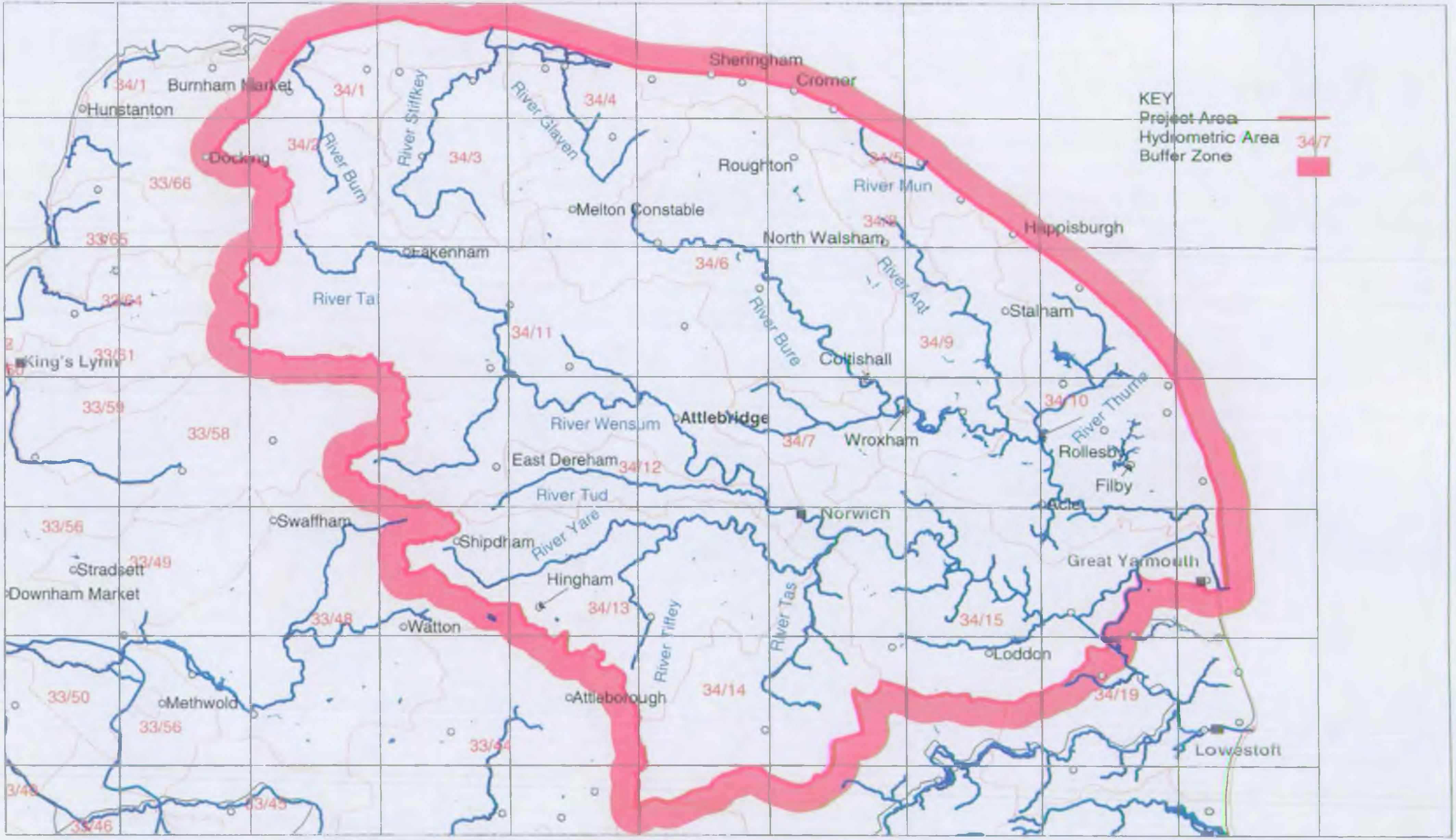

FIGURE A1 - PROJECT AREA, SHOWING MAIN RIVERS AND HYDROMETRIC AREAS

H:PROJECTS/hm-250/00-732(15770)/drawings/rr085 fig_a1.wor

FIGURE A2 - LOCATION OF RAIN GAUGES AND METEOROLOGICAL STATIONS

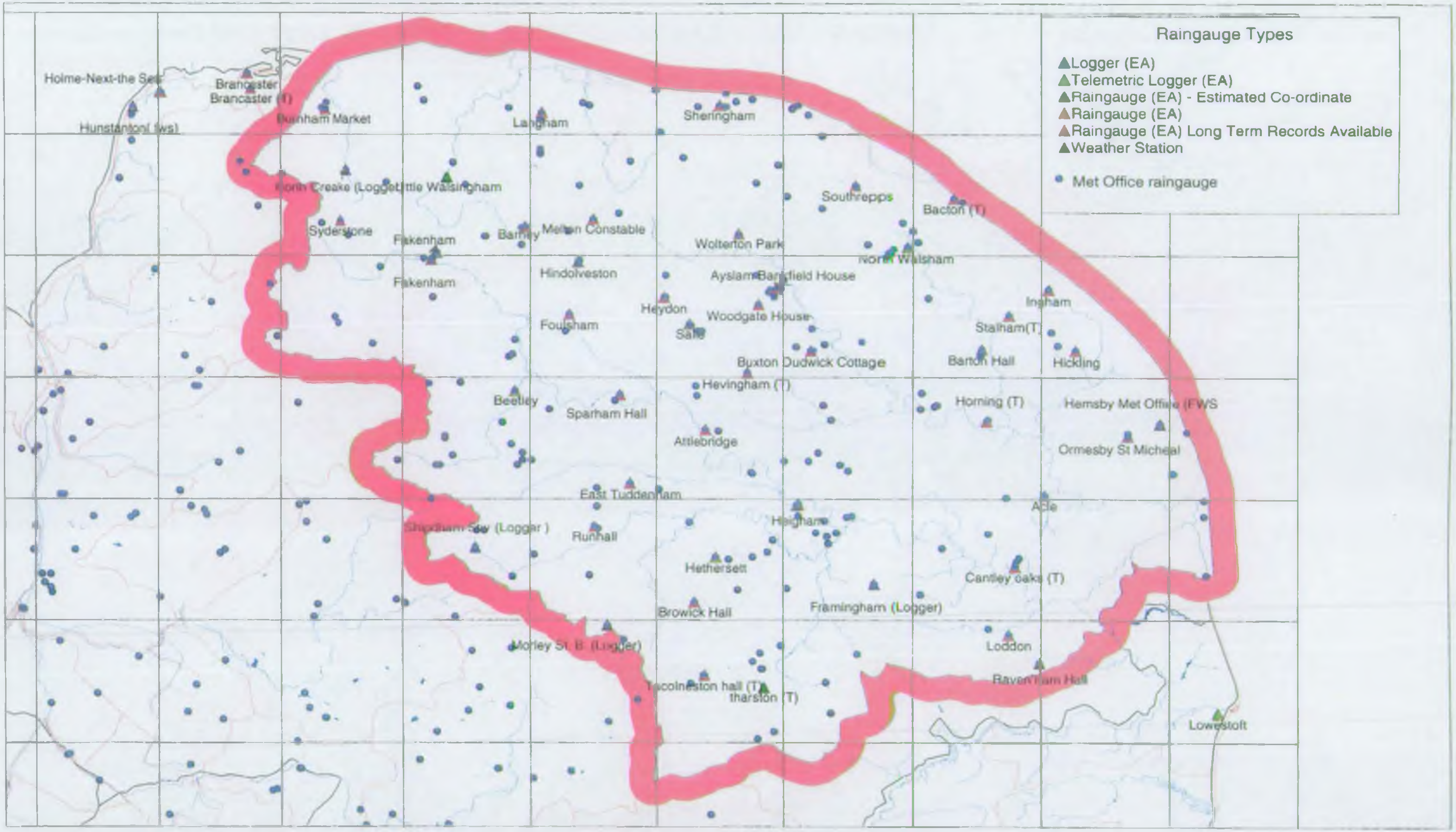

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Figure A3 RIVER GAUGING SITES (FLUVIAL, TIDAL AND 'SPOT' CURRENT METER)

