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Box 12

ENVIRONMENT AGENCY

ANGLIAN REGION

EVALUATING THE IMPACT OF GROUNDWATER ABSTRACTION ON KEY CONSERVATION SITES

STAGE 1 REPORTS FOR AMP3

Project No: KA 100128

PHASE 1 REPORT

hsi in association with ECUS

Hydrogeological Services International Ltd
6 Millmead
Guildford
Surrey
GU2 5BE

Environmental Consultancy
University of Sheffield
Endcliffe Holt
343 Fulwood Road
Sheffield S10 3BQ

February 1998

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Environment Agency

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Hydrogeological Services
International Limited
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Ref: 8.174.008/ANC/snc

25 February 1998

For the attention of: Dr M Whiteman
Environment Agency - Anglian Region
Kingfisher House
Goldhay Way
Orton Goldhay
Peterborough
PE2 5ZR

Dear Mark

RE: EVALUATING THE IMPACT O
CONSERVATION SITES - STAG
PROJECT NO KA 100128 - PHA

I have pleasure in enclosing three copies of t

Yours sincerely
for Hydrogeological Services International Li

A N Charalambous
Director

Enc.

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THE IMPORTANCE OF GROUNDWATER TO FEN SITES AND VEGETATION

PRE-AMBLE TO PHASE 1 EVALUATION REPORT

1. GENERAL

1.1 The present report concerns the first phase (Phase 1) of the Project on "Evaluating the Impact of Groundwater Abstraction on Key Conservation Sites" of 20 candidate wetland sites in East Anglia, the overall purpose of which is to form the basis of business cases for AMP3 submissions.

1.2 Generic costings for monitoring and investigation, and where appropriate alleviation works have already been agreed upon between the Agency and water companies, and these have been submitted to Ofwat for consideration. The present report, draft copies of which were sent to the Agency by fax and e-mail at various times between 10 - 17 February 1998, focuses on providing in a concise and clear form, the known ecology and water resources status of each site, together with recommendations for action on monitoring, investigations, alleviation measures, and site management. In the first instance, the aim of the report has been to provide a further check on the requirements (and, therefore costings) agreed upon between the Agency and the Water Companies. The second objective was to present the Agency with a preliminary view of the Consultants' understanding of the ecology, hydrogeology and water supply of the sites, with particular reference to the likely impact of water company abstractions, in order to enable the various consultees to comment upon.

1.3 The report contains an evaluation of 19 sites, East Ruston was not included in this Phase, as a preferred option, consisting of monitoring and 'peat stripping', has already been identified. In the process of evaluating the sites, it has become apparent that a few sites, such as Hall Farm, or Great Cressingham, may not be affected by water Company abstractions, but rather by private irrigation abstractions. Therefore, the classification of sites in terms of AMP3 abstraction categories does not always seem to reflect the impact on the sites by others. This is an aspect that may need to be addressed, and a course of action will need to be advised by the Agency. At other sites, such as Burgh Common & Muckfleet Marshes, present evidence does not indicate an adverse impact but the possibility exists of such an effect, if climatic conditions were to change in the future. At yet other sites, such as Strumpshaw Fen, management practices seem to have had adverse effects on wetland water supply. Though the project is intended to evaluate the impact of groundwater abstraction, at least in two sites, Cattawade Marshes and Burgh Common & Muckfleet Marshes, or possibly three, if Strumpshaw is included, the main water supply is from surface water.

1.4 Finally, the present evaluations have been prepared on the basis of existing knowledge, information and reports, without the benefit of site visits or of a detailed scrutiny of data. In view of this, conclusions reached and recommendations made must be considered as preliminary, and in some cases tentative, but it is hoped that even at this early stage, the evaluations presented will stimulate fruitful discussions, which should provide ideas and information for inclusion in the Phase 2 detailed reports.

2. REPORT STRUCTURE

This preamble is followed by reports, individually paginated, on each of the wetland sites (East Ruston has been excluded for the reason given in paragraph 1.3). For convenience, there are two parts:

PART A: HABITATS DIRECTIVE SSSIs (SACs AND SPAs)
PART B: NON-HABITATS DIRECTIVE SSSIs

An explanation as to the meaning of "Classification Dependency Categories" and ecological terms, together with a discussion on the importance of groundwater to fen sites and vegetation, prepared by Dr D B Wheeler and Dr S Shaw of ECUS, is presented in Appendix 1, at the end of this document. The use of categories as defined by Wheeler and Shaw, promises to be a useful tool, but its use for individual sites has not yet been critically examined from a hydrogeological viewpoint.

3. ACKNOWLEDGEMENTS

The report as a whole represents the collaborative efforts of HSI and ECUS but with a large measure of assistance and support from Dr M Whiteman of the Environment Agency, Dr S Rothera of English Nature, Mr D Harker of AWS and Ms M Elliot of ESWC. Without their help, it would not have been possible to prepare this work in such a short time.

GLOSSARY

AWS: Anglian Water Services
CWC: Cambridge Water Company
ESWC: Essex & Suffolk Water Company
EN: English Nature
PS: Public Supply

PART A

HABITATS DIRECTIVE SSSIs (SACs and SPAs)

Catfield Fen

Booton Common

Burgh Common & Muckfleet Marshes

Coston Fen

East Wretham Heath

Fouldon Common

Great Cressingham Fen

Hall Farm Fen, Hemsby

Sheringham & Beeston Regis

Stanford Training Area

Yare Borads & Marshes (Strumpshaw)

SITE: CATFIELD FEN

NGR: TG 3620 2130 **AREA: 50 ha (123.6 acres)**

1. DESCRIPTION OF SITE

The site lies within the Ant Valley, to the east of Barton Broad. In terms of its vegetation, this is arguably the single most important site in Broadland. Particular interest attaches to the (deteriorating) 'fine-leaved sedge–brown moss communities' (the *Peucedano-Phragmitetum caricetosum* of Wheeler (1980a) (no *NVC* equivalent – apparently not included) which contain internationally rare species, and some *Sphagnum*-rich areas. Much of the rest of the vegetation is not particularly special, but a notable feature of Catfield is the wide range of vegetation-types which occur, which make this site a mesocosm of the variation of Broadland fen vegetation.

The site lies within the Ant Broads and Marshes SSSI, and is included in The Broads SAC and Broadland Ramsar site and SPA.

2. ECOLOGY

2.1 CONSERVATION INTEREST

EN consider the main wildlife interest of the 'site' to be the *Phragmites australis–Peucedanum palustre* fen (S24) and *Cladium mariscus* sedge swamp (S2), and the base-rich aquatic dyke system supporting the nationally-rare plant species *Stratiotes aloides* and *Potamogeton coloratus*. The site supports two red data book plant species, *Dryopteris cristata* and *Cinclidium stygium*, and many RDB invertebrates, including swallowtail butterfly (*Papilio machaon*). *Dryopteris cristata* is also listed on the UK Biodiversity Action Plan (BAP) "long list of globally threatened or declining species".

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

SPA objective

- Increase the internationally important populations of breeding bittern and marsh harrier. The breeding bittern will only return to the Ant valley following improvements to the habitat and water quality. The EN and BA are currently undertaking a programme of habitat improvement on the fen.

SAC objectives

- Increase the extent of, and enhance the condition of the internationally important chalk-rich fen dominated by saw sedge (great fen sedge). This objective refers to *Cladium mariscus* sedge swamp (S2), *Phragmites australis–Peucedanum palustre* fen (S24) and *Juncus subnodulosus–Cirsium palustre* fen meadow (M22) vegetation types. Many areas that have been extensively peat cut in the past. Issues relate not only to summer drought, but also evidence of reducing base status, for Catfield Fen is now thought to be more rain fed than in the past. Note the presence of the rare moss *Cinclidium stygium*.

- Enhance the condition of the internationally important naturally nutrient rich lakes and dykes which are often dominated by pondweeds. This objective refers to water bodies both within the Catfield Fen and Sharpe Street sections, and includes invertebrate interest. The drastic reduction and loss of the Water Soldier *Stratiotes aloides* community since the 1970s has been noted within the dyke system (Mr K McDougall). Water quality and base status are both relevant with regards to this objective.

- Increase the extent and enhance the condition of the internationally important 'very wet mires often identified by an unstable quaking surface'.

- Maintain the internationally-important 'alder woodland on floodplains'.

- Maintain internationally important populations of Desmoulins snail.

<u>Ramsar features</u>

- Criterion 1a; many good and representative examples of wetland habitats characteristic of the biogeographic region. EN contend that this project would improve the quality of the wetland.

- Criterion 2a; supports an outstanding assemblages of rare plants and invertebrates. Within the Broads site, this includes 9 RDB plants, including *Dryopteris cristata* and *Cinclidium stygium*, both species present at Catfield, and 136 RDB invertebrates.

- Criterion 3c; recognises a number of bird species, which include the bittern and marsh harrier, as the SPA feature/objective.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

This site has shown a considerable vegetation change, much of which is related to the management practices of abandonment and reinstatement.

The base-impoverishment referred to in the EN Objectives primarily relates to the parts of the fen separated from the river by a peat rond (the 'Commissioner's rond'). It is most likely that this relates to the cessation of appreciable ingress of river water created by the rond. [Note that this acidification is different to the development of *Sphagnum* nuclei, which can occur almost anywhere in the fens and is largely independent of the base-richness of the underlying water. The loss of aquatics (*e.g. Stratiotes aloides*) from some fen dykes may also be a product of a reduction of base-status and nutrient status (some formerly rich areas have been largely replaced with oligotrophent *Utricularia* communities).]

There has been an apparent deterioration in floristic quality of the important *P.-P. caricetosum* communities (e.g. loss of *Scorpidium scorpioides*). In one site there has been expansion of *Sphagnum* (which appears to be a natural, ontogenic process); in another there has been a considerable loss of some characteristic plants coupled with an expansion of less desirable species (*e.g. Calliergon cuspidatum* has expanded at the expense of 'brown mosses'). The reason for this is not known. It may relate to on-going terrestrialisation, but another possibility is that, as this site appears to receive some river water inputs, there may be slow, but pervasive nutrient enrichment.

3. WATER RESOURCES

3.1 HYDROLOGY

The wetland consists of marshland containing ponds and areas of open water, of which many are remnants of shallow 19th Century excavations into peat.

It is bordered to the west by the tidal River Ant and Barton Broad. Drainage comprises a large number of dykes cut into peat. A peat wall (or rond) divides the Fen into a western part (external system) and an eastern part (internal system). The two are connected via a sluice. The western part is adjacent to and connected with the River Ant.

3.2 HYDROGEOLOGY

The hydrogeology beneath the site comprises:

- A near surface (0 - 6 mbgl) PHREATIC PEAT AQUIFER/AQUITARD which is hydraulically connected with the surface water bodies above. The lower undisturbed layers of peat are of low permeability and could, therefore, act as an aquitard impeding flow from or into the water-bearing strata below. Water levels are close to ground surface (0 - 0.6 mbgl) with no prevalent direction of groundwater flow. Water levels fluctuate seasonally.

- A thin (0.5 - 1 m in thickness) CLAY AQUITARD which underlies the peat aquifer, except locally where "clay windows" exist. Where it occurs, it acts as the basal aquitard to the peat and the semi-confining aquitard to the Crag aquifer above it. Its hydraulic significance is in impeding flow of water either upwards or downwards, depending on the relative water levels in the peat and Crag.

- The CRAG UNCONFINED - SEMICONFINED SAND AQUIFER. It is multi-layered (sands interbedded with clays). Water levels are 0.5 - 1.0 mbgl, fluctuate seasonally, and generally below peat water levels. The direction of groundwater flow is southwestward to the Fen. The Crag is of local importance as a source of water for irrigation, public supply and by the Agency for maintaining a fish refuge in Catfield dyke (proposed).

- The LONDON CLAY AQUICLUDE (40 - 50 mbgl). It acts as the basal aquiclude to the Crag aquifer and the confining aquiclude to the Upper Chalk aquifer below. It wedges out approximately 500 m west of the fen.

- The UPPER CHALK AQUIFER (>50 mbgl). It is confined by the London Clay aquiclude. Water levels are 1 - 2 mbgl. The Chalk is a major regional aquifer but is not exploited in the vicinity of the wetland, due to poor water quality. Groundwater flow from the Crag to the Chalk and vice versa is considered to be negligible.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water comprising rainfall and flood waters from the River Ant/Barton Broad are the main source of water to the wetland.

Groundwater contributions are small and are mainly from the Crag sand aquifer.

Estimates by various workers of inflows to the wetland suggest:
- Rainfall 65 - 82 % of total inflow
- Runoff 5 - 6 % of total inflow
- Groundwater 15 - 31% of total inflow

The estimates of groundwater inflow are probably high.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Categories: 1 or 2

There is no reason to suppose that any of the vegetation present on this site (including the valued *Peucedano-Phragmitetum caricetosum*) *requires* groundwater input, nor that there is any more than small, peripheral inputs of groundwater. The *P.-P. caricetosum* is restricted to turf ponds and is a characteristic rheo-topogenous community with a requirement for fairly base-rich water. At present, it seems most probable that the supply of base-rich water comes from dykes that directly connect the turf pond with this vegetation to Barton Broad.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: 5 no; 2 - 5 km abstractions are all very small.

Groundwater: 33 abstractions within 3 km, mainly from the Crag. The largest is operated by AWS (Grove/Ludham source at 2.69 km south; annual licence 680 tcma (21.5 l/s) and daily 273 m3/d (26.3 l/s). Proposed fish refuge supply 2.2 km southwest of the fen at 18 l/s from May to June.