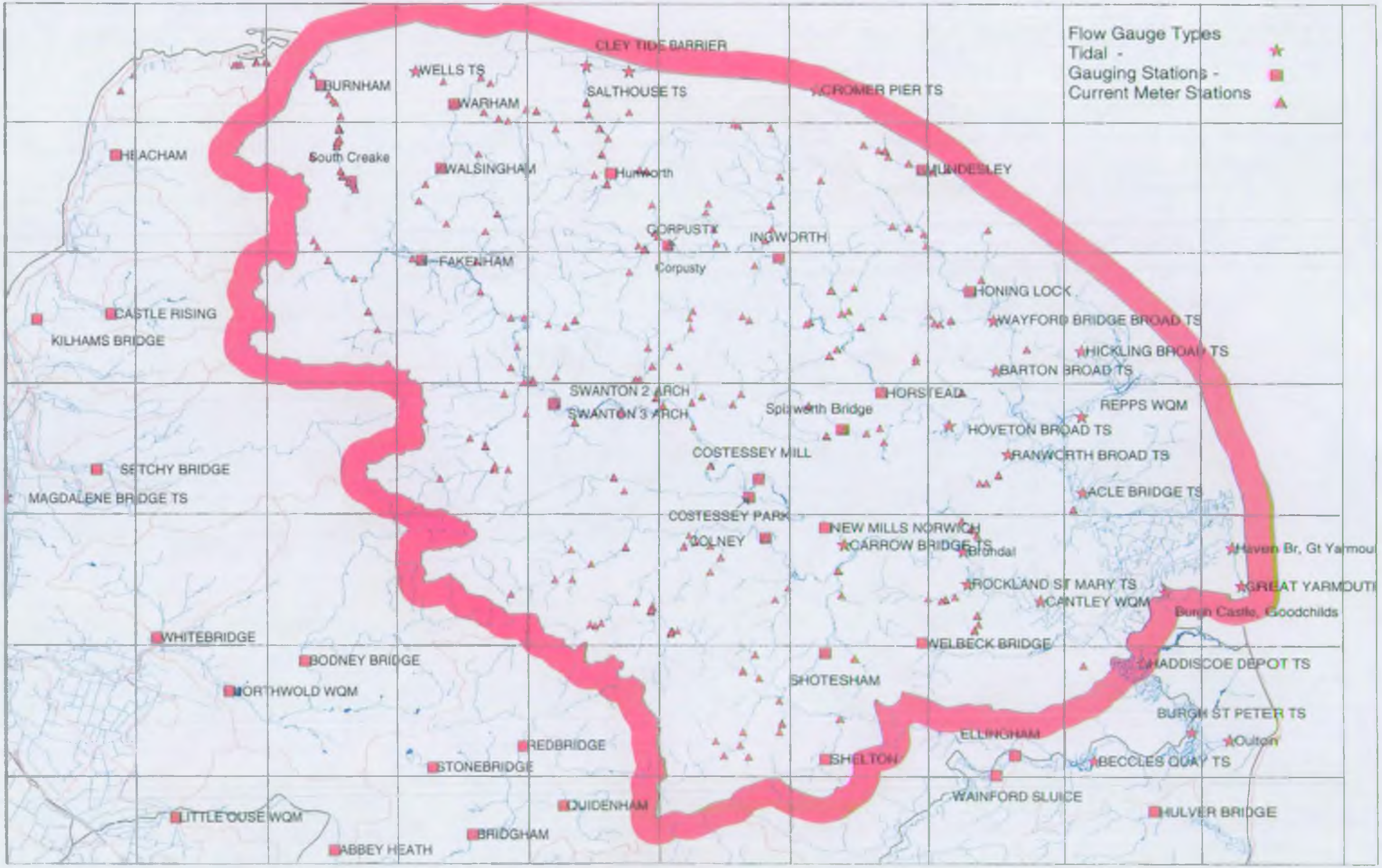

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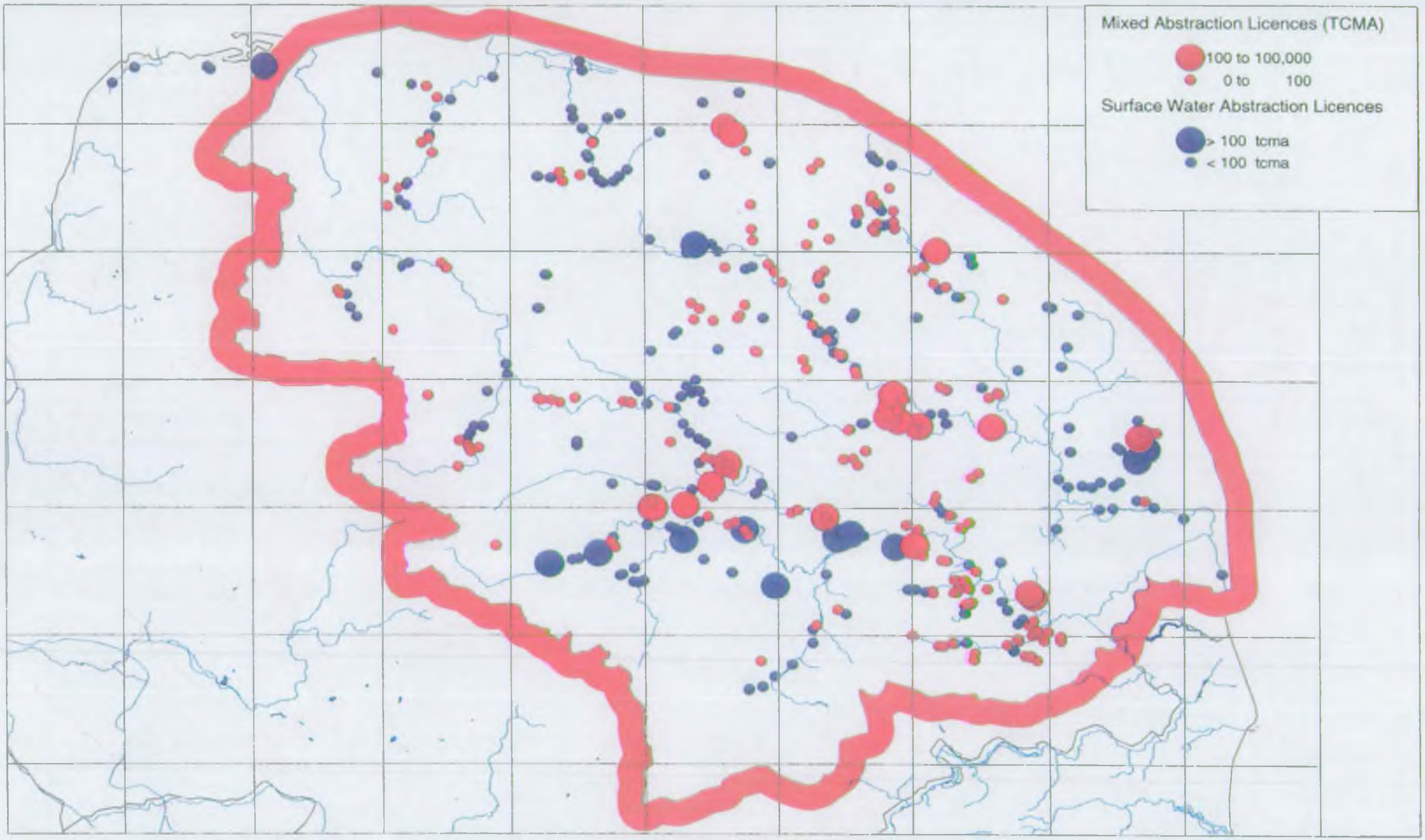
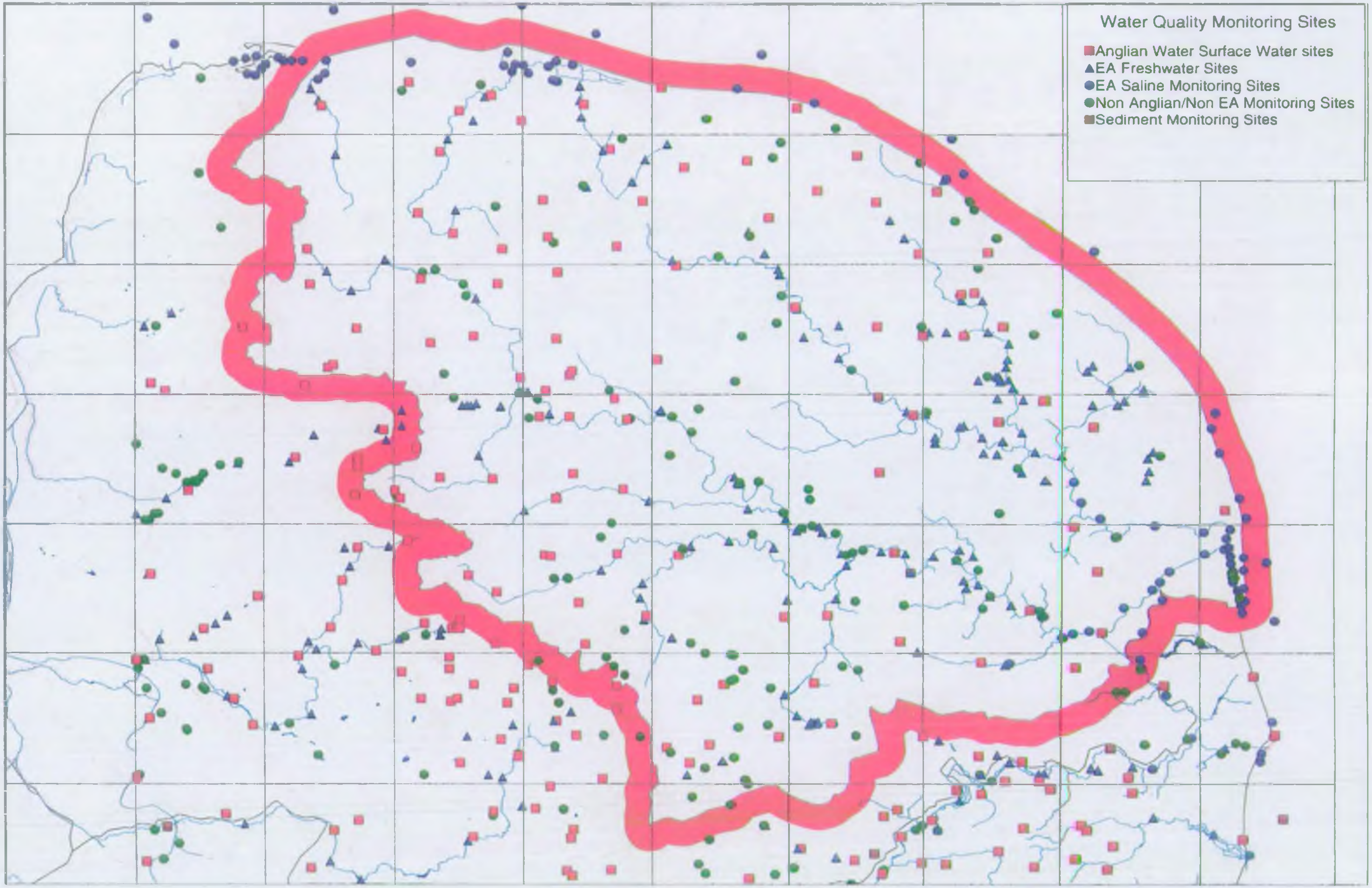
FIGURE A4 SURFACE WATER ABSTRACTION LICENCES



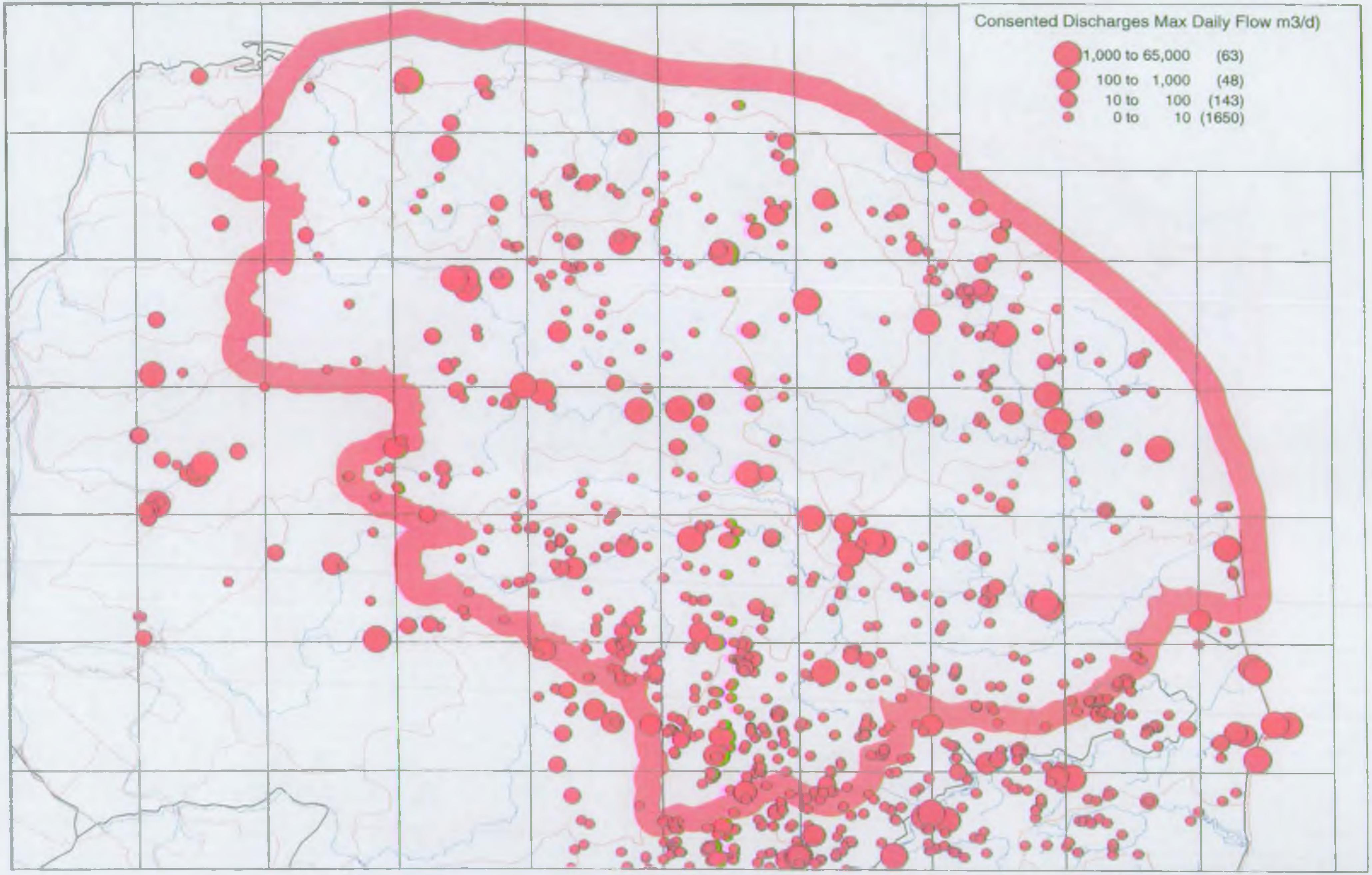
H:/PROJECTS/hm-250/00-732(15770)/drawings/rr085 fig_a4.wor

FIGURE A5 SURFACE WATER QUALITY MONITORING POINTS



H:\PROJECTS\hm-250/00-732(15770)/drawings/rr085 fig_a5.WOR

FIGURE A6 DISCHARGE CONSENT LOCATIONS



H:/PROJECTS/hm-250/00-732(15770)/drawings/rr085 fig_A6.wor

H:PROJECTS/hm-250/00-732(15770)/drawings/rr085 fig_a7.wor

FIGURE A7 - AVAILABILITY OF GEOLOGICAL MAPS AT 1:10 560 SCALE

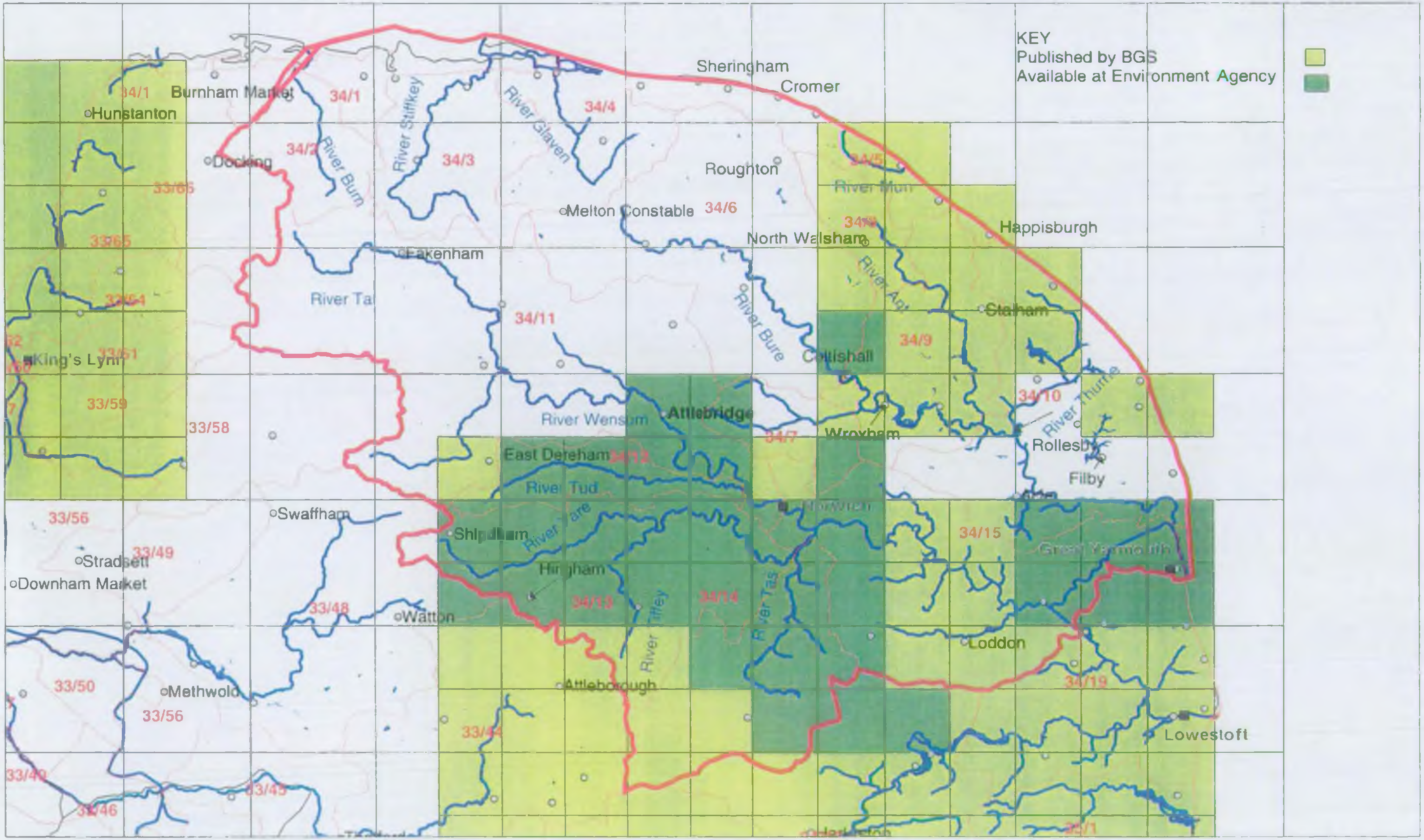


FIGURE A8 BOREHOLES IN BGS CATALOGUE

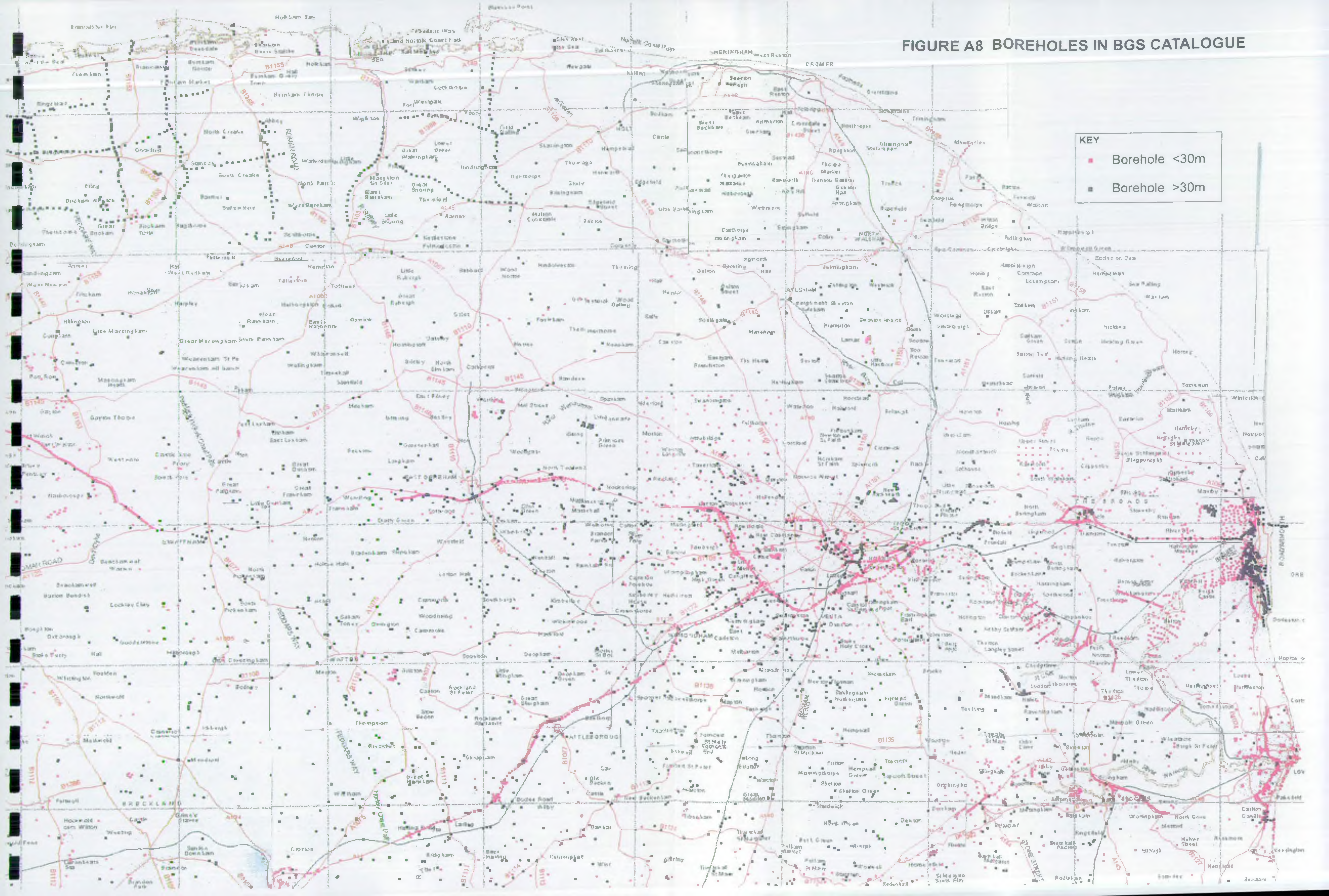
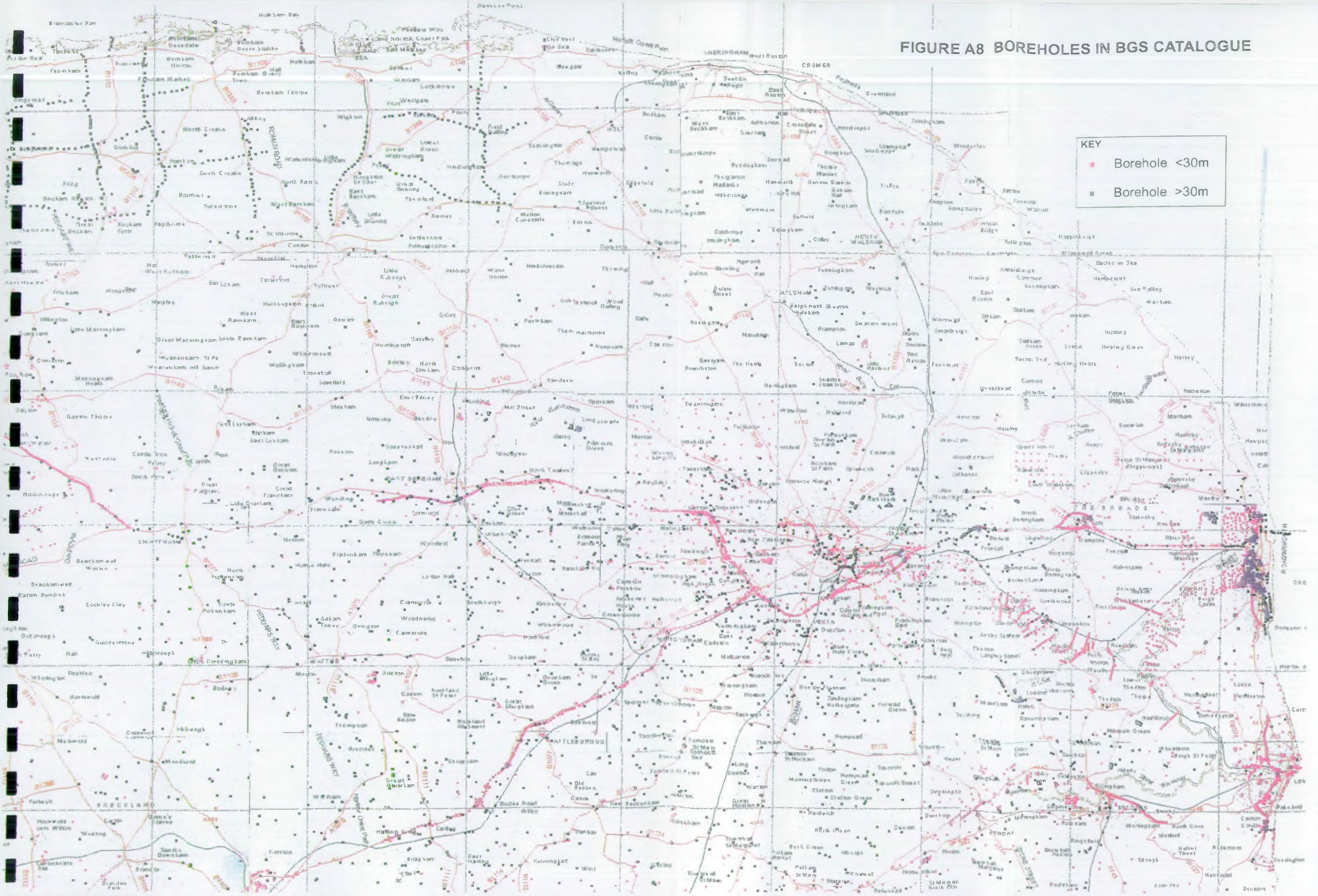


FIGURE A8 BOREHOLES IN BGS CATALOGUE



A9 GEOLOGY AND LOCATION OF GROUNDWATER LEVEL MONITORING BOREHOLES

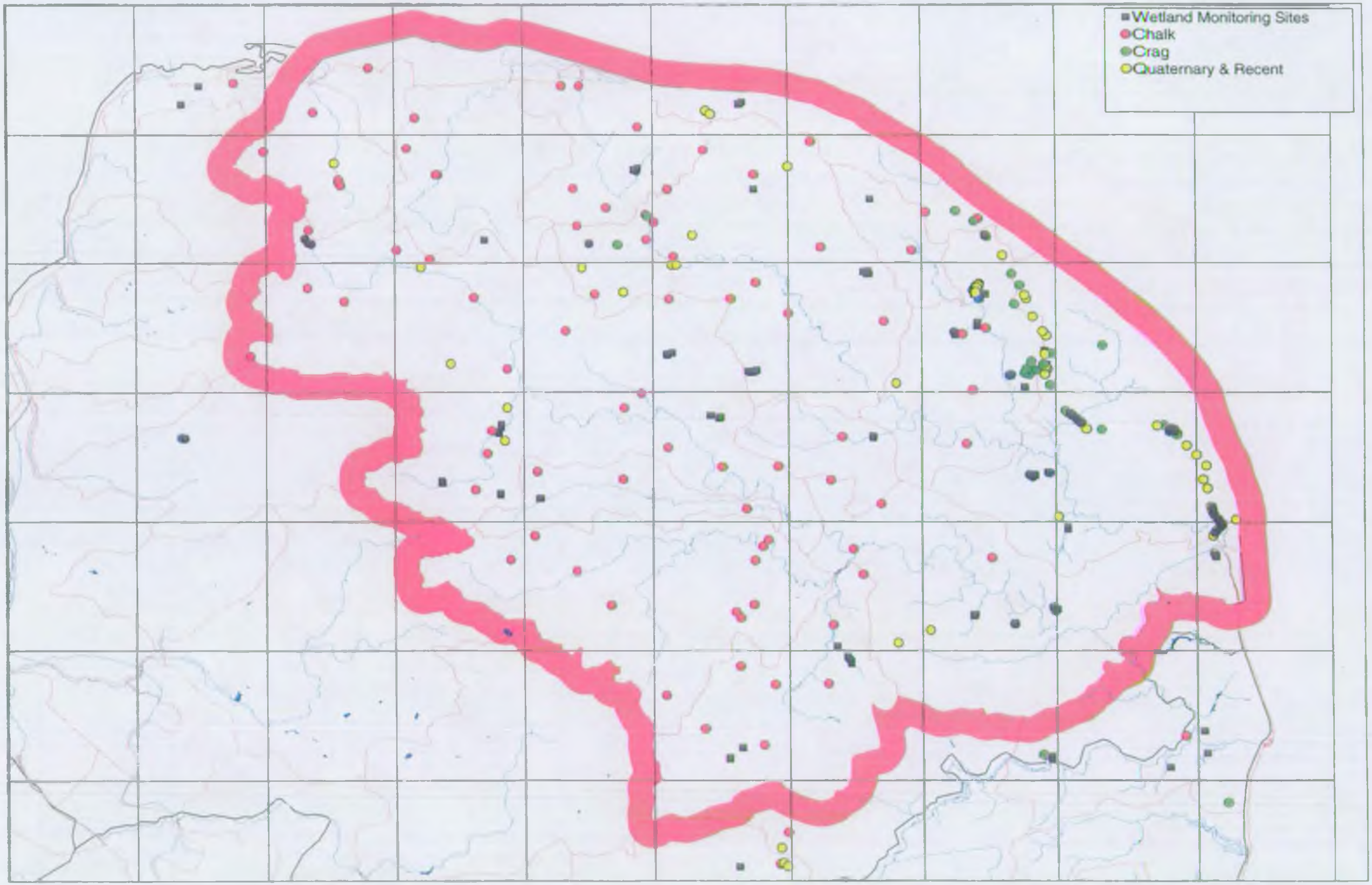


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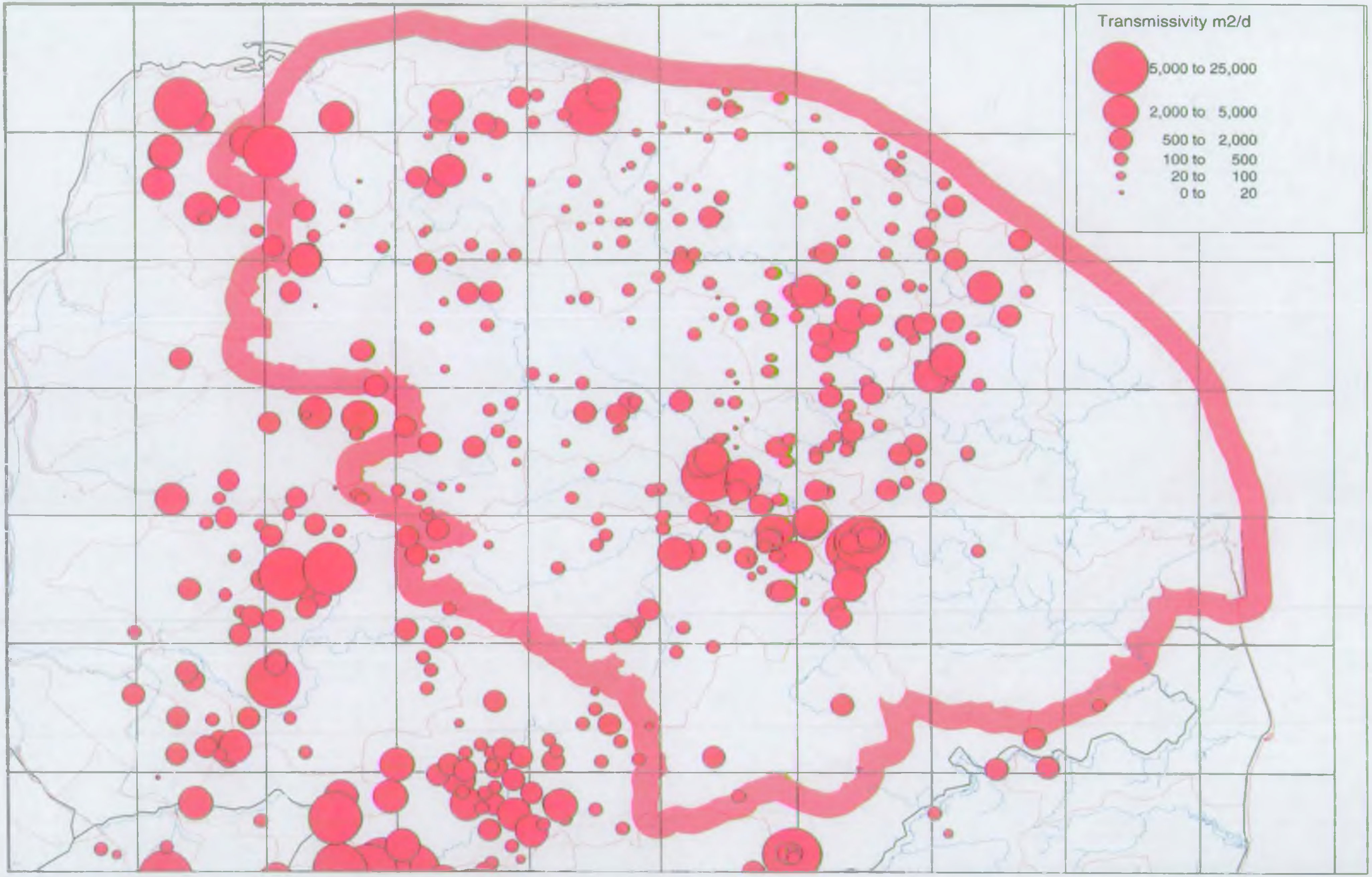
Figure A10a TRANSMISSIVITY VALUES FOR SITES IN AQUIFER PROPERTIES MANUAL