4.2 IMPACT OF ABSTRACTIONS

To date, groundwater level monitoring of piezometers in the general area has not indicated any effect on the wetland water-table which can be directly attributed to existing groundwater abstractions. Seasonal changes in groundwater levels are largely in response to natural variations in rainfall.

Although the EN Objectives express concern about summer drought, there has been no evidence of a consistent decline in water tables. Experience (and measurements) over the last 25 years suggests that the site is subject to very considerable between-year and within-year variation in water tables (> 1 m), which relate to external events (rainfall, river flooding *etc.*). Nonetheless, it is possible that within individual turf ponds, ongoing terrestrialisation is likely to raise the surface of the peat mat relative to the water table and, as it thickens, decrease its capacity to respond to water level fluctuations.

Modelling by LWRC (July 1997) indicated that abstractions from the proposed fish refuge borehole and the AWS Grove/Ludham source would cause a minimal depression (a few centimetres) to the wetland water-table.

The site has been assigned an AMP3 Water Abstraction Category 2, but present preliminary evidence would suggest Category 3.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None at present.

5.1.2 Proposed Monitoring

a) Monitor acidification problems (see 5.2.2).
b) Carefully targeted vegetation monitoring of the eastern upland margin and the species-rich areas in the Great Fen. Some permanent marker posts will need to be installed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: Within the fen; 3 gaugeboards measuring dyke water levels.

Outside the fen; continuous water levels at Weyford bridge (upstream of Barton Broad). Fortnightly measurements at Barton Broad, Irstead.

Groundwater: Within the fen; 4 piezometers in peat, superficials and Crag (Note: two at the northern boundary and two at150 m south of the southern boundary).

Outside the site; 6 piezometers northeast of the Fen (200 - 2000 m). 4 piezometers (Amoco) east-northeast of the Fen (1 - 2 km).

5.2.2 Proposed Monitoring

Surface water: Regular (monthly) monitoring of pH and EC in a few selected locations within the fen to address the potential problem of acidification.

Groundwater: Three piezometers in one cluster are proposed to monitor the impact of the AWS Grove/Ludham Source at approximately 300 m northwest of the source at TG 3825 2010; 1 piezometer to 50 - 60 m to monitor deep Crag water levels; a second adjacent piezometer to approximately 30 m depth to monitor water levels in the middle of the Crag; and a third adjacent piezometer to approximately 10 m depth to monitor shallow water levels in the Crag.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

None proposed. Baseline survey information is considered to be adequate.

6.2.2 Hydrology

a) Investigation of water quality gradients with reference to river water penetration into the fen, particularly with regard to eutrophication issues.
b) Utilise AWS Grove/Ludham source to carry out controlled (90 day) pumping test which will use existing and proposed piezometers for monitoring; analysis and evaluation of data.

6.3 ALLEVIATION MEASURES

None proposed at present.

6.4 SITE MANAGEMENT

On-going vegetation management is required.

SITE: BOOTON CARR & COMMON

NGR: TG 113 320 **AREA: 7.7 ha (19.1 acres)**

1. DESCRIPTION OF SITE

Booton Common is an elongated mire developed on a narrow seepage slope above a small tributary stream of the River Wensum, approximately 1.5 km east of Reepham. The valley axis runs in a south-west to north-east direction and higher ground rises normal to this.

The stream is flanked by carr, with drier woodland at the top of the slope. Herbaceous fen (prone to considerable scrub invasion) is sandwiched between these. The ground is strongly undulating, with much fen meadow, *Schoeno-Juncetum* {~M13} in strongly flushed areas, small patches of Acrocladio-Caricetum {~M9} in sumps and heathy *Molinia* grassland on drier areas and peat ridges.

The site is a Norfolk Wildlife Trust Reserve

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and included within the Norfolk Valley Fens SAC, for which the notified interest is "calcium rich spring water fed fens", here represented by the *Schoenus nigricans–Juncus subnodulosus* mire (M13) and *Carex rostrata–Calliergon cuspidatum* mire (M9) community.

The key feature of importance at this site is M13 vegetation. There is only a small amount of this, but it is of good quality and, despite its small size and vulnerability to scrub invasion, it has maintained many of the species present in early records. There is also a small area of low-grade M9 vegetation, possibly over an old peat cutting. The Consultants consider that it is not the best Norfolk valleyhead fen, but good.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain open fen area.
2. Control the development of carr woodland.
3. Maintain the high water table including seepage flows.
4. Enhance the condition of the mire communities.

There is a further international objective, as follows:

1. Enhance the condition of the internationally important calcium rich spring water fed fens (M9, M13).

2.3 EVIDENCE OF ECOLOGICAL CHANGE

At one time this site was grossly overgrown, but there is little evidence for deterioration of the M13 vegetation (it was fortuitously 'saved' by construction of an electricity line). The M9 community is small and of poor-quality, for reasons that have not been established. Although the site is now well managed and retains much floristic interest, there have been some species losses, with suggested a problem of dehydration, although there is no clear evidence for this.

3. WATER RESOURCES

3.1 HYDROLOGY

The northern boundary of the site is defined by a stream, a small tributary to the River Wensum. A number of ditches, including one at its southern boundary, drain into the stream.

3.2 HYDROGEOLOGY

The hydrogeology beneath the site comprises:

- A near surface (1 - 3 mbgl) PHREATIC PEAT AND SAND AQUIFER which is perched on a drift clay - silt aquitard. Water levels are close to the ground surface (0.1 - 0.2 mbgl) and where topography is low just above it, resulting in seepages.
- DRIFT CLAY SILT AQUITARD (20 - 25 m in thickness) which acts as the semi-confining aquitard to the Sand and Gravel aquifer below. The aquitard contains sand/gravel layers which are semi-confined by interbedded clays. Water levels in the aquitard are above ground levels (about 0.2 magl).
- The SAND AND GRAVEL SEMI-CONFINED AQUIFER (20 - 25 m in thickness) which is in hydraulic continuity with underlying Chalk aquifer. Immediately, beneath the site, approximately 7 m of clay/chalky clay directly overlies the Chalk and locally impedes upward flow from the Chalk into the Sand and Gravel. Water levels are approximately 0.5 magl (artesian flowing); thus the vertical component of groundwater flow is upward into the aquitard above it.
- The UPPER CHALK SEMI-CONFINED AQUIFER is in hydraulic continuity with the Sand and Gravel above it. The wetland is in a buried channel such that the Chalk is at a depth of approximately 47 mbgl (-21 m OD); a short distance from the wetland the Chalk is much shallower at 0 m OD or higher. The water level is approximately 2 m above ground surface (artesian flowing), and thus about 1.5 m higher than that in the Sand and Gravel. The vertical component of groundwater flow is upward into the Sand and Gravel, and ultimately into the Drift aquitard and phreatic peat/sand aquifer. Horizontal groundwater flow is southwestward, but it locally converges into the tributary valley where the wetland is situated. Water levels from boreholes at 3 - 4 km from the wetland fluctuate seasonally at about 1 m; they have steadily fallen during the recent periods of low rainfall (1989 - 1992 and post 1996) by 1 - 2 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water comprises rainfall and generated runoff. The steam which runs along the northern boundary does ~~to~~ not appear to contribute to the wetland.

Groundwater is the main source of water to the wetland. It comprises seepages which are primarily fed by upward flow from the artesian Chalk and Sand & Gravel aquifer beneath the site.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4

The sloping character of this site means that all of its fen vegetation is dependent upon soligenous inputs. The M13 stand is critically dependent upon groundwater inputs which almost certainly includes a substantial calcium rich water component. Although the M9 community is not, of necessity, dependent on soligenous inputs, the small stand at this site is probably dependent on these.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Licensed abstractions within 3 km are from the tributary stream and River Aisne.

Groundwater: There are 19 licensed abstractions within a 3 km radius. There is a small abstraction (0.5 tcma) just outside the wetland. At a distance greater than 1 km from the site, all abstractions are small (less than 5 tcma) except for the AWS Cawston source which is situated 1.7 - 1.8 km northeast of the wetland. It is licensed to abstract for public supply at 620 tcma (19.7 l/s) and daily, 2500 m^3/d (28.9 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstraction from the stream is not considered to impact on the wetland.

Despite the recent drought, existing groundwater abstractions do not seem to have caused groundwater levels to fall below the ground surface. Seepages from the underlying artesian Sand & Gravel and Chalk aquifers appear to have been maintained. Thus, the impact of existing abstractions on the wetland hydrology does not appear to have been significant. There is, however, anecdotal evidence that the site may now be drier than in the past.

The site has been assigned an AMP3 Water Abstraction Category 3. The present preliminary evaluation agrees with this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

There appears to be no routine periodic monitoring of the site. However, a baseline survey has been carried out. (NVC vegetation survey, Smart, 1993)

5.1.2 Proposed Monitoring

A carefully targeted periodic (annual) monitoring of vegetation in the potentially most sensitive areas is proposed. Installation of some permanent marker posts.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None.

Groundwater: There are 5 piezometers within the wetland: 3 shallow piezometers in drift; one in sand; and one deep in Chalk. All piezometers are within the fen.

5.2.2 Proposed Monitoring

Surface water: None is proposed.

Groundwater: Within the fen; none is proposed.

Outside the fen; 4 piezometers are proposed. 2 approximately mid-way between the Cawston PWS and the wetland at approximately TG 1200 2360 and 2 close to the PWS at approximately TG 1250 2410. At each location, one of the piezometers should penetrate the Chalk (approximate depth 50 m) and the other the Drift (approximate depth 15 m). The proposed piezometers are intended to act: a) as long term monitoring points; and b) as observation boreholes during the proposed pump-test (see 6.2.2).

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

No investigation is proposed.

6.2.2 Hydrology

Controlled long duration (90 day) pumping test using the AWS PS source at Cawston and the proposed and existing boreholes for water level measurements. The objective is to establish the extent of the cone of depression, aquifer behaviour and impact of PS on the wetland.

6.3 ALLEVIATION MEASURES

To await the results of investigations.

6.4 SITE MANAGEMENT

An on-going vegetation management is required.

SITE: BURGH COMMON AND MUCK FLEET MARSHES

NGR: TG 440 117 **AREA: 118 ha (291.6 acres)**

1. DESCRIPTION OF SITE

An extensive floodplain fen alongside the Muck Fleet, distinguished from most Broadland sites in that much of the site is regularly managed by grazing. Grazed areas are mainly relatively species-rich wet grassland/fen meadow, providing the most extensive development of this type of vegetation in Broadland, while wetter, ungrazed parts are dominated by common reed (*Phragmites australis*) with some alder/willow carr. The reedbeds have been invaded by scrub, although there have been some recent attempts at clearance. Beds of saw sedge (*Cladium mariscus*) also occur, possibly in old peat cuttings - there has also been some management of these areas in recent years (*Parmenter, 1995*).

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and lies within The Broads SAC, and Broadland SPA and Ramsar site. The site supports a range of nationally-uncommon fen plant species, including *Carex appropinquata, Sium latifolim, Cicuta virosa, Ranunculus lingua, Dactylorhiza incarnata* var. *ochroleucra*, together with rare birds and invertebrates (15 RDB invertebrates are recorded for Burgh Common/Muckfleet Marshes, including *Segmentina nitida* and the swallowtail butterfly *Papilio machaon*).
BDW Assessment:

Burgh Common is a species rich area of Broadland fen, though lacking some of the rarest plant species of these mires[1]. The diversity of this site doubtless partly stems both from the range of habitats present (hydroseral and non-hydroseral) and from the fact that some of the area is part grazed, which has produced a large area of the Broadland form of M22 fen meadow - probably the best example in Broadland - and, nearer the margins, a zone of *Cirsio-Molinietum*, again better developed than many Broadland examples. The nationally endangered species *Dactylorhiza incarnata ochroleucha* has been reported from this fen, but every apparent example of this taxon, examined by Dr Wheeler, at Burgh Common has turned out to be the more common albino form of *D. incarnata incarnata*. Therefore, there is uncertainty about the precise status of var. *ochroleucha* here. Nonetheless, this is undoubtedly an important site.

The adjoining Filby Broad has a narrow, and rather undistinguished, hydroseral fringe. In the past, a narrow slope adjoining the northern edge of the Broad supported a species-rich fen meadow community with some *Sphagnum*, but this seems to have been lost beneath a burgeoning canopy of megaforbs.

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[1] The absence of fine-leaved sedge - brown moss communities from this site, and their associated rare plant species such as fen orchid, has always been rather puzzling, as in terms of its location this would seem to be a highly appropriate site for such vegetation and species. The reasons for this absence can only be conjectured, but the two most likely possibilities are (a) the absence (or scarcity) of suitable, shallow turf ponds; and (b) the prevalence of grazing as a management regime.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

SPA objective

- Increase the internationally important populations of breeding bittern and marsh harrier. ~~[This objective applies to the whole Broadland SPA]~~

SAC objectives

- Increase the extent of, and enhance the condition of the internationally important chalk-rich fen dominated by saw sedge (great fen sedge). This objective refers to M22 and S24 vegetation types. Evidence exists of peat cutting in the past (Driscoll & Parmenter 1997 study).
- Enhance the condition of the internationally important "naturally nutrient rich lakes and dykes which are often dominated by pondweeds". This objective refers to water bodies and dykes within Burgh Common. Invertebrate interest is also included within this objective.
- Maintain the internationally important alder woodland on floodplain

Ramsar features

- Criterion 1a; many good and representative examples of wetland habitats characteristic of the biogeographic region.
- Criterion 2a; supports an outstanding assemblages of rare plants and invertebrates. Within the Broads site, this includes 9 RDB plants and 136 RDB invertebrates. 15 RDB invertebrates are recorded for Burgh Common/Muckfleet Marshes.
- Criterion 3c; recognises a number of bird species which include the bittern and marsh harrier, as the SPA feature/objective.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

In the experience of the Consultants, Burgh Common has shown considerable stability for the last 25 years, with differences mainly relating to the intensity and extent of grazing. However, there is evidence of species loss along the north edge of Filby Broad, but the reason for this is unclear. There is anecdotal evidence of drying of the ditches, with presumed adverse impacts on the aquatic flora and fauna.