H:/PROJECTS/hm-250/00-732(15770)/drawings/rr085 fig_A10a.wor

Figure A10b STORAGE VALUES IN AQUIFER PROPERTIES MANUAL

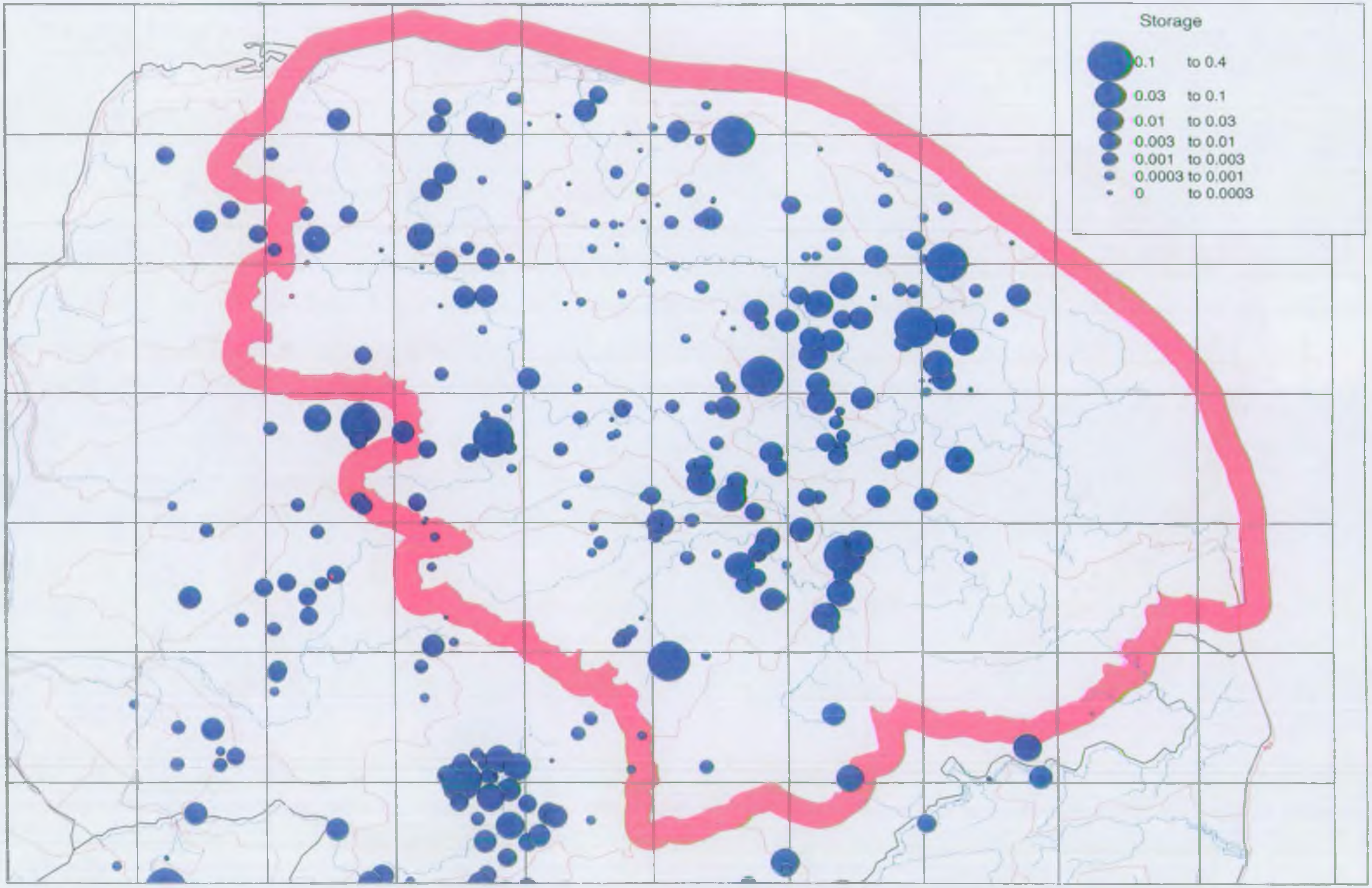


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FIGURE A11 GROUNDWATER QUALITY MONITORING POINTS

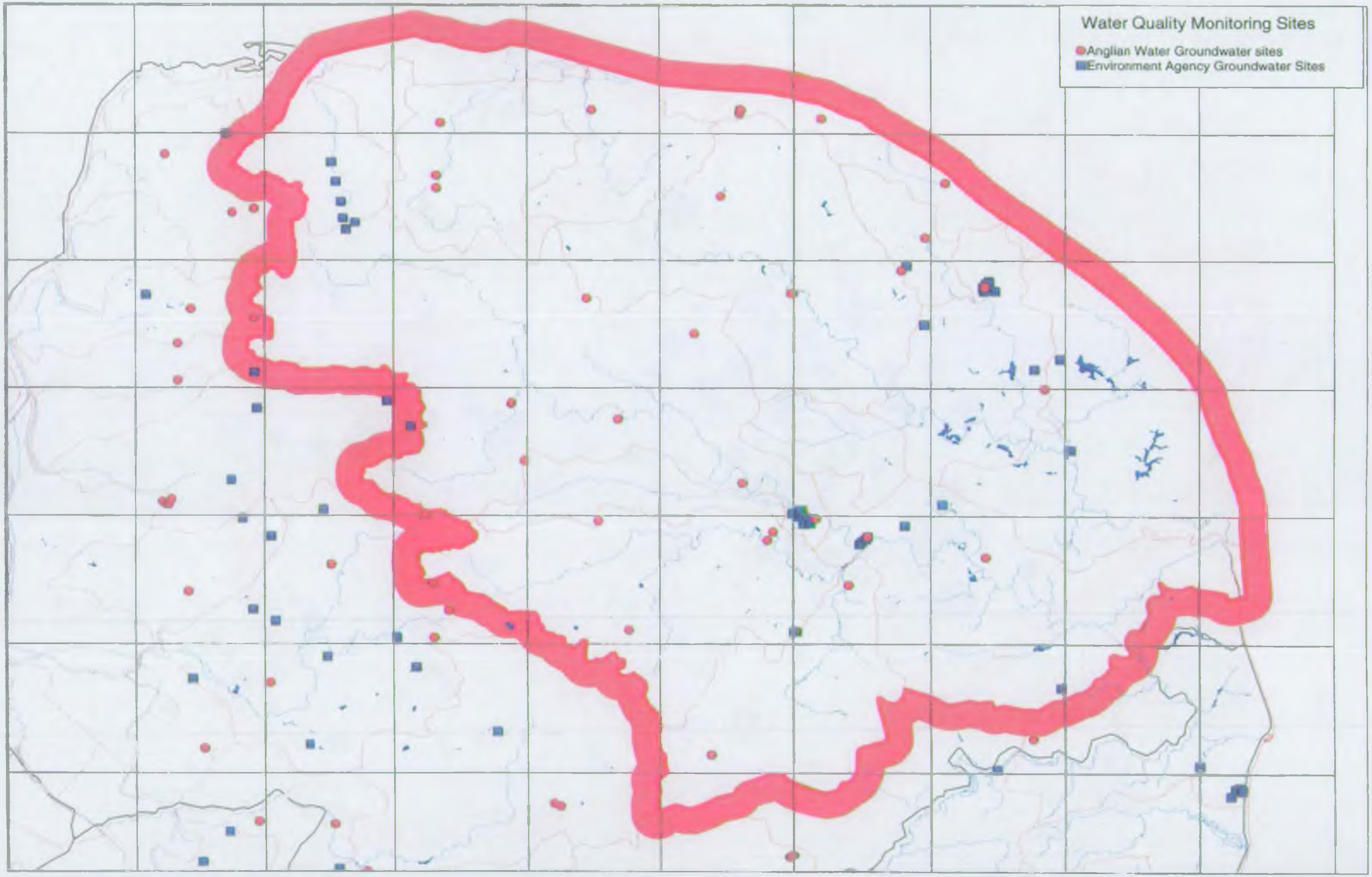

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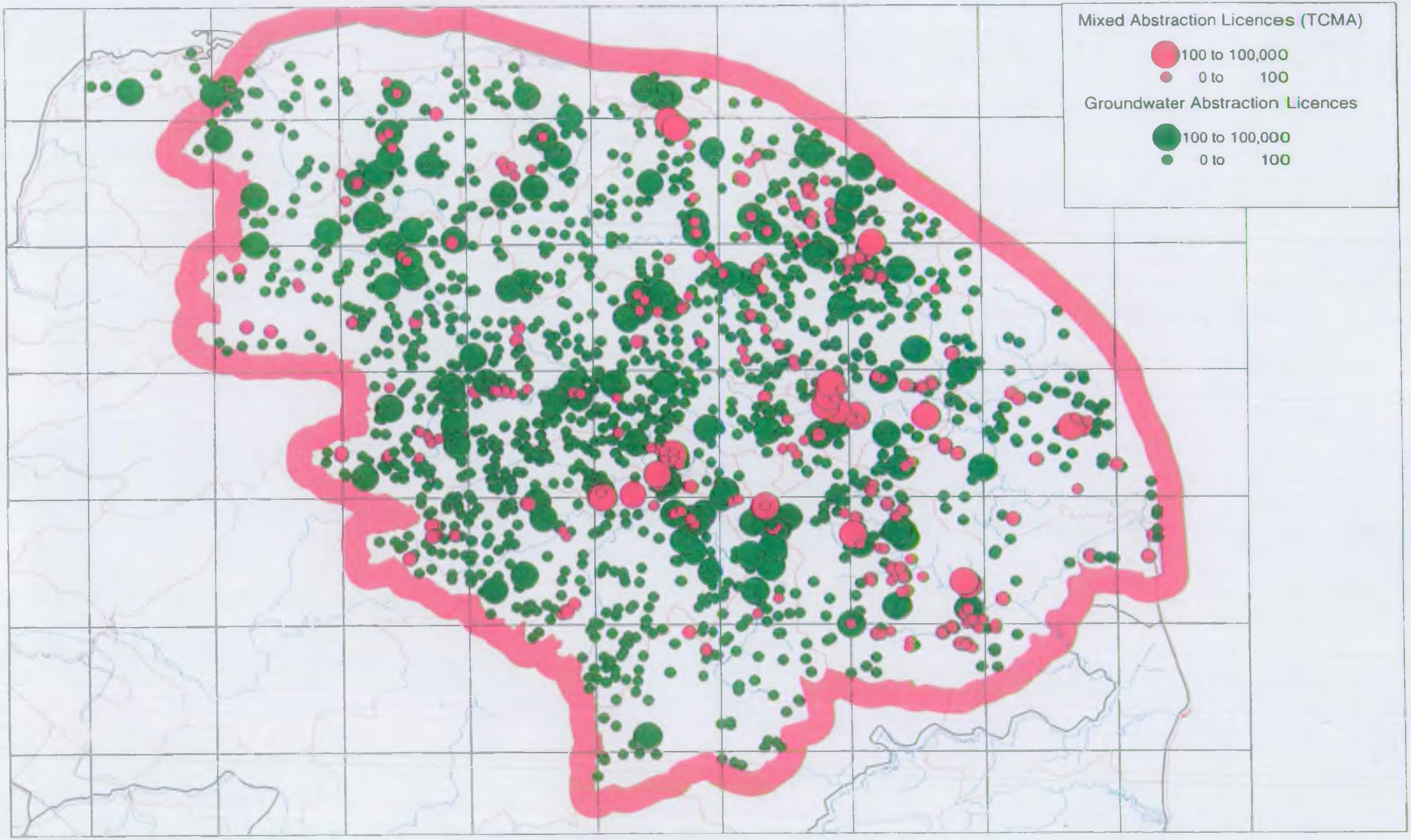
FIGURE A12 GROUNDWATER ABSTRACTION LICENCES



H:/PROJECTS/hm-250/00-732(15770)/data/mapinfo ABS_GW.wor

Appendix B
Bibliography

14 Pages

The bibliography presented in this Appendix contains a preliminary list of references for the Yare and North Norfolk study. The list includes the key references for the regional study, but it is intended that the list will grow as the project, and associated local studies, proceeds and it should not be considered as exhaustive. The list does not currently include, for example, individual details of the numerous wetland dossiers and wetland monitoring reports.

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BGS	1990	MAP Solid and drift Great Yarmouth Sheet 162 1:50k	BGS
BGS	to be published	MAP Solid and drift Mundesley and North Walsham Sheet 160 1:50k	BGS
BGS	to be published	MAP Solid and drift Swaffham Sheet 160 1:50k	BGS
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Environment Agency	Dec 96	Water level Management Plan for North Norfolk Coast SSSI Cley/Salthouse Marshes Final Plan	Environment Agency
Environment Agency	Dec 96	Water level Management Plan for North Norfolk Coast SSSI Burham Norton Final Plan	Environment Agency
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Scerri, A.E.,	1975	A Hydrogeological Investigation in N E Norfolk.	MSc Dept of Civil Engineering, Imperial College of
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Watts, B.,	1979	Hydrogeological factors in shallow subsurface disposal of hazardous liquid wastes in a minor crag aquifer.	MSc University of London
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Whitaker, D.A.,	1978	The hydrogeology of the Crag on the Felixstowe peninsula.	MSc University of Birmingham
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Williams, A., Gilman, K., & Barker, J.,	1995	Methods for the prediction of the impact of groundwater abstraction on East Anglian Wetlands.	NERC -British Geological Survey/Institute of Hydro
Winch, E.A.,	1980	A hydrogeological study of the Tud and Wensum catchments in Norfolk.	MSc Imperial College, London
Woodland, A.W.,	1970	The buriedl tunnel valleys of East Anglia.	Proc. Yats. Geo. Soc. 39:521
Woodland, H.B.,	1882	The geology of the country around Norwich.	Memo. Geo. Survey GB
Wootton N	1994	Are hardgrounds in the Chalk aquifer zones of enhanced groundwater flow?	MSc Hydrogeology Dissertation, UEA
WRC	1991	A Study of Nitrate in the Crag Aquifer of East Suffolk and East Norfolk	National Rivers Authority

Appendix C
External Consultation

50 Pages

Entec

Yare North & North Norfolk Groundwater Investigations: External Consultees

Organisation	**Consultee(s)**	**Date of Meeting**
Anglian Water Services	David Harker Gerry Spraggs	13 May 1999
BGS	Brian Moorlock *et al*	10 May 1999
Broads Authority	Michael Green Elliott Taylor Sue McQueen	13 May 1999 26 April 1999 26 April 1999
Country Landowners Association	Michael Sayers Tom Cook William Edwards	19 July 1999
English Nature, Norfolk	Stephen Rothera *et al*	17 May 1999
Essex & Suffolk Water	Guillaume Stahl Paul Saynor	23 April 1999
Individuals	Martin George Paul Ashford	24 May 1999 24 May 1999
King's Lynn Consortium of Internal Drainage Boards	Ben Hornigold	5 May 1999
NFU	Paul Hammett et al	23 April 1999
Norfolk County Council	Graham King *et al*	17 May 1999
Norwich Museum	Rob Driscoll	26 April 1999
Norfolk Wildlife Trust	Peter Doktor	letter only - 18 May 1999
RSPB	Rob Lucking	letter only - 3 June 1999

N.B. In addition to the above list, Professor Ken Rushton (Birmingham University) and Dr Kevin Hiscock (University of East Anglia) have been appointed as external expert advisors to the Agency on this project.

ENVIRONMENT AGENCY ANGLIAN REGION —GROUNDWATER STRATEGY IMPLEMENTATION

ELY OUSE AND NORTH NORFOLK SCOPING STUDY

CONSULTATION WITH ANGLIAN WATER SERVICES at CAMBRIDGE
(13 May 1999)

Discussion Summary

1 PRESENT

David Harker	Anglian Water Services
Gerry Spraggs	Anglian Water Services
Mark Grout	EA, Peterborough
Mark Whiteman	EA, Peterborough
Tim Lewis	*En*tec
Stuart Sutton	*En*tec

2 BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency subdivides the Anglian Region into four aquifer basins, the largest of which, (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over a 6 to 7 year period. Each area will be systematically studied by in a number of phases. The first phase is the systematic assembly and assessment of the available data and the development of a conceptual understanding which address the main water related issues. This may be followed by a period of additional investigation (if necessary) and then by the development of a distributed regional groundwater model (probably using an 0.5 or 1 sq. km mesh which can subsequently be used to model impacts of changes in management options or predicted climate changes. This model is unlikely to address individual local issues of features directly rather it will provide a quantitative framework based on sound science within which local issues can be addressed, where necessary by the development of nested finer mesh local models.

Throughout the study of any one area it is intended to form a Project steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

The resource assessment and model will address the question of available resource, the definition of key aspects of environmental water needs must come from other sources

Following tendering Entec have been retained by the EA as their term consultants for the next five years to provide the resources necessary for the implementation of the Strategy.

Present task is the preparation of scoping study and business case for the assessment and modelling of the water resources of the Ely-Ouse and North Norfolk/Yare North Catchment Areas. It is intended that the work is carried out in an open and collaborative way with the target being an overall quantification of the water balance in both areas which will provide an accepted framework within which local water resource allocations can be objectively addressed. From the outset it is recognised that understanding land drainage and the near surface soils and geology will be as important to the project as more traditional aspects of hydrology and hydrogeology.

The overall intended timetable is:

Complete scoping study and business case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 of Project (Data collation and analysis)	1 to 2 years
Further investigation if necessary	As required
Model Development	Probably 2001/02

3 ORGANISATION and ISSUES

DH and GS are part of the AWS Water Resource Management Group who are concerned with overall resource availability and its management. Any project which enhances the overall understanding of resource volume is welcome. AWS participation in the Project Steering Group would be led by GS.

Within AWS the Groundwater Management Group (led by Mike Cook) concentrates on operational models and individual source yields and issues.

The key issues for AWS are maintaining the performance of individual boreholes or well fields and servicing the Agency Licensing requirements.

Since 1989 licences have been time limited and 28 sources within the Ely-Ouse and north Norfolk areas are due for renewal in the period 2000/2004. Licence applications must be supported by Environmental Impact Assessments and the AWS policy is to base these on conceptual understanding of the hydrogeology rather than the development of distributed local or regional groundwater models. The contribution to the understanding of groundwater /surface water interactions that the proposed regional projects would provide would be extremely valuable.

Where conservation sites are potentially affected by abstraction detailed local studies are necessary to support the abstraction licence review. At present AWS have applied for funding (through OFWAT) for these **AMP3** studies. The programme anticipated is:

Fixing of AMP3 budget	Late 1999
Establishment of Technical Steering Group (EA/AWS)	Sept/Oct 1999
Start of AMP3 investigations	Aug/ Sept 2000

The AMP3 Technical Steering Group will establish priorities (set by Licence renewal programme) and agree work programmes. Funding for these studies will not be available for regional studies but the benefits that regional understanding can bring to local investigations is fully recognised. In particular the need for joint surface/groundwater modelling is clearly recognised.

4 DATA AVAILABILITY

All data held by AWS would be made available for the Ely-Ouse and North Norfolk Projects. Arrangements for access should be made through GS.

Data is held for approximately 450 boreholes at 200 sites throughout Anglian Region, LEAP documents are the best reference to sources in any one specific catchment.

For each source pumping data and water level data is held digitally as monthly maximum and minimum water levels since about 1993. AWS hold daily abstraction records back to 1993 and annual and monthly totals are reported to the EA. Water Quality data is held on the Public Register.

Each source has an SRO file which contains construction details, some levels, geological and production history summaries, step test information and results of CCTV or other logging. These are available for inspection. SROs are now also linked to GRAMS providing information on potential source pollution hazards. Each SRO is supported by a more detailed Technical File.

WWTW discharge data is generally available as consented flows although since 1996/97 a programme of instrument upgrading has been underway and calibration flow records are now available for a fair proportion of the larger works.

Intake data for Heigham/Cortessey (on R Wensum) available from LARS (Licensed Abstraction Recording Systems) at AWS.

Gross water supply figures are available for the past 30 years.

Within the Ely-Ouse area surface water abstraction takes place at Stoke Ferry (on Wissey, blending with groundwater is required for nitrate reduction) monthly abstraction data is available for an extended period and daily records exist since 1993. Some flow naturalisation data is probably also held.

AWS do not hold systematic shallow borehole database and do not maintain Met records separate from the EA.

Leakage information is available through District Meters although it is generally regarded as being close to 15%. The high gardening usage throughout the area must be allowed for.

Large scale development of groundwater for Public Water Supply in East Anglia originates from development of Airfield Supplies during WW2 which were subsequently taken over for public use by Parish Councils. The further development of these sources accelerated in the 1950's. Prior to WW2 the supply of larger towns like Bury dates back to the 1880's and village supplies were obtained through large and frequently deep hand dug wells.

5 SUMMARY

AWS welcomed the start of the implementation of the Groundwater Management Strategy and looked forward to participating constructively in the Project Steering Groups. The contribution that regional assessment will make to more local AMP3 studies was clearly recognised, but the different aims of the two groups of studies must be clearly recognised.

Stuart Sutton
18.05.99

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH AND ELY-OUSE SCOPING STUDIES

SUMMARY OF CONSULTATION MEETING AT BGS KEYWORTH

10 May 1999

1. PRESENT

Brian Moorlock Richard Hamblin Steve Booth Pete Balson (part)	BGS
Mark Whiteman Mark Grout	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify any sources of data/information held by, or known to, BGS. In particular to discuss the availability of recent geological mapping information in Norfolk.

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present tasks are precursors to the Phases described above, and comprise a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the Ely-Ouse area and the combined North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for Ely-Ouse, North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is similar for each of the two studies:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

Various information and data sources were discussed (in no particular order):

- Field surveys are done at 1:10K. Manuscript maps available at ~£75. Currently in process of being digitised and 'cut-down' to 1:50K. There will not be any 1:10K line work available for East Anglia (except Cromer), but 1:50K is available. The view was expressed that not a lot of information was lost by using the 1:50K maps.
- Currently digitised maps are '2-D' only, but there is an intention to make maps 'more intelligent'. This work is at very early stages presently: the main thrust of work is to digitise linework.
- BGS are hoping to build an 'interrogatable geology GIS' for Waveney District Council
- Sheets 130/131 are being digitised at 1:10K. BGS have obtained DTM data from Ordnance Survey at 1:10K and 1:50K, and plan to 'drape' the geology onto the DTM to try and resolve some 'geological problems', which arise from the complicated glacial history of the area. BGS will finish mapping of the Cromer sheet in November.
- Great Yarmouth area (Sheet 162): geological data from boreholes have been put onto Access database. Saxmundham and Lowestoft have also been done (but selected boreholes only), and the Cromer sheet **might** be. Synthesising the borehole geology information to get it onto a database is a relatively expensive process however, and needs to be justified internally at BGS. Cost is around £10 per borehole.
- BGS corporate policy is to get digital 1:50K maps available for whole country within 2 years. There is a 'push' on East Anglia however, so this may be completed sooner. BUT, not all of East Anglia is mapped to a 'currently acceptable' standard, e.g. Aylsham was last mapped in 1880s and won't be re-mapped for a couple of years, also Fakenham and Eye sheets. Forward programme is:

- 131 Cromer, mapping finished this autumn, Versatec plot/digital map available about one year after that
    - 130 Wells, available in about 2 years
    - 147 Aylsham, about 4-5 years
    - Thetford, after this

- It was noted that the BGS programme could be modified at the request of the Agency, but that there may be financial implications (there are only 4 geologists covering East Anglia)

- Field mapping programme for the UK will wind down in around 2005, then BGS will go into a process of 'continuous revision' as new boreholes are drilled etc. (this nationwide coverage will still include some old mapping)

- 1:10K for Eye, Swaffham, Fakenham, Wells, Aylsham are **not** available.

- BGS will provide a map/list showing availability of 1:10K/6" mapping

- (Mark Grout undertook to send BGS a map of the Agency project areas covered within the Strategy, and to find out whether the 'GPZ' map in the Strategy document is public domain and therefore available to BGS in digital form)

- we should not necessarily rely on descriptions of 'Norwich Brickearth' from old mapping

- Geological memoirs are no longer being done, but are being replaced by much shorter 'explanations'. Lowestoft and Saxmundham memoirs are done, but are not published. North Walsham will have 'explanation' document only.

- Main geological 'issues':
    - Tunnel valleys. Around 40 have been mapped so far.
    - Drift near North Norfolk Coast (complicated by more than one glaciation)

- 'till' becomes more permeable further east

- if Agency have money to drill new boreholes, BGS would be happy to log them (geologically, and possibly geophysically)

- it was noted that, as part of a review of the monitoring network (a separate project), the Agency are aiming for a regional density of one borehole per 25 km^2. This may require drilling of a significant number (possibly as many as 80) of new boreholes throughout East Anglia. These boreholes will be sited from a 'hydrogeological viewpoint' but if possible should be located to optimise geological information as well.

- In the southern part of East Anglia, a new Chalk stratigraphy is being developed (6 units), and has been applied to the Biggleswade sheet. The Chalk of NE Norfolk is stratigraphically higher than these however, so there would be a need for some 'new' units if this stratigraphy is developed further.

- BGS have May Gurney and Howland boreholes on their database (both May Gurney and Howland also have databases), but all information is confidential, so cannot be obtained from BGS without approval.

- Ely-Ouse: no BGS staff working here at present. Maps are available but not in digital form currently.

- May also be worth talking to:
    - Andrew McKenzie at Wallingford (WellMaster database of scanned geological logs etc.)
    - Coastal Geology Group (deal with near-shore environment): contact is Martin Culshaw or Pete Balson

    - Julian Andrews at UEA, working with BGS. Lead author on a paper in press on Holocene geology of North Norfolk. Data held mainly at BGS, and is geological rather than hydrogeological (Kevin Hiscock not involved).

- The IFPU/LOCUS MapInfo application ('3-D' geological GIS for London Underground) was examined: it was noted that a system providing similar types of information would in theory be useful to, for example, Agency abstraction licensing staff.

Prepared by Tim Lewis, Entec
03.06.99

ENVIRONMENT AGENCY, ANGLIAN REGION: GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING WITH BROADS AUTHORITY NORWICH

13 May 1999

(Issue 2)

1. PRESENT

Michael Green	Broads Authority
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region;
- Identify the main issues and/or concerns held by the Broads Authority (BA) relating to the use of water and the water environment;
- Identify any sources of data/information known to the Broads Authority.

This meeting followed an earlier meeting with Elliott Taylor and Sue McQueen on 26 April 1999 (reported separately).

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

Main issues mentioned were:

- There is a need to address the whole question of water resources in the Broads and the wider region: at present there seems to be no clear understanding of how much water is available.
- There are plans for tens of thousands of new houses in the Norfolk Structure Plan, with consequent water demands. The water companies say that water can be provided, and the Agency have said that this is reasonable, but at what cost to the environment?
- In terms of water levels/flows related to conservation: is maintaining the *status quo* adequate, or is the *status quo* actually causing degradation?

4.2 Data/Information

BA strategy is to select twelve key Broads for long term monitoring, although this has not been implemented. Currently looking for funds, probably from the corporate sector.

BA work in co-operation with the Agency, Geoff Phillips is main contact.

BA train long-term unemployed under the government's New Deal scheme. There may be a possibility of utilising such sources on aspects of this study (although tasks would have to be well defined and constrained). Costs to BA are minimal, being covered largely by New Deal, and it could provide useful training for unemployed graduates, etc. BA would need a few months' notice to organise this.

May be an aerial photo survey later this year.

Sailing clubs at Hickling Broad and Rollesby Broad are thought to measure water levels: Geoff Phillips probably has this information. BA also has water level data for Hickling Broad from mid-1990s.

May be worth talking to landowners re: land use changes, historic hydrological 'events' etc. BA has good contacts with landowners adjacent to Broads and could help with liaison (Cath Wilson, Trinity Broads warden). Major landowners include Simon Daniel (Trinity Broads, Cater family (Bure) and another family near Hoveton. BA can give specific contacts if necessary as fieldwork/analysis proceeds.

Work in Fens (most not directly related to water):

- Major LIFE project looking at new technology for harvesting fen 'materials' (eg harvester for cutting reed and sedge);
- BA looking to convert 1000 ha of carr and scrub back to Fen;
- Cannot keep up with scrub encroachment by hand;
- Grazing trials with different types of animals, to keep scrub at bay and maintain fen;
- Sutton Fen: extensive dyke survey (Rob Andrews at BA or Brian Wheeler at the University of Sheffield, partly funded by BA): being used for management of Fen (ESA tiers, etc);
- BA works closely with landowners: some are very keen on conservation-oriented farming. E.g. North Walsham/Dilham canal: programme of dredging and tree clearing. Landowner wants to make area 'wetter'.

Saline incursion: recognised as a problem, but not specifically addressed at strategic level (e.g. Broads Plan, Fen Management Strategy).

Much information in 'Broads Plan': updated every 5 years or so, 1997 is current one (copy provided).

4.3 Possible Benefits of the Study

Study is considered crucial to feed into Structure Plans/Regional Planning Guidance, etc. (i.e. assess water availability before committing to new development), as well as EA LEAPs and similar documents.

Policy decisions made at a high level tend to get 'pushed down' to lower levels in organisations: if there is a scientific basis for making decisions on whether water is available or not (which may go against 'policy'), then this must be a good thing.

Study should help in 'sustainability debate'.

Study should assist in assessing whether the area surrounding the Broads is being managed properly from a conservation point of view.

Prepared by Tim Lewis, Entec
22.07.99 (Issue 2)

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING WITH BROADS AUTHORITY, NORWICH
26 April 1999

1. PRESENT

Elliott Taylor Sue McQueen (part)	Broads Authority
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify the main issues and/or concerns held by the Broads Authority relating to the use of water and the water environment
- Identify any sources of data/information within, or known to, the Broads Authority

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

Main issues mentioned were:

- Diffuse pollution into Broads: where does it come from?
- Restoration of Broads and improving water quality are key

4.2 Data/Information

Much of the data of interest to the Broads Authority is collected by the Agency. Main data sets held by BA tend to be 'ecological' rather than 'hydrological', e.g. water quality changes, algal populations, macrophyte surveys etc.

It was thought that IDB pumping into Hickling Broad and Horsey Mere could be quantified and may already have been processed.

Main ongoing projects are at Trinity Broads (partnership between BA, the Agency and Essex & Suffolk Water), and the 'mud-pumping' restoration works at Barton Broad. Essex & Suffolk will be getting AMP3 money to look at Ormesby Broad. Geoff Phillips(Agency) and Joanne Pitt (Agency, Haddiscoe Labs) are best people to talk to re. these projects. Agency have done pilot study on Ant Broads and Marshes (Charlie Beardall?).

BA have a GIS (using SPANS software) which includes following information:

- Fen Resource Survey (1991-94). Vegetation classified into NVC types, also pH, conductivity and historical site data. Will be repeated starting 2001
- Woodland survey: ongoing to be complete 1999/2000, NVC classification
- 'Substrate' data, being collated 1999. Historical information on peat cuttings from nineteenth century.
- Land use: 1980s
- Dyke surveys: 1987 and 1997 aquatic plant surveys

It is thought that there is an agreement between BA and MAFF for exchange of GIS information

Planning Section of BA (Kerry Williams) also has GIS, but this is available in more detail from District Councils. Has not yet proved useful to BA.

Other data include:

- Aquatic macrophyte surveys (from 1982, most sites annually). Some sites, e.g. Upton Broad, show strong correlation between macrophyte health and hydrology
- Turf Pond monitoring: BA have created new turf ponds monitored for re-colonisation etc
- Aerial photos: full coverage colour (1988, 1995), black and white (1980), plus some black and white from 1940s, 1950s, 1970s
- Fen Dossiers for each site containing miscellaneous information
- Management records on database (Access)
- Various reports, probably mainly also held by Agency, e.g.
  - Hydrological investigations at Sutton Fen, ECUS 1998
  - The hydrodynamics of East Anglian Fen systems, 1988
  - Groundwater level monitoring since 1992
  - Hydrodynamics of Catfield Fen, Univ. of Birmingham, 1989

BA do not monitor any raingauges or groundwater monitoring boreholes.

4.3 Possible Benefits of the Study

By developing a quantitative understanding of the groundwater system, it is intended that a regional model could be used by the Agency to make 'fairer', science-based and defensible decisions on the allocation of water resources to optimise the delicate balance between abstraction, conservation and other environment needs.

Quantification of water inputs to Broads: very important information for Broads management.

Better understanding of hydrology may allow better planning and programming of water quality improvement schemes such as that underway at Barton Broad.

Prepared by Tim Lewis, Entec
01.06.99

ENVIRONMENT AGENCY, ANGLIAN REGION: GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING WITH THE COUNTRY LANDOWNERS ASSOCIATION, SPARHAM HOUSE, NORFOLK

19 July 1999

(Issue 2)

1. PRESENT

Michael Sayer	Norfolk CLA Committee Member
Tom Cook	Norfolk CLA Committee Member
William Edwards	Norfolk CLA Committee Member
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region;
- Identify the main issues and/or concerns held by the Country Landowners Association (CLA) relating to the use of water and the water environment;
- Identify any sources of data/information known to the CLA

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	August 1999
Presentation to Environment Agency Project Appraisal Board	September 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

Main issues mentioned were:

- current (1994) water balances are inadequately supported by science
- in particular, the 'excess' water (as identified by the water balances) in the Wensum catchment is thought to be unrealistic
- climate change
- trial pumping of new PWS borehole at Sparham Hill was undertaken in 'wet' conditions: what will effect of potentially drier future conditions be, especially in combination with abstraction from PWS at Lyng Forge?
- Wensum (and probably other rivers) now have a much 'flashier' response than a few decades ago. Runoff has increased (increased urbanisation of East Dereham and Fakenham), and low flows are much lower than previously, making them very susceptible to artificial discharges, e.g. Fakenham STW
- agriculture can be badly affected by large abstractions for Public Water Supply or other industry
- agriculture is the main industry within the region, yet has the 'least influence' in water resources debates
- Norfolk County Council under pressure from Government to 'accept' plans for new housing. Onus should be on Environment Agency to criticise Structure Plans more strongly
- re. time limited licences for Public Water Supplies: if renewal is refused, how will domestic users be supplied? This may put unfair (from a scientific point of view) emphasis on the case for renewal.