3. WATER RESOURCES

3.1 HYDROLOGY

The site lies to the southwest of Filby Broad, which is drained by Muck Fleet, a stream drain that runs through the site to discharge into the River Bure, approximately 2 km south. A sluice regulates flow at the confluence with the Yare. The site is characterised by marshland and open water (Little Broad) drained by numerous dykes. Muck Fleet forms the southwestern and southeastern boundaries of the site; the southern boundary is defined by the New Muck Fleet drain. Drains also mark the western half of the northern boundary. In the east, the site extends into the lowermost reaches of Filby Broad. Filby Broad is part of the more extensive Ormesby Broad, which extends 3 - 4 km northwards, approximately 1 km, southwest of Hall Farm, Hemsby. The Ormesby

Broad, including Filby Broad, down to the southwestern end of the site, has a catchment area of approximately 35 km^2. The Broads cover an area of approximately 1.7 km^2 and Filby Broad 0.4 km^2.

3.2 HYDROGEOLOGY

The hydrogeology of the wetland is little known. Regional information suggests the following hydrogeological units:

- A PHREATIC ALLUVIAL AQUITARD probably consisting of marshland deposits (peats and organic clays) with sand layers. Its thickness is not known, and would depend on whether the Broads and marshland are situated in old valleys which have been infilled by recent sediments. Water levels are suspected to be 1 - 3 m below surface, ie at or below sea level. They are most likely controlled by the dykes (and Muck Fleet) which act as drains to the aquitard, maintaining water levels below the ground surface.

- The SEMI-CONFINED CRAG SAND AQUIFER (30 - 40 m thick) underlies the alluvial deposits, the latter acting as the semi-confining aquitard. Hydraulic continuity between the two would be dependent on the lithological nature and thickness of the alluvial deposits, and differential hydraulic heads. The direction of the regional groundwater flow in the Crag is probably southwestward, that is from the higher ground in the northeast where water levels are at 1 - 2 maOD, to possibly 0 m OD in the wetland area. Whether the Crag aquifer together with the overlying alluvial aquitard feed the Broads and the wetland is not known. However, as they both lie in depressions surrounded by higher ground and presumably higher water-tables, groundwater seepages into the Broads must occur.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water in the form of rainfall and runoff are the main sources of water to the site. Ormesby Broad and Filby Broad feed into the Muck Fleet. Tidal flooding by the River Yare may also inundate the wetland from time to time.

Groundwater stored in the alluvials and underlying Crag is probably of indirect importance in two ways: firstly, it sustains, through seepages, the flows of the secondary drains (or dykes), and secondly, in a more regional context, it provides water to the Broads and wetland by lateral flow, and possibly by upward flow. The role of groundwater may become significant during extended severe droughts, or as a result of rising temperatures (and lower summer rainfall) due to global climate changes in the future.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 2 (3)?

None of the fen vegetation present at this site has a critical requirement for groundwater supply, but it is possible that in parts of this site groundwater discharge is at least locally important for the occurrence of wetland vegetation. If this applies at all (and little is known about the hydrodynamics of this site) it is most likely to apply to narrow stands of fen meadow and *Cirsio-Molinietum* at the northern margin of the fen, where there appear to be some thin 'seepage slopes', bordering the edge of the main topogenous fen. However, it is not clear if these slopes are fed by groundwater or by surface runoff.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the site there are 8 licensed surface water abstractions from the River Bure, dykes, Ormesby Broad and seepage lagoons. All except that by ESWC are small, less than 200 tcma (6.3 l/s) and are used for irrigation or for antifrost.

ESWC is licensed to abstract for public supply 36300 m^3/d (420 l/s) from the east bank of Ormesby Broad, situated at approximately 3.8 km NE of the site.

Groundwater: Within 5 km from the site, but none in close proximity, there are 23 licensed abstractions, all for irrigation/domestic and antifrost purposes. The largest is 150 tcma (4.75 l/s) but most are at less than 20 tcma (0.6 l/s).

There are no groundwater abstractions for public supply.

4.2 IMPACT OF ABSTRACTIONS

The impact of surface water abstractions from Ormesby Broad by ESWC on the hydrological and hydrogeological regimes is not known. Anecdotal evidence suggests that water-tables are high and the drains and Muck Fleet contain clear flowing water, low in nutrients.

The existing scanty information does not indicate an impact on the water-table as a result of abstractions from the Crag aquifer and overlying water-bearing strata. Groundwater levels are probably controlled by the draining effect of the dyke system. However, there may be an impact due to abstractions within the catchment on the general hydrological system, which may under severe climatic conditions of low rainfall and high temperatures, become significant.

The site has been assigned an AMP3 Water Abstraction Category 3. This preliminary evaluation confirms this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

Not known at present.

5.1.2 Proposed Monitoring

Carefully targeted monitoring of the vegetation communities along the fen margin, and of the invertebrates and vegetation in the dykes would provide useful supporting information. Some permanent marker posts will need to be installed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None known within the wetland.

Outside the wetland, there are staff gauges at Hall Farm (see report on Hall Farm).

Groundwater: None known within the wetland.

Outside the wetland: Observation boreholes are monitored at Hall Farm (see Hall Farm report). Also as part of the Amoco proposed pipeline study, HSI monitor monthly 5 boreholes in Crag/Corton Formation, 200 m north and 1.5 km east of Ormesby Broad.

5.2.2 Proposed Monitoring

Surface water: (It is assumed that none exist.)

a) 6 staff gauges at the banks of Ormesby/Filby Broad.
b) 4 staff gauges along the length of Muck Fleet.
c) 6 staff gauges in various dykes.
d) If appropriate, 2 gauging stations where the Muck Fleet enters and where it exits the wetland.
e) EC, pH monthly monitoring of surface waters, near the staff gauge installations; major ionic chemical analyses including nutrients (nitrogen and phosphorus), iron and manganese.

Groundwater:

a) 24 regional piezometers in the Crag/superficials at 12 sites (clusters of 2; one piezometer in superficials and a deeper one (10 - 15 m) in Crag) placed at strategic locations in and around the Broads and wetland.
b) 12 piezometers in the wetland, in the Crag/superficials, in clusters comprising 1 or 2 piezometers penetrating superficial deposits, and 1 piezometer penetrating the Crag (5 - 25 m deep).
c) EC, pH, six monthly monitoring including chemical analyses as described for surface water.

These proposals are made in the context of obtaining an understanding of the hydrology, groundwater conditions and hydrochemistry of the wetland and surrounding areas, which may be useful in overcoming future adverse climatic changes.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

None proposed; the present baseline ecological information is considered to be adequate, (Parmenter, 1995).

6.2.2 Hydrology

The following are proposed:

a) Review of all existing hydrological data, including rainfall and runoff, to arrive at a preliminary estimate of surface water inputs into the Broad, and their temporal and spatial variation.
b) A field survey of dykes and surface water features to establish baseline hydrochemistry, water levels and detailed monitoring requirements.
c) Scoping report of findings.
d) Evaluation of all hydrological, hydrogeological and hydrochemical data in order to obtain a better understanding of the baseline conditions with regard to the surface and groundwater regimes, their interaction and hydrochemical relationships (after the installation of monitoring structures). Preparation of report.
e) Continued monitoring for 5 years within annual interpretational evaluations.

Note: Computer modelling to await report (item d)). If it is found to be required, re-calibration and updating will need to be considered at yearly intervals.

6.3 ALLEVIATION MEASURES

To await the results of the baseline study report (item d)); it is assumed that the carrying out of items a) to e) will be of approximately 6 months duration.

6.4 SITE MANAGEMENT

On-going vegetation management is required.

SITE: COSTON FEN

NGR: TG 062 066 **AREA: 7.3 ha (18.04 acres)**

1. DESCRIPTION OF SITE

Coston Fen SSSI is situated in the upper to middle reaches of the Yare Valley approximately 1 km south-east of Runhall, Norfolk. The fen lies on the northern slope of the valley and its southern boundary is marked by the River Yare. The site includes an area of marshy grassland with relatively extensive base-rich flushes developed below seepages, separated from the River Yare by improved grassland.

2. ECOLOGY

2.1 CONSERVATION INTEREST

English Nature (EN) consider the main wildlife interest on the site to reside in the fen communities: *Schoenus nigricans–Juncus subnodulosus* mire (M13), *Juncus subnodulosus–Cirsium palustre* fen meadow (M22), and *Molinia caerulea–Cirsium dissectum* fen meadow (M24).

The site is an SSSI, and included within the Norfolk Valley Fens SAC, for which the notified interest is "calcium-rich spring water fed fens", here represented by the *Schoenus nigricans–Juncus subnodulosus* mire (M13). It is an example of rather degraded M13 vegetation, probably amenable to enhancement/restoration.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain, and enhance the condition of the internationally important calcium-rich spring water fed fens (M13).
2. Maintain the nationally rare and internationally important, M13b calcareous mire communities (*Schoenus nigricans–Juncus subnodulosus* mire; *Briza media–Pinguicula vulgaris* sub community) by grazing management.
3. Ensure sufficient water quantity, levels and quality are sustained to maintain the mire community.
4. Obtain further information, particularly concerning invertebrates and incorporate their requirements within the management regime.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

As this site was only discovered fairly recently, and as past records for this site may well have been confused with, or allocated to, the nearby Barnham Broom Fen, its exact status and condition is uncertain. It is possible that the site has been in its present condition for a long time. However, it is almost certain that it is not a very good quality example of M13 vegetation. Parts of this site seem to be rather disturbed, but the cause of this is not known. Observations on its present floristic composition suggest that this site has probably been adversely affected by reduction of its water supply.

3. WATER RESOURCES

3.1 HYDROLOGY

The River Yare marks the southern boundary of Coston Fen. Within the Fen, there are a number of flowing east-west drains, which connect with a relatively large network of drains in the northeast, parallel to the River Yare.

3.2 HYDROGEOLOGY

The regional geology of the area comprises Boulder Clay (0 - 30 m) underlain by Upper Chalk. South of Coston, there may be a buried channel, infilled with Sand & Gravel. In the River Yare valley, river deposits overlie the Boulder Clay, and Sand & Gravel or Chalk. The geology beneath the Fen is known from 2 piezometers (1 in Drift, 3 m deep and 1 in Chalk, 35 m deep) in the northwestern corner of the Fen, constructed in 1995 by AWS as a condition of their Runhall PS licence. The piezometers show drift (3.75 m thick) comprising gravels, sand and clay, 1.5 m, and chalky Boulder Clay below, underlain by putty Chalk to 13.5 m, and harder Chalk to total depth (35 m). Regional information, together with the information from the piezometers, suggest the following hydrogeological units.

- Thin (1 - 2 m) water bearing alluvium comprising clay and gravelly sand, perched on a BOULDER CLAY AQUITARD, which beneath the site has a small thickness of 1 - 3 m. The water level in the Boulder Clay and overlying alluvium ranges from 0.2 mbgl in the winter to 0.7 mbgl in the summer and autumn (1995 - 1996).

- Possibly a SEMI-CONFINED SAND & GRAVEL AQUIFER, up to 30 m thick, but absent beneath most of the site. Where present, it would be in hydraulic continuity with the underlying Upper Chalk.

- The UPPER CHALK SEMI-CONFINED AQUIFER which, away from the Yare Valley, occurs beneath the Boulder Clay aquitard at depths of 15 - 30 mbgl. Beneath the site, it occurs below the thin Boulder Clay aquitard. The Upper Chalk is the main aquifer of the region. It has a northeasterly regional direction of groundwater flow, along the Yare Valley, with flow converging into the valley and the fen. Piezometric levels at the Fen are approximately 30 maOD. The chalk piezometer at the site had a water level in March 1995 of approximately 3.9 m above ground level (artesian) which fell by August 1996 to approximately 1.4 m above ground level. The difference in water levels between the drift aquitard and the Chalk indicates an upward hydraulic gradient with flow from the Chalk into the drift aquitard. The putty chalk and the clayey nature of the aquitard impede flow. Water levels in the aquitard remain below ground level in part due to evapotranspiration losses.

  Reported spring seepages and wet ground on the lower valley slopes are most probably the result of upward flow from the Chalk aquifer. Drains dug into the superficial deposits are also probably fed by chalk groundwaters. The drain along the base of the seepage slope probably collects water from springs on the lower valley slopes. Water level fluctuations at the Fen have been monitored by AWS since 1995. In 1995, water levels fell by 2 m but remained more or less stable with a slight rise in the winter of 1995-1996. They continued to fall after April 1996 and by September

1996 they were 2.5 m lower than in February 1995. The recorded decline is consistent with the dry years of 1995-1996, though there appears to be a direct influence by the nearby irrigation abstraction by Jewson & Sons. This is indicated by the slight steepening of the well hydrograph slope in the summer of 1995, which suggests that approximately 0.25 m of the overall fall during this time was due to this abstraction. The nearest observation boreholes are at TG00/467, 2 km west, which has been monitored since 1983, and TG00/637 at Kimberley 3.2 km south, which has been monitored since 1952. At TG00/467 seasonal water level fluctuations are approximately 1 m, with a decline of 1 m during 1989-1992 and 1995 - 1996 periods of drought. At TG00/637, seasonal water level fluctuations in the last 44 years have been consistently at approximately 0.5 m, with a decline of 0.5 m during recent periods of drought. However, water levels rose to their pre-1988 level in the wet years of 1992-1994.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water may enter the southern part of the site during periodic flooding of the valley floor by the adjoining River Yare.

Groundwater from the Chalk aquifer is the main source of water to the site and to the spring seepages. It is in the form of upward leakage through the thin overlying drift deposits.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4

The sloping character of this site means that all of its fen vegetation is dependent upon soligenous inputs. The M13 stand is characteristic of calcium rich water, suggestive of a chalk water input. It appears that the rather degraded character of the M13 vegetation is a response to a reduction in spring flow and a lowering of water levels, though as mentioned in section 2.3, it is possible that the site has been in its present poor condition for some time.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the fen there are 7 surface water abstractions from the Rivers Yare and Blackwater, drains and dykes, mainly for spray irrigation.

Groundwater: Within 5 km from the site, there are 43 licensed abstractions. The great majority are from the Chalk for agriculture and spray irrigation, and at rates smaller than 5 tcma (0.15 l/s). The closest is Jewson & Sons, licensed to abstract from Chalk 45.5 tcma (1.4 l/s) and daily 955 m^3/d (11.05 l/s) from April to October.

AWS are licensed to abstract for public supply at:

a) Runhall: 1 Chalk borehole at 1.82 km N at 850 tcma (26.95 l/s), daily 2600 m^3/d (30 l/s).
b) Mattishall: 2 Chalk boreholes at 3.2 km NNW, at 850 tcma (26.9 l/s), daily 2350 m3/d (27.2 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not have an impact on the wetland.

Groundwater abstractions in combination with low rainfall have an overall effect on chalk water levels. The AWS boreholes though at some distance from the site are situated upgradient of the prevailing direction of groundwater flow and could have an indirect effect. The ecological evidence, though somewhat inconclusive, would suggest that there has been a reduction in chalk groundwater supply, but whether this has been primarily due to the AWS PS abstraction remains uncertain. The nearest agricultural abstraction by Jewson and Sons appears to contribute directly to the lowering of water levels during the irrigation season (April to October).

The site has been assigned an AMP 3 Water Abstraction Category 3. This preliminary evaluation confirms this category with regard to water company abstractions, but a Category 2 may be appropriate with regard to irrigation abstractions.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

Monitoring of vegetation has been carried out by AWS since 1994.

5.1.2 Proposed Monitoring

None proposed; continuation of existing monitoring.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None is known within the wetland.

Groundwater: AWS monitor 2 piezometers, one in Chalk and a second in drift, as a condition of the Runhall licence.

Outside the wetland: The Agency monitor 2 chalk observation boreholes, TG00/467, 2 km west and TG00/637, 3.2 km south.

5.2.2 Proposed Monitoring

Surface water: 1 or 2 staff gauges in dykes within the wetland.

Groundwater: Within the wetland: If accessible, a cluster of 2 to 3 piezometers near the River Yare; 1 in alluvium (2 - 5 m deep), 1 in Sand & Gravel (if it occurs, 10 - 20 m deep), and 1 in Chalk (15 - 40 m deep).

Outside the wetland: 2 Chalk piezometers (30 - 40 m deep) between the AWS PS abstraction at Runhall and the site; 1 piezometer at approximately 500 m from the site and a second at 1.5 km. The objective is to determine the extent of the cone of depression of the Runhall Source.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

No ecological surveys are proposed.

6.2.2 Hydrology

The following are proposed:

a) Field survey of wetland including water sampling of dykes for chemical analysis and location of proposed monitoring points.
b) Installation of monitoring structures, including piezometers.
c) Hydrogeological report after a) and b) have been completed.
d) Evaluation of vegetation and hydrological monitoring.

6.3 ALLEVIATION MEASURES

To await the results of the proposed hydrogeological evaluation.

6.4 SITE MANAGEMENT

On-going vegetation management is required to maintain species diversity.

SITE: EAST WRETHAM HEATH

NGR: TL 910 882 **AREA: 141.07 ha (348.59 acres)**

1. DESCRIPTION OF SITE

The main conservation interest of this site lies in the two fluctuating meres "Ringmere" and "Langmere", and in the areas of Breckland grassland. Water levels fluctuate in a cyclical, but irregular fashion, creating conditions for the development of an unusual series of aquatic and periodically-inundated plant and animal communities. Plants tolerant of alternate flooding and drying such as Reed Canary grass (*Phalaris arundinacea*) and Amphibious Bistort (*Polygonum amphibium*) are abundant. The seasonally-exposed shores support a number of rare plants, including the moss (*Physcomitrium erystomum*) (at its only known British location). Aquatic species include the nationally-rare Grass-Leaved Water Plantain (*Alisma graminea*) and a number of Pondweeds (*Potamogeton* spp.) and invertebrates characteristic of unpolluted base-rich waters.

The site also contains several smaller water bodies the largest being Fenmere. They contrast sharply with the others, in having more constant water levels, and a dense marginal vegetation dominated by Greater Pond Sedge (*Carex riparia*) and rushes.

The site is owned and managed by Norfolk Wildlife Trust.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and included within the Breckland SAC, for which the notified interest is "naturally nutrient rich lakes which are often dominated by pondweed" (Magnapotamion and Hydrocharition-type vegetation). The Grass-Leaved Water Plantain (*Alisma graminea*) is listed on the BAP long list of globally threatened / declining species. The invertebrate fauna of the lakes is considered a key element in the conservation interest of the site.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain the condition of the internationally important naturally nutrient rich lakes which are often dominated by pondweed.
2. Restore and maintain the natural hydrological regime of the internationally important meres to protect their characteristic invertebrate assemblages and vegetation structure.
3. Maintain the diversity of habitat types within the SSSI.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

No direct evidence of change.

3. WATER RESOURCES

3.1 HYDROLOGY

There are no surface water courses. There are, however, three water filled depressions or meres: The fluctuating meres of Ringmere and Langmere, and Fenmere. In recent years, the meres have been dry.

Clarke (1922) [TNNNS article - p273,274] describes Langmere as having an area of 12 acres 'when of average depth', and fluctuations in water levels as follows:

The mere was dry till the autumn of 1903, full in August, 1904, and quite dry throughout 1905. In February, 1906, it again contained water, and fluctuated till August, 1908, when it was full, but was again quite dry throughout 1909. It contained water in March, 1910, was full in April, 1911, nearly dry at Christmas, full in April, 1912, and so remained until 1920. It was low in March 1921, and quite dry in October. Similar water levels are described for Ringmere (p274).

3.2 HYDROGEOLOGY

The hydrogeology beneath the site comprises:

- A BOULDER CLAY AQUITARD (0 - 20 m thick) overlying the Upper Chalk in the easternmost part of the site. Sand layers in the Boulder Clay can form perched water-tables, recharged mainly by rainfall. Fenmere rests on Boulder Clay.
- The UNCONFINED-SEMICONFINED UPPER CHALK AQUIFER. It is unconfined over most of the site, but semi-confined in the east by Boulder Clay. A thin blanket of sands (? ancient dunes) is potentially in hydraulic continuity with the Chalk. Ringmere and Langmere rest on the Chalk aquifer but are separated from it by thin silt-clay lacustrine sediments at the base of the lakes, which potentially impede vertical flow from and into the Chalk aquifer. Water levels in the Chalk fluctuate seasonally. During the 1989 - 1992 and the 1996 - 1997 periods of low rainfall water levels fell by 3 -10 m. The water levels in the meres have been similarly affected, and in recent years the meres have been dry. Water levels in the Chalk are at present about 9 mbgl and the overlying sands are dry. Groundwater in the Chalk flows southward through the site. The main component of flow is lateral. Upward flow into the Boulder Clay is minor.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water contribution is minor, mainly rainfall and some runoff. Groundwater is the main source of water. When the water-table in the Chalk is sufficiently high, Langmere and Ringmere intercept lateral flow and also receive some upward vertical flow through the base. Fenmere may receive some flow from the Boulder Clay.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 3.

There is no reason to suppose that any of the vegetation present on this site *requires* groundwater input, though the site is undoubtedly dependent on groundwater inputs. It is a characteristic feature of these fluctuating meres that the extent and composition of the marginal vegetation varies annually in response to the frequency, amplitude and duration of water level fluctuations, and stable communities do not develop.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: 3 abstractions within 5 km

Groundwater: 18 abstractions within 5 km; there are none within 1 km; 0.3 l/s between 2 and 3 km; 2.4 l/s between 3 - 4 km. The AWS source at Two Mile Bottom (1659 tcma or 52.6 l/s) is at 5.9 km southwest of the Fen.

4.2 IMPACT OF ABSTRACTIONS

Groundwater abstractions are generally small, but have a combined contributory effect. The AWS abstraction is too far and down gradient of the Fen to have any significant impact. Seasonal and long term rainfall changes in the area are considered to be the main factor affecting the wetland. Note is made of the fluctuations in water levels in Langmere between 1903 and 1911, when the mere fluctuated from wet to dry, and when groundwater abstractions must have been less than at present.

The site has been assigned on AMP3 Water Abstraction Category 3. The present preliminary evaluation agrees with this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None is known.

5.1.2 Proposed Monitoring

None recommended.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: 3 gaugeboards in Fenmere, Ringmere and Langmere.

Groundwater: Within the site; 4 piezometers (3 in Chalk and 1 in drift).

Outside the site; 9 boreholes in Chalk within 3 km of the site.

5.2.2 Proposed Monitoring

None proposed.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

None proposed.

6.2 INVESTIGATION

6.2.1 Ecology

A baseline survey of aquatic invertebrates.

6.2.2 Hydrology

None proposed.

6.3 ALLEVIATION MEASURES

None proposed.

6.4 SITE MANAGEMENT

Not relevant.

Notes:

1) Monitoring from 1998 to determine impact of licensed abstractions under the Habitats Directive Regulations. Necessary monitoring installations have been placed under the Hydrological Monitoring of Wetland Project, Phase II.

2) According to the form on "Outline Case for Inclusions of AMP3 Water Company Abstractions" PWS will be investigated by groundwater modelling. There is need to discuss this further in the light of the findings of the present study.

3) It is a characteristic feature of these fluctuating meres that stable vegetation communities do not develop, and hence detailed vegetation monitoring is not considered appropriate in the current context.

SITE: FOULDEN COMMON

NGR: TF 762 002 **AREA: 136.8 ha (338.0 acres)**

1. DESCRIPTION OF SITE

Foulden Common is situated on the north-west edge of Breckland about 1 km north of Foulden, Norfolk. The site lies on the southern slope of a shallow valley of a tributary to the River Wissey. Higher ground rises to the east and south of the site with topographic gradients increasing eastwards, while the western and northern boundaries to the site are marked by the Foulden Common drain. Gooderstone Common is situated on the northern side of this water course.

The commons corporately form a large, flattish, complex area of grassland, fen and woodland. In Foulden Common, west of the road, the substratum is highly calcareous and the Foulden Common drain is bordered by a band of alder and rather fragmented *Cladium*-dominated fen. However, the main area of *Cladium* fen occurs in a large shallow basin to the south of this, separated from the drain-side fens by a slightly elevated band of grassland. In the more elevated parts of the fen, and at the margins, there is often a rather dry example of *Schoeno-Juncetum* {~M13} vegetation, grading out into *Cirsio-Molinietum* (~M24) or drier grassland. Near the drain, there are several small ground ice depressions, some of which coalesce with the streamside fens, supporting *Cladium* or *Carex elata* swamp, but the main pingo field is in the northeastern arm of the Common, east of the road. Here, on a dry sandy drift, there is much birch, and the smaller pingoes are almost completely shaded and dystrophic. Alongside the Foulden road, mixed fen (*Angelico-Phragmitetum*) has developed.

Gooderstone Common has largely been reclaimed for agriculture, but Gooderstone Fen, to the west of the Common, has some well developed springs and seepages with good base-rich mire vegetation, grading out into *Cirsio-Molinietum* {~M24} and drier grassland.

2. ECOLOGY

2.1 CONSERVATION INTEREST

EN consider the main wildlife interest to reside in the fen vegetation: *Schoenus nigricans–Juncus subnodulosus* mire (M13), fen meadow communities, and *Carex rostrata–Potentilla palustris* fen (S27). The nationally scarce Fen Pondweed (*Potamogeton coloratus*) and Orange Foxtail (*Alopecurus aequalis*) occur, the former requiring open water, while the latter is characteristic of pool margins. The site is also of Quaternary geological interest, having pingo pools with fen vegetation, and supports a rich invertebrate fauna.

The site is an SSSI, and included within the Norfolk Valley Fens SAC, for which the notified interest is "calcium-rich spring water fed fens", here represented in particular by *Schoenus nigricans–Juncus subnodulosus* mire (M13). Other communities considered to be of international importance are *Molinia caerulea–Cirsium dissectum* fen meadow (M24), *Cladium mariscus* sedge swamp (S2) and *Carex rostrata–Potentilla palustris* fen (S27). The site supports some nationally-uncommon fen species, and the nationally scarce Fen Pondweed (*Potamogeton coloratus*) and Orange Foxtail (*Alopecurus aequalis*). The invertebrate fauna also includes some RDB species.