- grazing regimes in valleys require water close to the surface: if water levels fall it is difficult to remedy the situation because of the natural fall in elevation of the valleys

4.2 Data/Information

The CLA have no particular data holdings, but may be able to offer useful anecdotal information on changes in land use practices and river flow regimes over the years.

For example, it was noted that the ecology of the Wensum had changed completely over the last 40 years, and that the flow regime is now much flashier, probably due mainly to increasing urbanisation.

Improvements in land drainage since the 1960s were discussed. It was noted that, in many areas, these drains simply replaced old (probably early to mid-nineteenth century) drains that had ceased to function properly because of collapse, siltation etc. Some meadows were ploughed up to convert to arable: this was generally on a small scale in the Wensum Valley itself, although much more took place in tributary valley bottoms. This was a major reason for supporting extensions to the ESA.

It was noted that the study will almost certainly result in the need to install new boreholes or temporary river gauging structures. The CLA offered to encourage members to be co-operative over land access arrangements, should the need arise, and offered to publicise that the study was happening in the CLA newsletter.

4.3 Possible Benefits of the Study

The CLA strongly endorsed the study. It is seen as vital to develop the understanding of how the water regime behaves, such that it can be properly and equitably managed.

Prepared by Tim Lewis, Entec
20.09.99 (Issue 2)

ENVIRONMENT AGENCY ANGLIAN REGION —GROUNDWATER STRATEGY IMPLEMENTATION

ELY OUSE AND NORTH NORFOLK SCOPING STUDY

CONSULTATION WITH ENGLISH NATURE, NORFOLK AT NORWICH (17 May 1999)

Discussion Summary

1. PRESENT

S Rothera	EN, Conservation Officer (Breckland, Fens, Nar, Wensum)
Helen Vine	(Wash, North Norfolk Coast)
Clive Doarks	(Broads)
Peter Lambney	(North Norfolk)
M Grout	EA, Peterborough
M Whiteman	EA, Peterborough
D Seccombe	EA, Ipswich
M Martin	EA, Ipswich
T Reynolds	EA, Brampton
T Lewis	*En*tec
S Sutton	*En*tec

Apologies: A Miller EN, Conservation officer (Valley Fens)

2. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency subdivides the Anglian Region into four aquifer basins, the largest of which, (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over a 6 to 7 year period. Each area will be systematically studied in a number of phases. The first phase is the systematic assembly and assessment of the available data and the development of a conceptual understanding which address the main water related issues. This may be followed by a period of additional investigation (if necessary) and then by the development of a distributed regional groundwater model (probably using an 0.5 or 1 sq. km mesh which can subsequently be used to model impacts of changes in management options or predicted climate changes. This model is unlikely to address individual local issues of features directly rather it will provide a quantitative framework based on sound science within which local issues can be addressed, where necessary by the development of nested finer mesh local models.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

The resource assessment and model will address the question of available resource, the definition of key aspects of environmental water needs must come from other sources

Following tendering Entec have been retained by the EA as their term consultants for the next five years to provide the resources necessary for the implementation of the Strategy.

Present task is the preparation of scoping study and business case for the assessment and modelling of the water resources of the Ely-Ouse and North Norfolk/Yare North Catchment Areas. It is intended that the work is carried out in an open and collaborative way with the target being an overall quantification of the water balance in both areas which will provide an accepted framework within which local water resource allocations can be objectively addressed. From the outset it is recognised that understanding land drainage and the near surface soils and geology will be as important to the project as more traditional aspects of hydrology and hydrogeology.

The overall intended timetable is:

Complete scoping study and business case	July 1999
Presentation to Environment Agency, Project Appraisal Board	August 1999
Phase 1 of Project (Data collation and analysis)	1 to 2 years
Further investigation if necessary	As required
Model Development	Probably 2001/02

3 ISSUES

English Nature emphasised their principal expertise was in the understanding and presentation of site ecology. This in turn provides important pointers towards the water requirements to sustain biodiversity at the site in question but does not define these categorically. At present liaison with the EA is through the Conservation Section, and careful thought must be given to resourcing support to other EA activities.

3.1 Generic Conservation Issues

A number of key issues relevant throughout the area were identified:

The uniqueness of each site (SAC/SSSI or other designation) must be recognised, the specific presentation of vegetation at each site represents the complexity and interactions at that site and care must be taken to avoid over generalised site groupings.

The ongoing review of consents is an important contribution to site sustainability and the development of understanding which the model should provide can only enhance this process.

The study and model must address the complexity of how rivers behave (interaction of runoff, drainage, groundwater, geology, etc.) and as such will contribute to assessment of 'in-river' needs.

Groundwater/surface water interactions must be addressed in a site specific manner. Also relative contributions of groundwater from different sources may be crucial.

It is important to have a tool available which can address the overall catchment water management strategy and assess the impact of strategic changes e.g. landuse.

The importance of the contribution that openness, in the implementation of the projects related to the Groundwater Strategy , can make to final acceptability should be emphasised and in this context the possible contribution of English Nature's hydrogeologist (Steve Bennett) will be investigated.

The current objectives of English Nature are to sustain, rather than enhance, individual sites although in some instances where degradation of the environment is marked an objective to enhance or improve may be identified. For the SACs (Habitats Directive sites) conservation objectives will be produced by the end of 1999. These objectives will be broadly based and will be supported by a tabulation of 'attributes' to define favourable conditions for each feature, a 'Favourable Condition Table' will be developed for marine sites.

Biodiversity and sustainability are the key drivers for English Nature.

3.2 Specific Issues--Ely-Ouse

A number of issues specific to the Ely-Ouse area were identified:

The impact of the operation of the Groundwater development scheme on the Brecklands area

The balancing of the needs served by the various water 'exports' (Cambridge, Essex, Wash) and their impact within the area.

Review of Denver outflow consents and the impact on the needs of the Wash SAC/SPA. It was recognised that Denver was only one component of freshwater inputs to the Wash and the complexities of requirements for channel scouring and meeting nutrient requirements were noted.

Abstractions for spray irrigation and their impact on wetlands other than SAC sites (e.g. East Harling Common, Knettishall Heath, Middle Harling Fen)

Public water supply impacts on non SAC sites (Didlington Parklands)

The impact of abstractions on the fluctuating groundwater meres particularly in the context of concerns arising from recent reappraisal that suggests that the 'available' drawdown range is substantially less than previously thought.

Judicious use of water from all stages of the hydrological cycle in the Breckland area. English nature have publicly favoured the development of surface storage of water from winter high flows abstracted as far downstream as is feasible.

3.3 Specific Issues–Yare North-North Norfolk

Salinity changes, as evidenced by e.g. water quality surveys (EN dyke survey in late 1980s and late 1990s), Holman & Hiscock work in Thurne catchment, saltwater shrimps now present in South Walsham Broad.

Valley Fens encroached by scrub in response to 'drying out' of land. (Scrub can take hold very quickly and sometimes (temporarily) disappears in a succession of wet years).

Broads strategy identifies which Broads are 'worth saving'. Potentially recoverable Broads may be lost because of intermittent saline intrusion.

Freshwater springs on North Norfolk Coast (and also discharges to mudflats elsewhere) important for habitat/birds etc. (It was noted that there may be freshwater springs further offshore than those currently identified).

Mix of waters derived from Chalk/Drift is often important for particular habitats/plant associations.

Water level and water quality requirements for particular vegetation types (it is accepted that the project will not address the current uncertainties over these requirements, but could provide useful information on how levels might change in future, so that the implications can be assessed).

4 DATA/INFORMATION

4.1 Held by English Nature

For each designated site the typical data hierarchy is:

Birmingham University Site Dossier	held by EA
HSI Site Report	held by EA
Biological Site Dossier	held by EN also for Wildlife Trust Sites (may include landuse)
Detailed NVC Surveys	held by EN

Detailed appraisal of landuse has only been carried out for Stanford Training Area Site (cf final Report of the Nature Conservancy Council on a Survey of the Stanford Training Area, Institute of Terrestrial Ecology Project No 465, 1978). A summary of this survey has also been published and SR will try to locate the reference.

For some key sites, EN have aerial photos every few years.

GIS of 2800 ditch locations in Yare (down to Norwich), Waveney (to Bungay), Ant, Bure and Thurne. Data on conductivity and plant species/communities in 1988/89 and more recently. Charles Beardall at the Agency has a copy of the data on spreadsheet, but not GIS.

Some data for ditches in North Norfolk also.

Digitisation of County Wildlife Sites is on-going. SSSIs have been digitised (but Agency will have these anyway).

4.2 Held Elsewhere

A number of other potential sources of data and information (for the Yare North/North Norfolk area) were mentioned:

- Land Use maps, including levels at 100 m centres (Bernard Ayling at Environment Agency)
- Fen survey differentiating groundwater and surface water fed areas (Broads Authority)
- Historic Land Use maps (Norwich Museum)
- Water quality information from Amoco pipeline investigations (Environment Agency)
- Water balance study on Halvergate (see Ben Hornigold at King's Lynn Consortium of IDBs): there are apparently some very active spring heads, evidenced by 'peat domes' a considerable distance from the edge of Halvergate.
- Hydrological modelling of Thurne Broads (Agency, Geoff Phillips)

5 OTHER ORGANISATIONS

Other conservation bodies with an interest in the study area include the County Wildlife Trusts, the RSPB and Fisheries research in the Wash. EN is probably close to the Wildlife Trusts but separate discussions should be developed with RSPB who are generally well resourced and are currently promoting SPA designation for parts of Breckland, particularly near Lakenheath.

Stuart Sutton
17.05.99

Issue 2 revisions by

Tim Lewis
14.06.99

ANGLIAN REGION – GROUNDWATER INVESTIGATIONS
ELY OUSE AND NORTH NORFOLK SCOPING STUDY
CONSULTATION WITH ESSEX AND SUFFOLK WATER AT HANNINGFIELD
(23 April 1999)

Discussion Summary

1. PRESENT

Guillaume Stahl) Paul Saynor)	Essex & Suffolk Water
Mark Grout	Environment Agency, Peterborough
Stuart Sutton	Entec

2. BACKGROUND AND TIME SCALE

Present task is the preparation of scoping study and business case for the assessment and modelling of the water resources of the Ely-Ouse and North Norfolk/Yare North Catchment Areas. It is intended that the work is carried out in an open and collaborative way with the target being an overall quantification of the water balance in both areas which will provide an accepted framework within which local water resource allocations can be objectively addressed. From the outset it is recognised that understanding land drainage and the near surface soils and geology will be as important to the project as more traditional aspects of hydrology and hydrogeology.

The overall intended timetable is:

Complete scoping study and business case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 of Project (Data collation and analysis)	1 to 2 years
Further investigation if necessary	As required
Model Development	Probably 20001/02

3. ISSUES

3.1. Yare North/North Norfolk

Essex and Suffolk Water have 3 sets of sources in North Norfolk Area

- Boreholes on River Bure and Belauch Intake
- Abstraction at Ormesby Broad and Trinity Broad
- Abstraction at Lound Ponds and Fritton Lake

Borehole sources at Grange Farm and July Farm have not been used for the past 5 years.

No major issues concerning water quantity affect these sites although water quality and nutrient issues are of concern at the Broads and Lound Ponds. Any contribution to refinement of level calibration at Lound Pond would be welcome. The Bure system is apparently well understood and is not a priority concern.

Essex and Suffolk hold historic water level data at Lound and Ormesby offices which is available on request.

3.2 Ely Ouse Area

For this area Essex and Suffolk receive water from the Ely Ouse to Essex Transfer operated by the EA. Clarification of issues related to:

- The operation and impact of the Groundwater Development Scheme
- Release requirements to control siltation at Denver

Could provide useful contributions to transfer volumes but this is not controlled by Essex and Suffolk Water.

3.3.Other and Future Issues

The upper reaches of the Essex Stour and the interaction with the SAGS boreholes are probably the primary concern of Essex and Suffolk Water. This has been discussed with Ipswich Area Office of the EA and the possibility of bringing the Stour forward in the implementation programme for the Groundwater Strategy would be welcomed.

The lower reaches of the Stour have been modelled by Mott & McDonald for AWS and the compatibility of these models with new model development should be considered.

The issues of particular significance are:

- Flow requirements in upper parts of rivers
- Groundwater/surface water interaction
- Definition of ecological/conservation water needs

Most of Essex and Suffolk Water AMP3 work will initially focus on the Essex Rivers particularly the Stour; of lower priority is the Waveney, followed by the Bure. It is anticipated that the situation at the River Dove will become important over the next 4/5 years. The present assumption is that Dove Boreholes can be available to support the Waveney but little data is available.

Some of Redgrave data and the Menes-Worthen Pilot Holes (Southern Science) may be of relevance to the Ely-Ouse area. The cost of the Redgrave replacement source is probably of the order of £4M.

A particular general topic that Essex and Suffolk Water would like to see addressed is the linking of the source specific SRO Reports with the aquifer level yield assessment.

Essex and Suffolk Water would welcome opportunities for collaborative working with the EA but would not wish to do this on a piecemeal basis. The overall development of an integrated programme for say the Stour or the Essex Chalk Catchments would be constructive.

Stuart Sutton
27 April 1999

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING WITH MARTIN GEORGE
24 May 1999

1. PRESENT

Martin George	
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify the main issues and/or concerns held by Dr George relating to the use of water and the water environment
- Identify any sources of data/information known to Dr George

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

Main issues mentioned were:

- Climate change/global warming will probably lead to increased 'storminess' (and therefore more frequent tidal surges) and increased frequency of severe droughts.
- Small tributary streams are a vital part of the ecosystem (and are often 'overlooked' as studies tend to concentrate on larger streams/rivers): drying out for even short periods can be critical. Anecdotal evidence is that streams dry out more frequently now than in past, although there are no hard data.
- Seasonal demand for irrigation and IDB pumping: increases severity of water shortage problems (for conservation/ecological needs) in the summer. (The move to time-limited abstraction licences may help the situation, but is unlikely to be a complete solution).
- Is it possible to commission the Bure Augmentation boreholes?
- Is it possible to use IDB drains for water storage? (an increase in water level of say 6" over 45 000 acres of drained marsh represents a large storage volume)
- Thurne catchment is particularly critical: ochre problem. (Answer would seem to be to raise water levels in Brograve Level).
- Concern over flows (especially in summer) in the Bure, particularly related to Belaugh intake.
- Nutrient enrichment a problem for Broads and fens (ecologically, hydrologically and for amenity).

4.2 Data/Information

Thurne – see work by Holman and Hiscock, also Rob Driscoll

Land use changes:

- E.g. Somerton Estates: area converted to arable 1985-86. Managed to arrange pumping regime (from dykes) to avoid problems at Martham Broad
- Conversely, conversion to arable at Stokesby/Muckfleet in early 1980s caused lowering of water levels and was a 'disaster'
- There was an intention to convert all of Halvergate (main 'wilderness' area) to arable, but Grazing Marsh Conservation Scheme set up to pay farmers not to convert. Was very successful and led to establishment of Broads ESA. This stopped arable conversion BUT there is no compulsion to comply (only some financial incentive). Outbreak of BSE etc. means that farmers may be more likely to convert to arable.