Although some of the fen is rather dry and examples of M13 are rather degraded, there are some good examples of this, especially in the Gooderstone Common section. However, the site is considered to be species-rich with a lot of interest, some of which stems more from its range of habitats and curious mix of species rather than being a good representative example of a calcareous valley-head fen.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain and enhance the condition of the internationally important "calcium-rich spring water fed fens" (M13).
2. Maintain and expand where possible mire and grassland communities especially the CG2 [*Festuca ovina–Avenula pratensis* grassland] and CG6c [*Avenula pubescens* grassland] types, and the internationally important M13b (*Schoenus nigricans–Juncus subnodulosus* mire, *Briza media–Pinguicula vulgaris* subcommunity).
3. Control expansion of scrub particularly where this involves the above communities.
4. Maintain a high water table and spring flows for the pingos and their invertebrate populations, and also for the benefit of the wetland communities.
5. Ensure the water source feeding the pingos remains unpolluted.
6. Maintain and increase populations of the nationally scarce Fen Pondweed (*Potamogeton coloratus*) and Orange Foxtail (*Alopecurus aequalis*).

2.3 EVIDENCE OF ECOLOGICAL CHANGE

EN consider that there has been marked drying of the fen community areas, although there is no direct evidence. One of the most interesting features of parts of Foulden Common is the occurrence of fen species (including some rare taxa) in conditions which would normally be too dry for them and in association with some species of dry calcareous grassland. It seems likely that these occurrences represent relict populations which have persisted *in situ* from a former wetter condition. If this is the case, it raises the question as to why such species are thought to disappear from the vegetation of other sites consequent upon drying. The answer is not known with any confidence, but it seems likely that it may be the result of interaction between continued management (grazing) and very low soil fertility (much of the substratum at Foulden Common is highly skeletal and has limited nutrient capital, so that not only is the soil intrinsically nutrient poor but also fertility increase caused by drying-induced mineralisation may not have been as important as at some other sites).

Scrub invasion is an ongoing problem.

3. WATER RESOURCES

3.1 HYDROLOGY

Foulden Common, which includes Gooderstone Fen in the west, lies in the River Wissey catchment. The northern boundary in the eastern half of the site is defined by a drain (Foulden Common drain). It flows westwards through the northern part of

Foulden Common. Further west, it marks the southern boundary of Gooderstone Fen and joins the north-south Oxborough drain, which defines the eastern boundary of Gooderstone Fen (and of the site). From there it flows into the River Wissey, 1.1 km to the southwest. In the southwestern boundary of the site, there is a spring which feeds a drain discharging into a pond (Balloon Covert), both situated to the south of the site, but diverted northwards into the spring drain. In the southernmost part, a small system of drains flow southwards to discharge just outside the site into a small pool at Talent Covert, and eventually into the River Wissey, 1.2 km to the southwest.

In the northeastern part of the site, there is a large number of water filled depressions, probably the result of periglacial activity during the last ice age. None of the depressions seems to be drained.

3.2 HYDROGEOLOGY

The regional geology of the site comprises Middle Chalk which is exposed over most of the site. In the southeast and in the Gooderstone Fen in the west, there are thin drift deposits. Outside the site in the south, east and west, the Chalk is overlain by Boulder Clay. Beneath the site the following hydrogeological units have been recognised:

- The UNCONFINED CHALK AQUIFER which is locally overlain by thin (1- 2 m) alluvial sands, silt and Sand & Gravel (approximately 2 - 3 m) in the southeast, all in hydraulic continuity with the Chalk. In the south, east and west, the Boulder Clay aquitard potentially semi-confines the Chalk aquifer. The Middle Chalk is probably 20 - 25 m thick and is underlain by Lower Chalk, which though of lower permeability is hydraulically connected to the Middle Chalk. The direction of groundwater movement is to the west under a hydraulic gradient of 0.002. Groundwater levels in November 1997 were 8 - 9 maOD in the eastern part of the site, falling to 5 - 6 maOD in the west. Depths to groundwater in the Chalk are very close to the ground surface (0.5 - 1.1 mbgl), whilst those in the overlying thin drift are similar or a few centimetres lower. The water filled depressions in the east of the site, and the various springs and drains intercept the shallow water-table and are therefore groundwater fed. The drains may, however, control the shallow water-table. The Agency have monitored 10 boreholes (9 in Chalk and 1 in alluvium), a few as far back as 1971 and others since 1981-1985, within a distance of 3 km from the site. The closest at Foulden Common (TF79/024) is at approximately 300 m SE of the southeastern boundary of the site; it had a minimum water level of 5.17 maOD (approximately 5 mbgl) in August 1992, and a maximum water level of 8.1 maOD (at near ground level) in January 1971. In general, seasonal water level fluctuations are 1 - 1.5 m. During the 1989-1992 and 1995-1996 periods of low rainfall, water levels fell by 0.5 - 1.5 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water inputs consist of rainfall and generated runoff, and surface water inflows from outside. According to BGS (1984) for a catchment area of 5.8 km^2, these amount to 70.6% of the total input, with rainfall amounting to 69.6%.

The close proximity of the Chalk water-table to the ground surface suggests that groundwater constitutes a significant source of water to the site, especially during periods of little or no rainfall. This is despite the estimates by BGS (1984) who suggest that groundwater amounts to only 29.4% of the total input to the site. Thus, the site and the numerous water filled depressions may be considered primarily as groundwater fed and dependent upon the position of the water-table.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4 (in part)

The relationship of the vegetation of this site to groundwater is quite difficult to ascertain. There can be little doubt that parts of the sites (especially the M13 stands in Gooderstone Fen) are critically dependent upon groundwater inputs (almost certainly including a substantial chalk water component), but the status of much of the site is not readily deduced from the floristic evidence. The vegetation of much of the fen is not (nowadays) critically dependent on groundwater discharge, nor on especially high water tables, but this may be (a) because groundwater discharge and parts of the fen have become summer-dry and the vegetation has developed in response to this; or (b) because large areas of the site have always been quite summer-dry (during the last few decades at least). What is clear is that the 'dry' conditions over some of this site are of long standing, dating from at least the 1960s but the cause of such conditions (direct drainage *versus* reduction of groundwater level *versus* natural state) is much less clear. Wheeler & Shaw (Site Dossier) inclined to the view that much of the fen, including the large area of *Cladium* vegetation in the south, may once have been fed by chalk water, but this was on the assumption (partly based on some comments of S.M. Haslam) that this area had once been a *Schoeno-Juncetum.* This view may still be correct, but it must be recognised that there is no direct evidence for it and experience elsewhere suggests that such areas of *Cladium* fen are not necessarily located in discharge areas. It is also the case that if this stand turned out to be situated on a low permeability deposit, this would be wholly compatible with the existing character of the vegetation and its known history.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km radius from the site, there are 18 licensed surface water abstractions from drains, ditches, lagoons and the River Wissey and its tributaries, all for general agriculture/domestic and spray irrigation.

Groundwater: Within 5 km from the site, there are 17 licensed abstractions. Most are small, less than 10 tcma (0.3 l/s) and a few at 100 - 150 tcma (3.2 - 3.8 l/s) for general agriculture and irrigation. There are no licensed abstractions within 1 km of the site.

AWS are licensed to abstract for public supply from 4 Chalk boreholes at Beachamwell, 4.35 km NNW at 4977 tcma (157.8 l/s), daily 13638 m^3/d (157.8 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not have any impact on the wetland.

Groundwater abstractions within 3 km from the site are small (there are none within 1 km). The largest abstraction is by AWS at Beachamwell, 4.35 km NNW of the site. Its relatively great distance, and its hydrogeological position along groundwater contour 4 - 5 maOD and downgradient of the wetland, suggest that its impact on the wetland is negligible.

The site has been assigned an AMP 3 Water Abstraction Category 3. This preliminary evaluation confirms this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None known to exist.

5.1.2 Proposed Monitoring

Carefully targeted annual vegetation monitoring at Gooderstone Fen. Some permanent marker posts will need to be installed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: In the wetland, there are 6 no staff gauges in drains, ponds and depressions (installed in 1997).

Groundwater: In the wetland, there are 9 no piezometers: 4 in drift deposits, 3 in Middle Chalk and 2 in Lower Chalk (7 were installed in 1997 and 2 in 1985).

Within a 3 km distance from the wetland, there are 10 boreholes in Chalk monitored by the Environment Agency.

5.2.2 Proposed Monitoring

Surface water: None is proposed

Groundwater: None is proposed.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in 5.1.2.

6.2 INVESTIGATION

6.2.1 Ecology

A baseline NVC vegetation survey (Smart, 1993) exists, which is considered to be adequate.

6.2.2 Hydrology

The following are proposed:

a) A survey of irrigation abstractions within 2 km from the site.
b) Hydrochemical survey of surface waters and groundwaters.
c) A brief report, after completion of a) and b).
b) Evaluation of monitoring information after 3 years.

6.3 ALLEVIATION MEASURES

None are proposed at present; position to be reviewed in 3 years.

6.4 SITE MANAGEMENT

In order to maintain the species diversity of the fen communities, a major programme of scrub clearance is required, together with fencing so that grazing can be controlled and further scrub invasion halted.

SITE: GREAT CRESSINGHAM FEN

NGR: TF 848 022 **AREA: 13.65 ha (33.85 acres)**

1. DESCRIPTION OF SITE

This site lies in the valley of the River Wissey, approximately 0.5 km north-west of Great Cressingham. The fen is situated on the western side of the Wissey in a small basin-like side valley with higher ground rising to the west and north-west. It retains a series of vegetation types, ranging from dry, unimproved grassland on the highest slopes, through wet, species-rich fen grasslands where springs emerge, to tall fen vegetation in the valley bottom.

Much of the site supports a good development of rheo-topogenous fen communities, as well as overgrown fen meadow, in parts of the basin. Some vegetation, particularly towards the SW end is semi-floating *Acrocladio-Caricetum* {~M9} and is probably over former peat workings. Springs, particularly in the NE corner, sustain low-growing soligenous fen (*Schoeno-Juncetum* {~M13}) and produce water tracks through other parts of the basin.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and included within the Norfolk Valley Fens SAC, for which the notified interest is "calcium-rich spring fed fens", here represented by the *Carex rostrata–Calliergon cuspidatum* mire (M9) and *Schoenus nigricans–Juncus subnodulosus* mire (M13) communities. In addition, the *Juncus subnodulosus–Cirsium palustre* fen meadow sub-communities represented (M22c and M22d) and the plants Marsh fern (*Thelypteris palustris*) and Lesser Tussock-sedge (*Carex diandra*) are nationally rare.

It is considered that this site is of exceptional importance. It is a good example of a base-rich, rheo-topogenous fen and supports one of the best examples of M9 vegetation in lowland England. There is also an area of M13 vegetation, but this is not of particularly high quality

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain and enhance the condition of the internationally important "calcium-rich spring fed fens" (M9 and M13).
2. Ensure the flow of ground water and its quality is maintained at sufficient levels to maintain mire communities.
3. Maintain the extent of the mire communities present, particularly the nationally rare M22c and M22d types, and the internationally important M9b and M13c.
4. Maintain and if possible expand populations of the nationally rare plants Marsh fern *Thelypteris palustris* and Lesser Tussock-sedge *Carex diandra*.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

Although there is no conclusive evidence for this, it seems likely that the areas of M9 vegetation have developed upon turf ponds. Ongoing terrestrialisation of these is likely to lead to a progressive change in the character of the vegetation, probably towards a less valuable type.

This important site seems only to have been located in 1975. It has probably changed rather little since then, but this is difficult to know because of a lack of appropriate surveys.

3. WATER RESOURCES

3.1 HYDROLOGY

The River Wissey marks the southeastern boundary of the site. A bund on the river bank separates the river from the wetland, but floodwaters probably enter the lower part of the fen from upstream. A rectangular system of drains within the Fen combine into a stream in the south of the Fen, which flows southeastwards and joins the Wissey. The rectangular drain is fed via a drain by a spring in the northeast, and other short drains discharging into the northern branch of the rectangle. At the northern corner of the rectangular drain, a flight pond has been dug.

The flow of the stream discharging into the Wissey has been measured from 1984 to 1987, by means of a weir. However, due to leakage around the weir current metering has been used since September 1987. Flows in the summer and autumn prior to 1989 were in the range of approximately 1 - 10 l/s. Since then flows have diminished; the stream was dry in August, September, October and occasionally November in 1989, 1990, 1991 and 1992.

1.2 HYDROGEOLOGY

The regional hydrogeology consists of unconfined Upper Chalk, which is locally overlain by thin Boulder Clay. Beneath the site the hydrogeology comprises:

- A thin (1 - 2.5 m) alluvial SAND PHREATIC AQUIFER in direct hydraulic continuity with the underlying Chalk. In September 1997, the sand aquifer was dry, but in November 1997 there was water in the bottom 0.5 m of the 1m thick sand at piezometer TF80/231. The drift piezometer TF80/193 in the southern wetland boundary, monitored since 1988, showed a seasonal fluctuation of approximately 1 m, falling by approximately 1 m after the wet period of 1993 - 1994.

- The CHALK UNCONFINED AQUIFER occurs near the surface at a depth of 1 to 2.5 mbgl. In September 1997, water levels were 3.41 mbgl (25.54 maOD) at the northern site boundary and 2.58 mbgl (25.29 maOD) at the southern boundary, indicating a southwestern direction of groundwater flow through the site. Regional groundwater flow is in the same direction, with piezometric elevations of 27.5 - 30.0 maOD in the northeast falling to 22.5 maOD in the southwest (November 1997). The average hydraulic gradient is 0.002. Long-term water level fluctuations (1971-

1997) at two chalk observation boreholes (TF80/010, 1.3 km east of the site and TF80/005, 1.5 km west of the site) show seasonal fluctuations of 2 - 5 km and a decline during the drought period of 1989-1992 and 1995-1996 of 1 - 2 m. Water levels recovered near their pre-1988 level during the wet period of 1993-1994. At the wetland boundary, chalk piezometer TF80/192, monitored since 1987, showed a seasonal fluctuation of approximately 2 m, and a fall of approximately 3 m in 1996, after the wet period of 1992-1994. There is good correlation between flows in the stream and groundwater levels, demonstrating their dependency on the aquifer water-table.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water comprises rainfall and surface runoff following rainfall events. Along the southeastern boundary, floodwaters from the River Wissey enter the lowermost part of the wetland.

Groundwater from the Chalk aquifer is the main source of supply to the wetland. It supports the spring and drains, and provides moisture when the water-table is close to ground surface mainly in the winter and spring.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4

The M13 stand is critically dependent upon groundwater inputs (almost certainly including a substantial chalk water component). Although the important M9 vegetation is not exclusively associated with groundwater-fed fens, at this site is seems likely that the conditions it requires (base-rich, nutrient-poor water) are supplied primarily by groundwater, thus giving it a strong dependence on groundwater inputs.

The semi-floating character of the M9 vegetation mats provide some buffering against water level change, but the limits of this are not known.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the site there are 2 licensed surface water abstractions.

Groundwater: Within 5 km from the site, there are 24 licensed abstractions. Most of them are small, less than 10 tcma (0.3 l/s), with a few between 40 - 320 tcma (1.3 - 10.2 l/s) and are used for agriculture and domestic purposes.

Within 3 km from the site there are 7 licensed abstractions, all for general agriculture and spray irrigation. Except for one, they are all at less than 5 tcma (0.16 l/s), daily 16 m^3/d (0.18 l/s). South Pickenham Estates have a licence to abstract for spray irrigation (April - September) from 3 boreholes at distances of 1.546 km NNW, 1.615 km WNW and 2.561 km NW. The combined licence is for 272.727 tcma (8.65 l/s), daily 7194 m^3/d (83.26 l/s). (The licence expired in September and a licence application is now being determined by the Agency.)

Public supply abstraction by AWS is from 3 Chalk boreholes at North Pickenham at a distance of 3.9 - 4.1 km NNE. The licence is for 1874 tcma (59.4 l/s), daily 6819 m^3/d (78.9 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the wetland.

Groundwater abstractions have the overall effect of depressing the Chalk water-table which, in combination with the recent periods of low rainfall, has since 1989 caused the springs (and stream) of the wetland to dry up in some months during the summer and autumn. A hydrogeological evaluation by the NRA (now Environment Agency) in 1990 following reports that the fen and spring flow dried up in August 1989, concluded that irrigation at the South Pickenham Estates contributed to the lowering of the water-table likely to prolong the period when there is no stream flow at the fen. The abstraction licence was temporarily banned in 1992 but replaced, (apparently for the same quantity in 1993, expiring in September 1997).

The AWS PS abstraction approximately 4 km north of the Fen does not have a direct impact on the water supply to the wetland.

The site has been assigned an AMP3 Water Abstraction Category 3. The present preliminary evaluation confirms this category in the context of the category being specifically related to water company abstraction. However, a higher category 1 is indicated in relation to irrigation abstractions.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

Some vegetation monitoring has been carried out as part of the South Pickenham Estate irrigation licence.

5.1.2 Proposed Monitoring

Targeted annual vegetation monitoring, including the installation of permanent marker posts.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: 2 gaugeboards, one at the top northwestern corner of the rectangular drain, and the second in the stream discharging into the River Wissey, were installed in 1997. A rectangular weir in the stream supplemented by monthly current meter gaugings.

Groundwater: Within the wetland there are 6 piezometers; 3 in Chalk and 3 in alluvial sand, four of which were installed in 1997.

Within 3 km from the site the Agency monitor 3 Chalk boreholes, two since 1971 and one since 1995.

5.2.2 Proposed Monitoring

Surface water: None is proposed.

Groundwater: 1 no Chalk observation borehole (10 - 15 m deep) 750 m NNW of the Fen to monitor more closely the impact of irrigation abstractions from South Pickenham.

If possible, 3 - 5 shallow (1 - 2 m) dipwells in peat (see 6.2.1 c.)

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

The following are proposed:

a. A survey of peat stratigraphy across the site.
b. Topographic survey of the peat surface.
c. Installation of 3 - 5 "peat anchors" levelled to OD (and adjacent shallow dipwells, if access permits).
d. Monthly monitoring of peat rafts (and water levels) for at least one year, to establish the temporal vertical mobility of the vegetation rafts and thus their buffering capacity against water level variations.
e. Evaluation report after one year.

6.2.2 Hydrology

Hydrochemical study of groundwaters and the River Wissey water.

6.3 ALLEVIATION MEASURES

a) In order to ensure that the water-table and springflows in the Fen are maintained, particularly during periods of drought, the licensed abstraction at South Pickenham (now under consideration by the Agency) should be revoked or substantially decreased (50 - 75%).

b) Alternatively (or in conjunction with a reduction of the licensed abstraction at South Pickenham) and providing that the water quality of the River Wissey during periods of low flow is suitable, consideration may be given for supplementing the water supply to the Fen with river water.

6.4 SITE MANAGEMENT

There is a requirement for on-going vegetation management. A small amount of scrub clearance is also required.

SITE: HALL FARM FEN

NGR: TG 4810 1700 **AREA: 11.1 ha (27.4 acres)**

1. DESCRIPTION OF SITE

A small area of unimproved, wet, grazing marsh and species-rich fen meadow. Supports a rich flora, attributed to the presence of both acidic and calcareous conditions, and includes some unusual orchid hybrids. The site is bisected by numerous dykes, which support a well-developed aquatic flora and fauna, including a nationally-rare water snail *Segmentina nitida.*

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and lies within The Broads SAC and Broadland SPA and Ramsar site.

According to Dr B D Wheeler, the site is a mixture of wet grassland and M22 fen meadow. The latter tends to occupy shallow depressions of greater or lesser extent and, for the most part is rather non-descript and not very species rich, though it does support some locally interesting fen species (*e.g. Anagallis tenella, Menyanthes trifoliata*). One rather curious feature is that the M22 vegetation represented at Hemsby has stronger floristic affinities with the 'normal' version of M22 that occurs widely (though infrequently) throughout SE England rather than with the 'Broadland' version of this community. A consequence of this is that the fen meadow at Hemsby is different to many other examples of Broadland fen meadow. On the one hand, this gives the site greater local importance, but on the other it reduces its national significance.

As may be implicit in this assessment, the consultants find it difficult to tally their own knowledge of the fen vegetation at Hemsby with the relevant stated EN Conservation Objectives for this site. (For example, *Cladium mariscus* does not figure in any of Dr Wheeler's/Dr Shaw's own records from this site; and whilst it is possible that this is an oversight, and a few plants of this species may occur, it is equally clear that this is not an "internationally important chalk-rich fen dominated by saw sedge (great fen sedge) (*Cladium mariscus*)".

2.2 ENGLISH NAUTRE (EN) CONSERVATION OBJECTIVES

<u>SPA objective</u>

- Increase the internationally important populations of breeding bittern and marsh harrier. This refers to the dyke network and fen, providing feeding opportunities for both species.

<u>SAC objectives</u>

- Increase the extent of and enhance the condition of the internationally important chalk-rich fen dominated by saw sedge (great fen sedge) (*Cladium mariscus*). This objective refers to the M22 vegetation.
- Enhance the condition of the internationally important naturally nutrient rich dykes which are often dominated by pondweeds. This objective refers to dykes within Hall Farm Fen, Hemsby. Invertebrate interest is also included within this objective, including *Segmentina nitida*.

<u>Ramsar features</u>

- Criterion 1a; many good and representative examples of wetland habitats characteristic of the biogeographic region.
- Criterion 2a; supports an outstanding assemblages of rare plants and invertebrates. [Within the Broads site, this includes 9 RDB plants and 136 RDB invertebrates.] Note *Segmentina nitida*.
- Criterion 3c; recognises a number of bird species which include the bittern and marsh harrier, as the SPA feature/objective.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

No clear evidence of change: the current composition of the M22 fen meadow at Hemsby Common appears to be much the same as when sampled by Dr B D Wheeler in 1974. There is anecdotal evidence of drying of the ditches, with presumed adverse impacts on the aquatic flora and fauna, (see Water Resources evaluation).

3. WATER RESOURCES

3.1 HYDROLOGY

The fen is drained by a series of southwestward trending dykes which discharge into Ormesby Broad. A north-south dyke marks the eastern boundary of the Fen; it receives surface runoff at its northern end and is also fed by a series of east-west dykes, outside the Fen, which extend as far as Hemsby. In September 1996, most dykes contained iron-stained standing water. Except for some runoff during periods of rainfall, they are groundwater fed. Dyke waters in their natural state are of calcium bicarbonate type with ECs of 800 - 1000 μS/cm 20°C , but enriched in SO_4, where they cut through Breydon Clays. Pollution as a result of farm waste disposal has occurred in two dykes which show elevated ECs (1700 - 2200) and very low pH (3.4 - 5.3).

3.2 HYDROGEOLOGY

The hydrogeology beneath the site comprises:

- A PEAT WATER TABLE AQUIFER (0 - 3 mbgl) in the southern part which merges into BREYDON FORMATION SANDS in the north. Groundwater levels are near the surface (0.3 - 0.8 mbgl). They are controlled by dykes, which generally have a lower water level indicating groundwater seepages from the peat/sands into the dykes. Seasonal fluctuations are approximately 1 m.

- A thin clay AQUITARD (1 - 2 m) belonging to the Breydon Formation. It separates the peat/sands above from the Yare Valley Gravel/Crag aquifer below.

- The YARE VALLEY GRAVEL/CRAG SAND UNCONFINED - SEMI-CONFINED AQUIFER. It constitutes the main aquifer and is more than 30 m thick. Water levels are near the surface (0.6 mbgl) but possibly slightly higher than those in the peat/sands, suggesting potential for upward flow. This is impeded somewhat by the Breydon Clays. Nearby irrigation abstractions from the Crag influence groundwater levels.

The groundwaters of the phreatic Breydon Sands in the southern part of the fen have a high EC (1680 μS/cm), very high sulphate (791 mgl/ SO_4), nitrate below detection limits but high iron (40 mg/l Fe). The shallow sands in the northern part of the Fen have a relatively high EC (936 μS/cm), sulphate (115 mg/l SO_4), chloride (115 mg/l Cl) and iron (26 mg/l Fe) but very high nitrate 62 mg/l Cl NO_3). Agricultural activity is probably responsible for the high nitrates.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface runoff from the north and east during periods of rainfall feeds the various dykes which discharge into the dykes of the fen. Infiltration from rainfall also contributes.

Groundwater is the main source of water to the Fen. It is mainly derived from the underlying Crag sand aquifer by upward flow into the near surface phreatic peat/sand aquifer.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Categories: 2 (or 3).

The fen vegetation at Hemsby Common does not have a specific dependence upon groundwater discharge. Nonetheless, groundwater discharges are important in keeping the site wet.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: There are three surface water abstractions within 5 km from the Fen. The closest is for PWS by Essex and Suffolk Water Company from Ormesby Broad, (part of a linked licence of 10,000 tcma daily; amount from the Broad 36,300 m^3/d).

Groundwater: There are 30 abstractions mostly for spray irrigation at quantities of less than 100 tcma (c. 3 l/s). None of the water companies abstract from the Crag aquifer within 5 km from the Fen. Close to Hall Farm, there are three abstractions of significance: (a) At the northern edge of the Fen (licence no 7/34/10/*G/129) there are 18 well points with a licence for 48 tcma (1.5 l/s) and maximum daily of 800 m^3/d (9.25 l/s); (b) 500 m east of the Fen (licence no 7/34/10/*G/110) there are 18 well points with a licence for 56.5 tcma (1.79 l/s) and a maximum daily of 1640 m^3/d (18.98 l/s); (c) 800 - 1000 m southeast of the fen (licence no 7/34/10/*G/008) 3 wells with a licence of 1.98 tcma (0/006 l/s) and maximum daily of 5.4 m^3/d (0.06 l/s).

4.2 IMPACT OF ABSTRACTIONS

Irrigation abstractions operate mainly during April to October, though in recent years, due to low rainfall, pumping continued into the winter months. The abstractions have caused groundwater levels to fall, especially during the irrigation season and the dykes to dry up. Evidence to date does not suggest a steady decline of water levels, but it is not certain whether water levels in the winter recover to their natural level; this has been made more difficult to determine in recent years due to low rainfall. Agricultural practice has led to increased nitrates and to acid waters in some dykes, due to possible disposal of agricultural waste.

The site has been assigned an AMP3 Water Abstraction Category 3. The present preliminary evaluation indicates a link between irrigation abstractions and the hydrology of the wetland. A Category 2, but with respect to agricultural abstraction, is considered to be more appropriate.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None are known.

5.1.2 Proposed Monitoring

Carefully targeted annual monitoring of vegetation communities along the fen margin and of the invertebrates and vegetation in the dykes would be useful.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: Within the fen; 1 Agency gaugeboard.

Outside the fen; 2 gaugeboards (Amoco) in dykes 200 m east of the Fen.

Groundwater: Within the fen; 1 Agency dipwell, 2 shallow and 1 deep (Crag) piezometers (Amoco).