Nutrient enrichment:

- East Anglian Water Company measured nitrogen levels at Horning for many years (quoted in Martin George's book)
- Fens used to be flushed with low-N water, also nutrients used to be 'taken out' by managed cropping. Now, many fens overgrown with alder (an N-fixer), they are also being flushed with high-N water and less is removed (no cropping), hence N enrichment. Phosphate levels are also elevated but this problem is relatively easily dealt with by putting phosphate strippers in sewage treatment works.
- It is important to note that **fens** as well as **Broads** are susceptible to nutrient enrichment

In general, the land is better drained than it used to be, also rivers have been straightened and dredged more ruthlessly than in the past. This has led to increased 'flashiness' of rivers in response to rainfall, although this is partly offset by increased weed growth. UEA study (1994?) looked at this. (It was noted that the Agency had some concerns over the method of hydrological analysis in this study).

Would like to see more water flushing through the Broads in summer: slower rate of flushing leads to more phytoplankton growth and increased sedimentation, with consequent higher cost of dredging and generally 'keeping the Broads in order'. (It was noted that mud-pumping operations at Barton Broad are costing around £2.8M).

Hickling Broad choked with vegetation: this affects amenity (sailing etc.) but also has safety implications for contact watersports (swimming/windsurfing). Solution **appears** to be suction dredging at a cost of several £M. Particular type of weed is suited to growth in sediment layer around 20 cm thick: it is thought that the development of this layer is directly related to reduced flushing rates.

Wensum-Yare: fewer sites so critically dependent on water quality and flushing (compared to Ant-Bure-Thurne)

4.3 Possible Benefits of the Study

Better management of water resource as a whole. Should allow scientifically defensible decisions on the allocation of water resources to optimise the delicate balance between abstraction, conservation and other environment needs.

Model would also allow investigation of what-if scenarios (climate change etc.)

Optimisation of flows into Broads: hopefully increase flushing, reduce sedimentation and weed growth, with consequent financial savings on suction pumping operations etc.

Study will include consideration of headwaters and smaller tributary streams, important to consider whole catchment.

Prepared by Tim Lewis, Entec
03.06.99

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING WITH PAUL ASHFORD

24 May 1999

1. PRESENT

Paul Ashford	
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify the main issues and/or concerns held by Mr Ashford relating to the use of water and the water environment
- Identify any sources/items of data/information known to Mr Ashford

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

Main issues mentioned were:

- Groundwater cannot be considered in isolation from surface water in resource studies
- Minimum flow requirements of many rivers in area are poorly understood
- Demand for water in Norwich will increase. It is thought likely that there may be (in future) proposals for additional supply to be obtained from boreholes on Wensum/Bure divide
- Is 'creeping derogation' occurring (i.e. is the total impact of abstraction greater than the sum of individual impacts?)
- Can river flows be supported (by groundwater) without loss/damage elsewhere?

4.2 Data/Information

Although there are abstractions from it, Wensum flows are well maintained down to near Norwich. There is scope for supporting river flows from groundwater in upper Wensum. Downstream of Norwich: flows supported by discharge from Sewage Treatment Works, which 'replaces' loss to irrigation supply further upstream.

Bure is different to Wensum: no support from treatment works.

Bure is extremely sensitive: need to maintain freshwater inflows to the tidal section.

Bure augmentation boreholes not used since testing caused subsidence of house at Saxthorpe (dewatering of a solution cavity in Chalk)

Transfer of the intake from Horning to Belaugh (because of saline incursion problems) was not ideal, but little alternative at the time.

Paul Ashford commented (to Broads Authority) on work done by UEA in 1994 on Bure, Wensum and Nar (copy of comments provided).

North Walsham Sewage Treatment Works discharge diverted from Ant to the sea resulted in quality improvement but (fairly obviously) reduction in flows.

Would expect the Bure to 'behave' differently to the Waveney because of differences in Drift cover.

Bure has higher proportion of groundwater as baseflow: groundwater support scheme therefore more difficult to optimise.

In North Norfolk, Burn Action Group are very active (Col. Pears).

Groundwater divide must be different to surface divide near Hunstanton: there are springs with very large flows, but which have very small surface catchments.

Concern that licensed groundwater abstractions in Great Ouse catchment south of Hunstanton may dry up some of these springs.

Norfolk County Council sometimes used to drill 6" holes for getting rid of road drainage (through Boulder Clay into Chalk)

4.3 Possible Benefits of the Study

There is a need for a 'water resources policy' covering the whole area. This study should form an important contribution to it.

Study should enable Agency to address the issues mentioned above (Section 4.1).

Prepared by Tim Lewis, Entec
03.06.99

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING AT KING'S LYNN CONSORTIUM OF INTERNAL DRAINAGE BOARDS

5 May 1999

1. PRESENT

Ben Hornigold Frances Lovell	King's Lynn Consortium of Internal Drainage Boards (KLCIDB)
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify the main issues and/or concerns held by KLCIDB relating to the use of water and the water environment
- Identify any sources of data/information held by, or known to, KLCIDB

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 *Issues & Concerns*

Issues/concerns were not discussed *per se*, but any study that aims to improve knowledge of the water environment and therefore help in management of water resources would be welcomed.

4.2 Data/Information

Various information and data sources were discussed (in no particular order):

- There are around 30 pumping stations east of Norwich. In this area, 4 IDBs have only been with the KLCIDB for a few years: before this there are few records.
- Key report is Ian Holman's work in Thurne catchment.
- The capacity of pumping stations is known, so from records of pump hours the quantities pumped can be derived. The Agency have already done some work on this. (e.g. for hydraulic models of Broads).
- Water resources study done on Halvergate by John Ash/RPA for ADAS. Was also reviewed by another consultant.
- Bacton pipeline reports for Amoco (Dave Seccombe at Agency Ipswich office should have copies of these).
- In the next 3 years, KLCIDB establishing telemetry starting with 'western group' of IDBs around King's Lynn/Wisbech. Automated rain gauges, flow and level monitors.
- In general there is more 'information' on the western group than on the IDBs further east (i.e. the 'finger' boards and those in the Broads/Halvergate).
- Use of 'grey water' is being considered for irrigation in the western IDBs.
- KLCIDB have a GIS under AutoCAD 14, although this will shortly move to AutoCAD 2000. Layers on this include:

  - Boundaries of all IDBs
  - Pumping station locations (all applicable IDBs)
  - Main Drains (all IDBs)
  - Field Boundaries (all IDBs)
  - Water control structures (not yet fully collated)
  - Locations of areas subject to Water Level Management Plans
  - Borehole positions (data from the Agency)
  - Conductivity measurements (information belongs to Broads Authority)
  - Pumping Station records (pump hours per week, on database linked to AutoCAD)
- KLCIDB happy to exchange GIS information, as long as it doesn't contravene Data Protection Act etc. There may be a need to charge for some of the information unless some exchange can be worked out.
- Most weirs within the IDB drains are essentially control structures for ESA. There is no flow information available for these structures. Water levels at these structures are measured on an *ad hoc* basis for operational needs only.
- KLCIDB welcomed the study, and would be happy to help out where possible with bits of data collection, obtain
- ing water levels, installing gauge boards etc. (obviously within reason)
- KLCIDB have no water quality data or any information on discharges from Sewage Treatment Works (available from the Agency, but information is of variable quality)
- English Nature did water quality and flora & fauna survey (2000 points) around 15 years ago, repeated last year.
- Pilot scheme to control saline intrusion at Horse Fen underway now: improvements are dramatic, but the success of such schemes is dependent on groundwater knowledge (see Clive Doarks at English Nature for report).
- KLCIDB have recently appointed a Conservation Officer (Heidi Mahon)

Other potentially useful contacts:

- Ken Buckley, used to be Clerk to Boards, engineer for Norfolk And Suffolk rivers, now retired. Lives in Norwich (01603 431829)
- Richard Powell, RSPB
- Chris Warren, Breckland District Council Land Drainage Officer (ex-NRA)

4.3 Possible Benefits of the Study

Better management of groundwater should enable better planning of use of pumping stations.

Enable quantitative assessment of the effect of reversion from arable land to 'wetter' land (English Nature/Broads Authority).

Assess some ideas on water management: e.g. the possibility of installing retention structures in some of the relatively steeply graded 'finger boards' to increase recharge through stream banks and assist wetland habitats etc.

Input to plans for control of saline intrusion.

Prepared by Tim Lewis, Entec
03.06.99

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING WITH NFU/BAWAG AT MANOR FARM, DILHAM

23 April 1999

1. PRESENT

Paul Hammett	NFU, Newmarket
James Paterson, Manor Farm, Dilham Nick Crane, Hall Farm, Upton Andrew Alston, Church Farm, Catfield John Place, Church Farm, Tunstead	Broadland Agricultural Water Abstraction Group (BAWAG)
Mark Whiteman David Seccombe	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify the main issues and/or concerns held by the NFU/BAWAG relating to the use of water and the water environment
- Identify any sources of data/information within, or known to, the NFU/BAWAG

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

BAWAG represent a large group of water abstractors (mainly spray irrigation) in North East Norfolk. They are well aware that the abstraction licensing system is under close scrutiny and review, and have previously met with Steve Dines and Paul Bradford (from the Agency, Ipswich office) and Clive Doarks (English Nature). The concerns of BAWAG are likely to be shared by similar groups and abstractors in other areas.

The following points and major concerns were raised (in no particular order):

- Many abstraction licences have been used for decades, and much capital is invested in associated infrastructure.
- A problem peculiar to East Anglia is the close proximity of SSSIs and other conservation sites to Grade 1 arable land. Elsewhere in the country there tends to be more of a 'buffer zone' between the two.
- Many crops simply **cannot** be grown without irrigation.
- Well aware of environmental needs of the area, but great concern that agriculture tends to take a 'poor second' place to conservation needs.
- Perception that there is adequate water available, but that it is poorly 'managed' (in the widest sense).

- Agriculture is a major employer in the rural areas of Norfolk: revocation of water abstraction licences would therefore have direct cost and employment implications.
- Great concern over the possible implications of the Habitats Directive.
- Time-limited licences make investment decisions very difficult (may even be easier to invest overseas where water is not as strictly regulated).
- There is a lot of water transfer out of the area to Essex and the Cambridge area, possibly to the detriment of local resources.
- A major distinction differentiating 'small' abstractors (such as BAWAG members) from 'large' abstractors (such as the water companies), is that water companies have much more flexibility in re-locating abstraction boreholes, or obtaining supplies from outside the locality. 'Small' abstractors are limited to locations within their property.
- 'burden of proof' is currently with the Agency, but the emphasis seems to be changing.
- Numerical models are never 'exact', so how will we **know** for sure what the impact of a particular abstraction will be?
- Is it feasible to supply fens with additional water from the Chalk in drought years?

4.2 Data/Information

Land use changes have been widespread since World War Two. Lack of management of wetlands has led to scrub development

Areas growing potatoes have moved westwards in last 10-15 years.

Irrigation requirements are different for supported/unsupported crops.

Water Level Management Plans (MAFF initiative, but prepared by Agency) sometimes have incorrect information in them, e.g. Upton has a discharge location marked in the wrong place.

'Excess' water from irrigation probably results in fields being back at capacity two months earlier than in the absence of irrigation.

Many farmers have wells on their property that could potentially be monitored to provide additional information. Some may be willing to undertake controlled pumping tests.

This willingness to provide additional data was gratefully acknowledged, but it was noted that the usefulness of such data would depend on the knowledge of well construction, geology etc. and could not be instantly assessed. It would also depend on the level of existing knowledge and monitoring in the area.

There was some discussion as to how the existence and state of these potential monitoring wells could be ascertained; the Agency may know about some of them from historic well surveys but it may be appropriate to issue a questionnaire (which would be co-ordinated via the NFU) during Phase 1 of the study.

4.3 Possible Benefits of the Study

By developing a quantitative understanding of the groundwater system, it is intended that a regional model could be used by the Agency to make 'fairer', science-based and defensible decisions on the allocation of water resources to optimise the delicate balance between abstraction, conservation and other environment needs. The study would thereby facilitate addressing most of the issues and concerns raised, since the majority are concerned with the **quantity** of water available at certain times of year. It must be noted that the 'optimum' allocation of water may result in a reduction in licensed quantities in some areas, but the end result should be better management of the overall water resource.

It is accepted that numerical models are not exact; the Agency explained that the model is expected to form a 'cornerstone' in available methods for adjudicating licences, but would not be 'the answer': there will still need to be consultation and liaison with abstractors.

The study should be able to assess the feasibility of supplying fens with additional water from the Chalk in dry summers, although it was noted that there may be water quality issues, since some fen habitats are sensitive to a particular 'mix' of waters.

Prepared by Tim Lewis, Entec
01.06.99

ENVIRONMENT AGENCY ANGLIAN REGION —GROUNDWATER STRATEGY IMPLEMENTATION

ELY OUSE AND NORTH NORFOLK SCOPING STUDY

CONSULTATION WITH NORFOLK COUNTY COUNCIL AT NORWICH
(17 May 1999)

Discussion Summary

1. 1 PRESENT

G King	Countryside Manager, NCC
D Housego	Soils Laboratory, NCC
H Field,	Waste Management, NCC
P Billington	Area Engineer (South), NCC
J Longhurst	Area Engineer (North), NCC
M Grout	EA, Peterborough
M Whiteman	EA, Peterborough
D Seccombe	EA, Ipswich
T Lewis	*En*tec
S Sutton	*En*tec

2. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency subdivides the Anglian Region into four aquifer basins, the largest of which, (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over a 6 to 7 year period. Each area will be systematically studied by in a number of phases. The first phase is the systematic assembly and assessment of the available data and the development of a conceptual understanding which address the main water related issues. This may be followed by a period of additional investigation (if necessary) and then by the development of a distributed regional groundwater model (probably using an 0.5 or 1 sq. km mesh which can subsequently be used to model impacts of changes in management options or predicted climate changes. This model is unlikely to address individual local issues of features directly rather it will provide a quantitative framework based on sound science within which local issues can be addressed, where necessary by the development of nested finer mesh local models.

Throughout the study of any one area it is intended to form a Project steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

The resource assessment and model will address the question of available resource, the definition of key aspects of environmental water needs must come from other sources

Following tendering Entec have been retained by the EA as their term consultants for the next five years to provide the resources necessary for the implementation of the Strategy.

Present task is the preparation of scoping study and business case for the assessment and modelling of the water resources of the Ely-Ouse and North Norfolk/Yare North Catchment Areas. It is intended that the work is carried out in an open and collaborative way with the target being an overall quantification of the water balance in both areas which will provide an accepted framework within which local water resource allocations can be objectively addressed. From the outset it is recognised that understanding land drainage and the near surface soils and geology will be as important to the project as more traditional aspects of hydrology and hydrogeology.

The overall intended timetable is:

Complete scoping study and business case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 of Project (Data collation and analysis)	1 to 2 years
Further investigation if necessary	As required
Model Development	Probably 2001/02

3 ISSUES

From the NCC perspective the three generic issues are:

Environmental concerns arising from the impact of abstraction on water supported habitats and the environment

Uncertainty of the water resource quantity and the potential impact on development as outlined in the County Structure Plan (61000 new houses by 2011: Copy of Plan obtained)

Uncertainty as to long term impact of climate change

Understanding of groundwater flow regime could contribute to landfill risk assessment.

The response to the proposed Projects was positive particular in that they should provide a quantification of the regional water balance and ultimately distributed groundwater model making best scientific use of the information available.

NCC are involved (jointly with English Nature) in a European funded (through Inter Reg 2C) wetland enhancement scheme directed at river restoration in the Waveney and Little Ouse Catchments. This will be based on ecological assessment and is presently at the pilot stage with the objective of identifying pilot projects (eg meander reinstatement) by June/July 1999. Further data assembly will take place during 2000 possibly for main project implementation in 2001. A quantitative water resource (ground and surface) could contribute to this effort.