Outside the site; 2 shallow and 1 deep (Crag) piezometers approximately 200 m east of the Fen; 1 piezometer deep (Crag) approximately 500 m southeast of Fen; 1 piezometer deep (Crag) approximately 500 m northwest of fen. All Amoco piezometers.

5.2.2 Proposed Monitoring

Surface water: Possibly 1 staff gauge; however owner controls dyke water levels and he considers that a staff gauge may not be relevant.

Groundwater: Present coverage is considered to be sufficient.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

None required; the vegetation was surveyed by Parmenter, 1993. Also, Nicholas Pearson Associates carried out ecological surveys of dykes in 1996 as part of the Amoco Proposed Pipeline Project.

6.2.2 Hydrology

Monitoring should continue in order to determine impact. For the last year, all piezometers and staff gauges, and hydrochemistry have been monitored monthly by HSI on behalf of Amoco. Six-monthly interpretational reports are prepared.

6.3 ALLEVIATION MEASURES

These are as follows:

a) Stopping of disposal of agricultural waste by farmer which appears to have caused pollution of dyke waters.
b) With regard to effects of agricultural abstraction (licence 7/34/10/*G/129) options are:
   i) reduce abstraction licence 50 - 75% during irrigation season (April - October).
   ii) provide compensation water either in the form of a deep (40 - 50 m) borehole in the Crag at the southern boundary of the fen (the reason for a deep borehole is so that groundwater is drawn from the deeper strata and thus the effects on the near surface water-table and licensed abstraction is minimised); or by pumping from Ormesby Broad, situated at 800 m from the centre of the fen.

6.4 SITE MANAGEMENT

On-going vegetation management is required.

SITE: SHERINGHAM AND BEESTON REGIS COMMONS

NGR: TG 164 424 **AREA: 23.9 ha (59.06 acres)**

1. DESCRIPTION OF SITE

A fairly small area of fen vegetation along the bottom of a heathy valley between Sheringham and Beeston Regis. There is a mix of basicolous and more acid-tolerant species, similar to that found at Buxton Heath and Roydon Common, but more intimately mixed here. This may reflect the juxtaposition of calcareous springs within acid sands but overall the site is less 'calcareous' than many other Norfolk valleyhead fens.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The water tracks are sometimes lined with a *Schoenus* {~M13 / M14} community, with flanking fen meadow (often *Juncus subnodulosus*-dominated), but in the main valley much of the main drainage axis is occupied by fen meadow. There are also *Schoenus* stands (and analogues) on seepage terraces lateral to the water tracks. There are also two areas of reed, with carr invasion.

The site is an SSSI and included within the Norfolk Valley Fens SAC, for which the notified interest is the "calcium-rich spring water fed fens", which includes the internationally-important *Schoenus nigricans–Juncus subnodulosus* mire (M13) community.

This is an extremely important site, one of the most important in Norfolk and in Britain, on account of its vegetation types and their juxtaposition (zonation). However, the reasons for this evaluation are not fully co-incident with the International Objectives listed by EN. Because of this, some further comment is appropriate.

M9 Given as an objective by EN, but the Consultants have no record of this community at this site.

M13 The vegetation at this site is regarded as an example of M13 – which is probably where it would be allocated within NVC – but this tends to obscure the fact that this specific version of M13 is rather different to, and arguably more important than, most examples of M13 in Norfolk, on account of the range of acid-loving plants that are intimately mixed with calcicolous species[1]. Because of this, it is considered that this vegetation is of greater national and international importance than the normal M13. At Sheringham & Beeston, this vegetation is still – for the most part – in good condition.

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[1] A comparable - but less good - example of such vegetation exists atHolt Lowes. Although these may be placed within M13 within NVC, it can be argued that this part of NVC is less than perfect as on both ecological andfloristic grounds such vegetation seems to have greater affinities with the NVC *concept* of M14.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain and enhance populations of Schedule 5 amphibians and reptiles present.
2. Maintain the species/community diversity.
3. Maintain viable populations of all recorded rare or scarce plant species.
4. Maintain the open heathland habitat.
5. Maintain and enhance the mixed valley mire plant communities.
6. Maintain the ground water levels that support the fen and mire plant communities.

There is a further international objective, as follows:

1. Enhance the condition of the internationally important calcium-rich spring water fed fens (M9 and M13).

2.3 EVIDENCE OF ECOLOGICAL CHANGE

Anecdotal evidence suggests that there has been a reduction in species diversity and invasion of species preferring drier conditions (e.g. brambles and grasses), probably developing over the last 4 years. This may partly relate to issues of vegetation management, as well as water supply.

3. WATER RESOURCES

3.1 HYDROLOGY

Sheringham and Beeston Regis Commons are separated by a spring fed stream which flows in a northeasterly direction. The stream bifurcates in the centre of the site into a northern branch which discharges into a drain and pond along the ~~northeastern~~ edge of the site, and a northeastern branch which discharges in a wet area in the northeastern part of the wetland. The stream receives its flow from spring seepages and overflow from the AWS PS.

There is one drain fed pond in Sheringham and some ephemeral shallow hollows in the eastern part of Beeston Regis.

3.2 HYDROGEOLOGY

The hydrogeology beneath the site comprises:

- A near surface PHREATIC SAND/GRAVEL AND PEAT AQUIFER (up to 10 m in thickness) perched upon Boulder Clay. Water levels are near the surface (0.2 - 0.4 mbgl). The water-table slopes to the north, indicating that groundwater moves from south to north. Springs emerge south and west of the wetland, at approximate elevations of 55 maOD and 40 maOD, respectively. Seepages in the northwest corner are at approximately 26 - 27 maOD. Groundwater levels fluctuate by approximately 0.5 m.

- A BOULDER CLAY AQUITARD (10 - 25 m in thickness). It comprises sandy clay and forms the basal aquitard to the phreatic sand/gravel aquifer and the confining aquitard to the underlying Crag and Chalk aquifers.

- The SEMI-CONFINED CRAG SAND AQUIFER (5 - 20 m in thickness). It consists of sand, pebbles and sandy clay and is in hydraulic continuity with the underlying Chalk aquifer.

- The SEMI-CONFINED CHALK AQUIFER which occurs at a depth of approximately 40 mbgl in the south and 25 mbgl in the north. Water levels are at approximately 15 mbgl, falling from 35 - 40 maOD in the south to 10 maOD in the north. Groundwater flows northwards. Water levels fluctuate seasonally by about 0.25 m, but in recent years they have shown a decline of approximately 3 m. Upward flow from the Chalk/Crag aquifers into the perched water-table sand aquifer is considered to be unlikely.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water comprises rainfall and generated runoff. In addition, overflow from the AWS PS contributes water to the site.

Groundwater seepages emerging from the Sand/Gravel phreatic aquifer within and outside the site are the main source of water to the wetland. Hydrogeological evidence indicates that chalk groundwaters do not contribute to the site.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4

The M13/14 stand is critically dependent upon groundwater inputs, but the source of these can be questioned on the basis of floristic and hydrochemical evidence. Whereas most examples of M13 in Norfolk seem to be dependent upon calcium rich (chalk) water discharge, this cannot be assumed for Sheringham & Beeston, where the water is somewhat less base-rich, and is considerably less well buffered, than that at many other sites. This may indicate either that the fen does not receive any chalk water, as suggested by hydrological evidence, or that a calcium rich water component is mixed with water from less base-rich sources.

Sheringham & Beeston Common appears to belong to a very select group of mires that are of fairly high pH but are not strongly buffered. Such systems appear to be *more* susceptible to damaging environmental change than the more strongly buffered examples, which may well account for their rarity. The main problem seems to be that such systems can acidify quite rapidly, leading to loss of the calcicolous component of the vegetation. They are particularly sensitive to drought-induced acidification (Boeye & Verheyen, 1994; Haesbroeck *et al.*, 1997) and may well be also particularly susceptible to pH changes driven by precipitation contaminants ('acid rain') (Kooijman, 1993). Although there is some evidence that drought-induced acidification is at least partly reversible, it is clear that such systems may be more disfavoured by drying than better-buffered examples. Moreover, if the system is partly fed by calcium rich water, any reduction in the proportion of calcium rich water within the total water inputs may render the site more vulnerable to acidification.

It is important to recognise that many of the details of the hydrochemical status of Sheringham & Beeston Common remain to be established and that the comments made here are based on limited hydrochemical information (though corroborated by the floristics). Nonetheless, there is a *prima facie* case that this site may be particularly vulnerable to changes in the quantity, and proportion, of groundwater supply, due more to indirect hydrochemical effects than to a direct effect of water levels within the fen.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 3 km there is one licensed abstraction from an impounded ditch, 600 m east of the site.

Groundwater: There are 7 licensed abstractions within a 3 km, amounting to 3599 tcma (114 l/s). The largest is by AWS for public supply at Sheringham, comprising 5 chalk boreholes at distances of 0.58 - 2.2 km south-southeast of the wetland. They have a total licensed abstraction of 1600 tcma (50.7 l/s) and a daily maximum of 650 m^3/d (75 l/s). Other abstractions, mainly from the Chalk, are minor. One abstraction from the Sand and Gravel at 950 m southwest of the site amounts to 92.7 tcma or 355 m^3/d (4.1 l/s).

4.2 IMPACT OF ABSTRACTIONS

Although the AWS public supply abstractions form the Chalk are substantial and fairly close to the wetland, they possibly do not exert any influence, as the Chalk appears to be hydraulically separated from the phreatic sand/gravel aquifer. Existing piezometries confirm this, however, the natural Chalk piezometry prior to abstraction is not known. The steep northward hydraulic gradients beneath the site are probably the result of groundwater discharges into the sea, 1 - 1.5 km north of the wetland. Nevertheless, the AWS abstraction closest (c. 580 m southwest) to the wetland (Licence No 7/34/05/G/036) could have caused a cone of depression with some impact on the potential for upward flow into the overlying Boulder Clay.

The eastern stream is said to have dried up, and the fen area to have become drier, probably over about the last 4 years. In previous years, the stream has not dried up, even during the drought in 1992.

The site has been assigned an AMP3 Water Abstraction Category 2. Present preliminary evidence does not indicate a direct relationship with the AWS PS abstraction.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

There is no known vegetation monitoring of the site. However, a base line NVC vegetation survey has been completed for the site (Smart, 1993).

5.1.2 Proposed Monitoring

Targeted vegetation monitoring every year is proposed. Some permanent marker ports will need to be installed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None. A staff gauge was considered for installation in the pond but was rejected due to possible vandalism.

Groundwater: Within the site; there are 2 shallow piezometers in sand/gravel.

Outside the site; Chalk and drift observation boreholes at 2 km west, close to the AWS Dales, Upper Sheringham abstraction; 1 borehole in drift at All Saints Church, near the Dales; and a Chalk borehole at Bodham 4.2 km southwest of the wetland.

5.2.2 Proposed Monitoring

Surface water: A staff gauge in the pond could be reconsidered.

Groundwater: Three observation boreholes near the AWS PS at Sheringham/Mundesle, (Licence No 7/34/05/G/036); one in Sand and Gravel; a second in the Crag (or Boulder Clay aquitard); and a third in Chalk.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

No investigations are proposed.

6.2.2 Hydrogeology

The following are proposed:

a) Survey of seepages/drains/ponds within wetland including levelling of water features, hydrochemistry and where possible flow measurements. Evaluation of data and preparation of report.

b) Cessation of pumping at abstraction licence No 7/34/05/G/036 for a period of approximately 15 days, to allow water level recovery. Measurement of water levels and establishment of present "non-pumping" piezometry in Chalk.

c) Following recovery, controlled long duration pumping test using the PS borehole (90 days); water level observations in existing and proposed boreholes for the purpose of evaluating the influence of PS on aquifers/aquitard. Analysis and evaluation of data.

6.3 ALLEVIATION MEASURES

To await the results of investigations. If investigations demonstrate the link between the AWS abstraction and wetland, options are:

a) Relocation of AWS source.

b) Compensation water from a new borehole or by diverting some of the AWS pumped water.

6.4 SITE MANAGEMENT

On-going vegetation management is required; problems are currently addressed by EN.

SITE: STANFORD TRAINING AREA

NGR: TL 870 940 **AREA: 4597 ha (11360 acres)**

1. DESCRIPTION OF SITE

The SSSI incorporates the main area of semi-natural vegetation within the MoD Stanford Training Area. The site mainly comprises grassland, heath and woodland, but also includes wetland areas and lakes. The latter form part of the series of 'Breckland Meres', which are of most concern in the current context. In character, they are similar to those described for the near-by East Wretham Heath, some having naturally-fluctuating water levels, with a characteristic invertebrate assemblage, while others are artificially maintained. The wetland areas also attract a variety of birds, many of which breed in the carr.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and supports a number of nationally-uncommon plants and animals, including non-wetland species. In the current context the main importance is that the site is part of the Breckland SAC, the notified interest being "naturally nutrient rich lakes which are often dominated by pondweed". The invertebrate assemblage associated with these lakes is considered of particular importance, and includes many rare species.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain the condition of the internationally important "naturally nutrient rich lakes which are often dominated by pondweed".
2. Restore and maintain the natural hydrological regime of the internationally important Meres to protect their characteristic invertebrate assemblages and vegetation structure.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

No direct evidence of change.

3. WATER RESOURCES

3.1 HYDROLOGY

The Stanford stream runs east-west through the centre of the site. It starts at Thompson Water in the east (this is an artificial lake, partly in Chalk, in Thompson Common SSSI) and flows westwards to join the River Wissey in the west. The River Wissey forms the northwestern boundary of the wetland. Agency staff, during a visit in April 1995, visually estimated the flow in Stanford Stream to be 80 - 140 l/s. In the southern part of the wetland, a smaller stream runs northwestward, also joining the River Wissey. Its northern branch starts at Bagmore Pit and its southern branch at West Tofts Mere.