4 RELEVANT INFORMATION HELD BY NCC

4.1 Soils Laboratory

The lab holds records of close to 5000 site investigation boreholes drilled throughout the county, principally for roads, landfill and drainage investigations, since the mid 1960's. Water levels in some of these are monitored monthly (occasional records up to 15 years, generally shorter) and recorded as time and level (OD). All of this data is held in paper format with locations plotted on 1:10000 scale plans.

The County Geologist (M Burnstead) was unable to attend this meeting due to illness but was most familiar with the data, lab phone number is 222417.

4.2 Landfills

Groundwater level and quality data monitored at 12 sites (5 operational) and data held digitally with geological information.

Also risk assessments in progress for up to 100 closed sites. Risk Assessment reports are circulated for inspection.

NCC will attempt to provide a location plan.

4.3 Drainage

Only active pumped highway drainage is at Bacton. Most highway drainage is collected to outfall although possibility of soakaway to enhance recharge has been considered. Virtually all towns in the county operate combined storm and foul drainage although separation has been implemented at some new developments around Norwich

North Norfolk District Council at Cromer may hold records of cliff drainage schemes. (Brian Farrow)

4.4 Conservation

Locations of County Wildlife Sites is held on GIS and currently identification of water supported sites is underway.

4.5 Land Use

Formal land use data not held but reference made to 1930's and 1960's land use surveys (1987) (Coleman, Kings College). NCC hold full county coverage (at 1:10000) of colour aerial photography. A 1940's set of aerial photos is held by the County Archaeological Unit at Gressenhall Rural Life Museum, contact is Derek Edwards. A small scale 1960's set may also once have existed.

Graham King offered to ask NCC minerals section whether they have any useful information and let EA know if so.

5 CONTACTS

Liaison will be maintained through Graham King for NCC and Mark Grout for the EA.

Stuart Sutton
17.05.99

ENVIRONMENT AGENCY, ANGLIAN REGION : GROUNDWATER STRATEGY IMPLEMENTATION

NORTH NORFOLK/YARE NORTH SCOPING STUDY

SUMMARY OF CONSULTATION MEETING AT NORWICH CASTLE MUSEUM

26 April 1999

1. PRESENT

Rob Driscoll	Norwich Museum
Mark Whiteman	Environment Agency
Tim Lewis	Entec

2. PURPOSE

The main purposes of the meeting were to:

- Introduce the Environment Agency Strategy for Groundwater Investigations in the Anglian Region
- Identify the main issues and/or concerns held by Rob Driscoll relating to the use of water and the water environment
- Identify any sources of data/information held by, or known to, Rob Driscoll

3. BACKGROUND AND TIME SCALE

The Groundwater Management Strategy of the Environment Agency (the Agency) subdivides the Anglian Region into four aquifer basins, the largest of which (the East Anglian Chalk) is further subdivided into five subregions. The purpose of these subdivisions is to permit a systematic reassessment of the water resources (ground and surface) throughout the region to be carried out over the next few years.

Each area will be studied in a number of phases. Phase 1 is the systematic assembly and assessment of the available data and the development of a conceptual understanding of how the groundwater-surface water system behaves. Depending upon the findings of Phase 1, and availability of existing information, this may be followed by a period of additional field investigations and data collection (Phase 2), and then by the development of a regional groundwater model (Phase 3).

Once adequately developed, the model may be used to assess the impacts resulting from changes in water resource management (e.g. different abstraction patterns) or predicted climate changes (Phase 4). The regional model will also provide a consistent, quantitative framework, based on sound science, within which 'local' issues, such as detailed impact of abstractions on wetlands, can be assessed. This may require the development of 'nested' local models within the regional model.

Throughout the study of any one area it is intended to form a Project Steering Committee through which interested parties and stakeholders will be kept informed and invited to participate.

Following a lengthy competitive tendering procedure, Entec have been commissioned by the Agency as their term consultants to provide the resources necessary for the implementation of the Strategy.

The present task is a precursor to the Phases described above, and comprises a 'Scoping Study' and the development of a 'business case', including cost-benefit analysis, for the assessment and modelling of the water resources of the North Norfolk and Yare North Areas. (These areas are based on the Local Environment Agency Plans (LEAPs) for North Norfolk and the Broadland Rivers respectively, except that the Waveney catchment is not included in the 'Yare North', but will be studied as part of 'Yare South' at a later date).

It is intended that the work is carried out in an open and collaborative way such that issues and concerns can be dealt with from the outset, with the target being an overall quantification of the water balance which will provide an accepted framework within which local water resource allocations can be objectively assessed.

The intended timetable is:

Complete Scoping Study and Business Case	July 1999
Presentation to Environment Agency Project Appraisal Board	August 1999
Phase 1 (Data collation, analysis and interpretation)	1 to 1.5 years
Phase 2 (Further field investigations)	As required
Phase 3 (Regional Model Development)	Probably 2001/02 (depends on Phase 2)
Phase 4 (Use of model for quantitative resource management)	After Phase 3

'Local' studies may be initiated and partially developed at any time during this timescale, although they may not be incorporated into the regional model until Phase 3.

4. DISCUSSION

4.1 Issues & Concerns

Basic concern is over increasing salinity of water in the Broads and dykes, causing changes in flora and fauna.

4.2 Data/Information

Various data sources were mentioned

Soils and geology

- Soil Survey: database now well catalogued and computerised, can easily produce maps of borehole locations etc. (Soil Survey tend to work with shallow boreholes on 300m grid). Surveyed all peat in Broadland. Soil memoir for Halvergate Marshes exists.
- BGS memoir for Great Yarmouth Geological map sheet (162) is good source of information
- There is now a reasonable understanding of the stratigraphy of alluvial filled valleys. Away from valleys, knowledge is less good. Some shallow boreholes drilled for anti-aircraft emplacements.
- 1:25K soils maps/descriptions available for TM49, TG40, TG31, TG14 and TG11

Land Use

- 1983 paper by Driscoll (provided): review of previous land use surveys
- Broads Authority have land use maps, but don't have the 'data behind the maps'
- Current MSc student at UEA looking at changes in land use on Catfield Fen 1982-1995
- Work by Parmenter for Broads Authority (BARS 13): description of historical land use changes for each fen since 1797 (contains information on relative wetness of land, i.e. marsh/drained/agricultural etc.) Lots of anecdotal information. 158 sites looked at. Some sites include a lot of recent detail. Vegetation maps (?now on Broads Authority GIS)

- Driscoll has also published paper on land use changes in Thurne catchment from 1930s to 1973 (convenient summary of lots of information held by Rob Driscoll). Looks at total of five sub-areas within Happisburgh-Winterton and Smallburgh IDB areas. Copy of paper provided.
- Broadland land use survey in 1967, unpublished maps held by Norfolk County Council (Stuart Thompson in Planning Dept.)
- 1908 vegetation survey by Gurney. Comparison of recent information at Gurneys sites shows dramatic evidence of drying out (e.g. Honing Common)
- Away from Broads
  - river corridor surveys done by English Nature/Nature Conservancy Council
  - Complete land use survey of Britain in 1930s produced 'land utilisation' maps. Most of these for East Norfolk are available for inspection at the Museum This survey used 6 land classes. Survey 'handbook' for Norfolk available for inspection at Museum.
  - Whole country re-surveyed in 1960s, (organised by Alice Coleman) but couldn't afford to publish maps. The Museum has 'some' of these. The remainder are available for inspection at Kings College London (Land Use Research Unit, Dept. of Geography, KCL, WC2R 2LS, (01) 836 5454). This survey used 13 land classes, sub-divided into ~40.
  - In general, marsh to arable conversion from early 1970s, but stopped in early 1990s because of ESA designation of e.g. Halvergate. (Rob Driscoll offered to copy a paper summarising changes from marsh to arable)

Salinity/water levels etc.

- Old (nineteenth century) OS maps often have water levels marked in ponds and lakes
- Pallis (1911) study on salinity in dunes near Waxham: fresh water but saline underneath
- Deep drains near coast have caused increase in salinity (work by Holman)
- Chloride surveys done by Driscoll in 1974, 1983, 1997 in Thurne catchment (Happisburgh-Winteron IDB). 1997 work took 500 conductivity measurements: not written up yet, although Rob Driscoll has produced a map showing distribution
- In general: increased salinity due to deepened drainage, causes changes in flora and fauna (which can be used as an indicator): (copies of several papers provided). There has been a corresponding increase in saline-tolerant species.
- Some of these changes in flora/fauna in response to salinity can be very rapid (1 year)

4.3 Possible Benefits of the Study

Greater understanding of movement of water throughout the region should allow improvement in 'management practices'.

4.4 Papers provided

Driscoll, R.J., 1984, Changes in Land Use in the Thurne Catchment Area During the Period 1931-32 to 1973, Trans. Norfolk Norwich Nat. Soc. 26, pp282-290

Driscoll, R.J. and Z.L. Waterford, 1994, Potamogeton Acutifolius and Epiphytic Diatoms at Buckenham, Trans. Norfolk Norwich Nat. Soc. 30(1), pp80-88

Parmenter, J.M. and R.J. Driscoll, 1996, The Broadland Fen Resource Survey, 1991-1994, A Brief Summary, Trans. Norfolk Norwich Nat. Soc. 30(5), pp 564-574

Waterford, Z.L. and R.J. Driscoll, 1992, Epiphytic Diatoms in Broadland Dykes, Trans. Norfolk Norwich Nat. Soc. 29(3), pp 199-216

Driscoll, R.J., undated, Changes in the Dyke Vegetation at Oby, published in ?, pp 289-296

Driscoll, R.J., 1986, Changes in Land Management in the Thurne Catchment Area, Norfolk, between 1973 and 1983 and their Effects on the Dyke Flora and Fauna, Proceedings EWRS/AAB 7th Symposium on Aquatic Weeds

Prepared by Tim Lewis, Entec
01.06.99

→ copy Tim Lewis,
Entec

NORFOLK WILDLIFE TRUST
72 Cathedral Close, Norwich, Norfolk NR1 4DF Tel: (01603) 625540 Fax: (01603) 630593

Mr M.Whiteman
Environment Agency
Kingfisher House
Goldhay Way
Orton Goldhay
PETERBOROUGH
PE2 5ZR

Your Ref: MW/657/1/1/3

ENVIRONMENT AGENCY
ANGLIAN REGION
20 MAY 1999

18 May 1999

Dear Mark

Groundwater Investigations and Modelling Review of the Groundwater Resources of the Yare (North) and North Norfolk Catchments

Many thanks for your recent letter outlining the above-proposed project. We certainly welcome any efforts to better understand water availability in an area that contains as it does so many important water-dependent nature conservation sites.

In your letter you asked for our comments on what we felt were the important issues within the study area that the Agency should be addressing. We have attempted to identify these in the paragraphs below:

There needs to be a proper understanding of the groundwater supply needs of wetland sites and rivers. The first concern here is obviously the internationally and nationally important designated sites. However, frequently overlooked are the sites of regional or county importance such as the County Wildlife Sites in Norfolk. Greater emphasis is being put on such sites in the 'wider countryside' through documents such as the Habitats Directive (Article 10) and the recent Government consultation document on SSSIs. Given the number of such sites in the study area it is difficult to see how they could be integrated individually into your present investigations. However, some consideration of the needs and implications of groundwater change in the wider countryside would be welcomed, rather than focussing solely on statutory sites.

Linked to issues of water quantity and the maintenance of habitats is that of adequate groundwater supply for wetlands and rivers in order to sustain water quality objectives. This is an issue particularly in the Broads where water quality can affect rivers, broads and fen habitats. Related to this point is the matter of saline intrusion within the tidal rivers.

wildlife TRUSTS

Founded in 1926 as The Norfolk Naturalists Trust, the first Wildlife Trust

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Company limited by guarantee no. 217338 Registered Office: 72 Cathedral Close, Norwich, Norfolk NR1 4DF.

We would value some investigation of the present state of groundwater levels compared with their 'natural' state. One aspect of this is the intuitive view that due to present overall on-going groundwater abstraction there is a regional/wide-scale reduction in groundwater levels. However, we have heard it stated that is not the case. Some clarification on the present typical and worst-case behaviour of groundwater levels at the catchment scale due to currently licensed abstraction would be welcomed.

Due to the potential changes in rainfall patterns and intensity arising from presently envisaged climate change, we suggest that the effects of this on groundwater recharge and subsequent availability is investigated. The results of any modelling at the catchment scale may point towards how water availability for the environment and abstraction may change in future. Similarly it may indicate potential adaptation strategies, such as large-scale land management to enhance aquifer recharge, that could mitigate the effects of such change.

Finally, you asked about any sources of data or information that may be relevant to the study. Certainly in terms of hydrological information we collect no data, relying instead upon any work done by yourselves. Similarly in terms of ecological monitoring we have some detailed surveys (NVC) of our reserves that could be used as a baseline, but as yet no time-series data that could show any ecological effects of possible dehydration.

I hope that the above comments are of some use. If we can be of any further help please do get in touch. Otherwise we look forward to seeing how the project develops.

Yours sincerely

Peter Doktor
Conservation Officer

→ Tim Lewis, Entec

RSPB

The Royal Society for the Protection of Birds, East Anglia Office, Stalham House, 65 Thorpe Rd, Norwich, Norfolk NR1 1UD
Tel: 01603 661662 Fax: 01603 660088

ENV... AGENCY
ANGLIAN REGION NORTHERN AREA
7 - JUN 1999

Entec
- 9 JUN 1999
Project File Number
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Mark Whiteman
Senior Hydrologist
The Environment Agency
Kingfisher House
Goldhay Way
Orton Goldhay
Peterborough
Cambs
PE2 5ZR

03 June 1999

Dear Mr Whiteman,

Environment Agency Anglian Region Strategy for Groundwater Investigations and Modelling Review of the Groundwater Resources of the Yare (North) and North Norfolk Catchments.

Thank you for your letter of 27 April inviting the RSPB's input into the above project.

The most important issues the RSPB would like to see addressed by such a study are broadly as follows:

- an assessment of whether there is sufficient water within the catchment to supply internationally and nationally important wetland habitats whilst at the same time providing for domestic and agricultural needs
- what is the environmental capacity of the catchment in terms of the projected water needs for households, industry, agriculture and nature conservation?
- the Norfolk Biodiversity Action Plan sets out targets for the creation and restoration of wetland habitats within the Broads. Where are the most appropriate sites for wetland creation in terms of water supply?
- the potential impacts of climate change upon water availability for existing and future wetlands

Two of my colleagues (John Sharpe and Will Woodrow) have already spoken to Environment Agency staff (John Adams, Charles Beardall, Pauline Smith and Wendy Brooks) to discuss the potential for a joint RSPB/Environment Agency study looking at suitable areas for wetland creation and the availability of water resources in the Anglian region as a whole. It would be very useful if the two projects can complement each other and we should ensure regular communication between all involved in the projects.

Hydrological data for the RSPB's reserves in the Mid-Yare can be found in the relevant Water Level Management Plans (Lower Bure and Halvergate, Lower Yare 1st and Lower Yare 4th). We also have data on breeding waders and wintering wildfowl within the area covered by the Broads ESA which we can make available if required.

I hope these comments are useful and I look forward to seeing the results of the initial scoping study. If you would like to discuss our comments further, please do not hesitate to give me a call.

Yours sincerely,

Rob Lucking
Assistant Conservation Officer
East Anglia