The wetland is characterised by some 17 water filled depressions, many artificial and some natural. The more important ones are: a) West Mere in the eastern part of the site, which drains into the Stanford Stream; b) Stanford Water, an artificial lake on the Stanford Stream; c) Bagmore Pit which is probably man-made; d) West Tofts Mere situated at the southwestern boundary; e) Fowl Mere, Devil's Punchbowl and Home Mere, at the southeastern corner of the site, which are considered to be the best examples of fluctuating meres. Devil's Punchbowl represents a doline, a subsidence feature caused by solution of the underlying Chalk.

3.2 HYDROGEOLOGY

In the southernmost part between Smokershole and West Tofts Mere, there is a buried channel, aligned NW-SE, where deposits are probably 30 - 40 m thick. Another buried channel ends just outside the site at ThompsonWater. Elsewhere, drift deposits are 5 - 15 m thick, except locally in the northwest where the Chalk is exposed.

The hydrogeology beneath the site comprises:

- A DRIFT PHREATIC AQUITARD/AQUIFER which consists of Boulder Clay, brick earth and loams, alluvium, and Sand & Gravel. The Boulder Clay covers the northwestern and part of the mid-southern parts of the site. It forms the aquitard to the underlying Chalk aquifer, but sand layers within it can act as minor aquifers. Sand & Gravel southwest of the site forms a water-table aquifer, probably in hydraulic continuity with the underlying Chalk. The fluctuating meres and the Devil's Punchbowl are located within the Sand & Gravel. Groundwater levels in the Drift aquitard are surmised to be close to the ground surface, but their precise relationship to the Chalk below is not known due to the absence of drift piezometers.
- The CHALK UNCONFINED-SEMICONFINED AQUIFER. The Chalk aquifer occurs at depths of 5 - 15 mbgl, except where it is exposed in the northwest or at the buried channel in the south, where it may be 30 - 40 mbgl. It is semi-confined by the Boulder Clay and unconfined where it is exposed or where it occurs beneath Sand & Gravel. Along the Stanford Stream, groundwater levels are 1 - 2 mbgl in the winter and spring, but fall by a few metres in the summer and autumn. North of the stream, water levels are deep, 14 - 18 mbgl, and up to 29 mbgl in the autumn. In the southern part, they are again deep, 15 - 30 mbgl, except at Fowl Mere (Devil's Punchbowl) at the southern periphery where they are about 4 mbgl (minimum) and 13 mbgl (maximum). Piezometric elevations are about 30 maOD in the east falling to 20 maOD in the west (April 1983) but at present are probably a few metres lower. Groundwater flow is from east to west. Annual water levels fluctuate by 3 - 6 m. During the 1989 - 1992 drought, water levels fell by 5 - 9 m in the north and south, and by 2 - 7 m along the Stanford Stream.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water contributions are from rainfall, and runoff generated during periods of rain.

Groundwater feeds the wetland and provides baseflow to the stream when water-tables in the drift deposits are high, during the winter and spring. Upward flow from the Chalk into the drift is thought to be largely seasonal when water levels are high, but also localised, mainly along the Stanford Stream where topographic elevations are low, 20 - 30 maOD. At Fowl Mere (Devil's Punchbowl) minimum Chalk water levels are 25.06 maOD (13.28 mbgl) and maximum 34.33 maOD (3.95 mbgl). Water from the Chalk would enter the mere only at times of high water-table, providing of course it is deep enough to intercept it.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 3.

There is no reason to suppose that any of the vegetation present on this site *requires* groundwater input, though the site is undoubtedly dependent on groundwater inputs. It is a characteristic feature of these fluctuating meres that the extent and composition of the marginal vegetation varies annually in response to the frequency, amplitude and duration of water level fluctuations, and stable communities do not develop.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 7.5 km from the site there are 4 licensed water abstractions from drains, lagoons and the River Wissey.

Groundwater: There are 38 licensed abstractions within 7.5 km, mainly for domestic and agricultural use. Most are from the Chalk and a few from Sand & Gravel. Abstractions are less than 50 tcma, except for two by AWS for PS, which are:

a) 2 Chalk boreholes at High Ash, 7.0 km NW of the centre of the site, licensed at 675 tcma (121.4 l/s), daily 3500 m^3/d (40.5 l/s).
b) 2 Chalk boreholes at Mundford, 7.0 km W of the centre of the site, licensed at 159.11 tcma. (5.05 l/s).

Both are at 3 km from the western site boundary.

Within a 10 km radius, AWS are licensed to abstract at Watton at 1278 tcma (40.5 l/s), daily 3500 m^3/d (40.5 l/s), and the Environment Agency from 24 boreholes at various locations (Brettenham, Harling, Hockam, Wretham, Roundham, etc) at a combined licensed of 13070 tcma (414 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the wetland.

Groundwater abstractions, especially those of AWS at High Ash and Mundford at the western boundary of the wetland probably contribute to the depression of water levels in the western part. It is suspected that their effect on Fowl Mere and Home Mere, situated 9 - 10 km to the southeast, is negligible. Any recent declines in the water supply of the wetland are probably the result of recent low rainfall conditions rather than PS abstractions.

The wetland has been assigned an AMP3 Water Abstraction Category 3. This present preliminary evaluation confirms this.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None known.

5.1.2 Proposed Monitoring

None proposed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None.

Groundwater: Within the wetland: There are 14 Chalk boreholes, of which some have been monitored by the Agency, since 1969 and others since 1977.

Outside the wetland: Within 8 km, there are 58 boreholes (8 in Chalk and the remainder in Drift) plus those which have recently been installed at East Wretham. The earliest monitoring started in 1967.

5.2.2 Proposed Monitoring

Surface water: 4 gaugeboards (Bagmore Pit, West Mere and Stamford Stream)

Groundwater:

a) 2 piezometer clusters; at each cluster one drift (4 -5 m deep) and one Chalk borehole (20 - 30 m deep): 1 cluster at Bagmore and a second at West Mere.

b) 6 shallow drift (2 - 5 m deep) piezometers adjacent to existing Chalk boreholes (within the wetland).

c) 2 piezometer clusters (drift, 5 - 10 m deep, and Chalk 20 - 30 m deep) between High Ash AWS PS and the wetland at a distance of approximately 500 m and 1500 m from the source. This is in order to determine the extent of the cone of depression.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

A base-line survey of the aquatic invertebrates is proposed, although it is recognised that it will be very difficult to relate any future change directly to abstraction issues.

6.2.2 Hydrology

Evaluation of data after the proposed monitoring installations have been constructed.

6.3 ALLEVIATION MEASURES

To be defined after a period of monitoring (up to 3 years).

6.4 SITE MANAGEMENT

Not relevant.

SITE: YARE BROAD AND MARSHES (STRUMPSHAW FEN)

NGR: TG 3300 0630 **AREA: 197 ha (488.7 acres)**

1. DESCRIPTION OF SITE

Strumpshaw Fen RSPB reserve comprises 197 ha of open water, reedbed/fen, carr, woodland and grazing marsh. Much of the vegetation on this site is highly degraded, probably in response to various influences. It is important to recognise that the present degraded communities were not always present, though equally lack of documentary evidence makes it difficult to trace the processes of vegetation change.

In the early 1970s Strumpshaw Fen was broadly similar to Wheatfen (on the opposite side of the river). Much of its was typical, colourful forb-rich 'Yare Valley Fen' (*sensu* Pallis, 1911), though more derelict than at Wheatfen. The former communities with *Cinclidium stygium* (referred to in the EN Objectives) had long since disappeared. The land margin edge was slightly more diverse than the more riverward areas, with a greater abundance of such species as *Carex appropinquata* (in this respect also showing the same pattern as at Wheatfen). Since the 1970s there has been a further loss of diversity.

Much of the fen vegetation is of NVC type *Phragmites australis–Peucedanum palustre* fen (S24). Nationally-scarce plants include water soldier *Stratiotes aloides,* marsh pea (*Lathyrus palustris*), cowbane (*Cicuta virosa*) and marsh sow-thistle (*Sonchus palustris*). Over 80 species of bird breed on the reserve, including the RDB species bearded tit (*Panurus biamicus*), marsh harrier (*Circus aeruginosus*), Savi's warbler (*Locustella luscinoides*) and Cetti's warbler (*Cettia cetti*). The site is also important for invertebrates, including the 'endangered' swallowtail butterfly (*Papilio machaon*), plus a number of RDB and nationally-notable species.

2. ECOLOGY

2.1 CONSERVATION INTEREST

Strumpshaw Fen is part of the Yare Broads and Marshes SSSI. The site lies within The Broads SAC and Broadland Ramsar Site and SPA.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

<u>SPA objective</u>

- Increase the internationally important populations of breeding bittern and marsh harrier. Breeding bittern will only return to the Yare valley following improvements to the habitat and water quality. The RSPB are currently undertaking a programme of habitat improvement on the fen.

SAC objectives

- Increase the extent of, and enhance the condition of the internationally important chalk-rich fen dominated by saw sedge (great fen sedge). This objective refers to the S2 and S24 vegetation types. These vegetation types are situated within the northern part of the fen, in areas that have been extensively peat cut in the past (Parmenter pers. comm.).
- Enhance the condition of the internationally important naturally nutrient rich lakes and dykes which are often dominated by pondweeds. This objective refers to water bodies both within the Strumpshaw Fen and Common sections, and includes invertebrate interest. Improvements in water quality on the site and the reduction of the river supply are required to achieve the objective.
- Maintain internationally important populations of Desmoulins snail. EN believe this objective is not relevant to the present case (as this snail is not considered to be particularly sensitive to variations in water level and nutrients).
- Maintain the internationally-important 'alder woodland on floodplains'.

Ramsar features

- Criterion 1a; many good and representative examples of wetland habitats characteristic of the biogeographic region. EN contend that this project would improve the quality of the wetland.
- Criterion 2a; supports an outstanding assemblages of rare plants and invertebrates. Within the Broads site, this includes 9 RDB plants including Cinclidium stygium, a species formerly present at Strumpshaw, and 136 RDB invertebrates. Improvements to water quality on the site would be of benefit to this feature.
- Criterion 3c; recognises a number of bird species which include the bittern and marsh harrier, as the SPA feature/objective.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

Considerable changes have occurred on site over a long period of time, in particular as a result of deterioration of water quality in the River Yare. In 1978, the RSPB instigated a work programme to protect the broad and surrounding fen from the polluted river water. This was carried out by damming off the main dyke linking the River Yare with the broad and fen, and building up embankments around the fen. In order to compensate for lack of river water, water is extracted from a compensation borehole sunk into the underlying Chalk (185,000 m^3 in 1989) in order to help maintain the conservation interest of the fen. Additional work has included 'mud-pumping' the broad, clearance of scrub/carr, re-instatement of reed cutting, clearance of dykes and excavation of 4 ha of shallow turf ponds.

A report by Tickner et al (1991) describes the management work, and subsequent progress towards recovery, including improvements in water quality, increase in aquatic macrophytes in the broad and dykes. Changes in the fen vegetation were slow, but there was some indication of an increase in *Phragmites australis*, and a decline in such species as *Glyceria maxima* and *Epilobium hirsutum*, possibly in response to improvements in water quality. Invertebrates and birds also responded positively to the improvements in habitat, in species numbers and breeding populations. Scrub encroachment is an ongoing problem. (Higher water levels could help to alleviate the problem, but would not solve it).

There is no doubt that substantial changes have occurred, probably related to both drying and nutrient enrichment, though it can be difficult to separate the two as in these systems considerable nutrient release can be induced by drying (this was evident at Wheatfen: one drought year resulted in a switch from a relatively diverse, *Phragmites*-dominated community to a very impoverished community with much *Epilobium hirsutum, Filipendula ulmaria* and *Urtica dioica*).

Ecologically, there is no doubt that, as with most Broadland fens, Strumpshaw Fen is naturally a system where water-tables are strongly influenced by river water levels. This almost certainly means that parts of the fen show a natural tendency to dry out considerably in drought years. However, even without such extreme events, the natural character of the vegetation of the Yare Fens is almost certainly partly a product of a greater degree of seasonal water level fluctuation than is found in the northern valleys of Broadland. The richness of the distinctive 'Yare Valley Fen', described by Pallis (1911), in dicotyledons (including uncommon species such as *Lathyrus palustris*) is almost certainly because these fens naturally have relatively low summer water levels and are slightly more nutrient rich than many other fens in Broadland. It thus seems likely that attempts to exclude river water from the systems will shift these systems away from their natural condition. Likewise, attempts to make good the water deficit induced by exclusion of river water by the introduction of a supplementary supply will also shift the system from its natural state. Nor is such an approach addressing the real cause of the problem. It is fully recognised that the desire to exclude river water from parts of Strumpshaw Fen stems mainly from the nutrient richness of this water, but we would suggest that as this fen is naturally fed primarily by the river, the only real solution to reinstating its former character is to reduce the nutrient loadings in the river.

Moreover, it is important to recognise that Strumpshaw is not the only fen the Yare Valley, nor is it necessarily any 'better' than some of the other examples (Wheatfen has long displayed some of the 'best' vegetation gradients, and greatest floristic diversity and remains a particularly good example of Pallis' 'Yare Valley Fen'). Many, if not all, of these sites would benefit substantially from improvement in river water quality.

3. WATER RESOURCES

3.1 HYDROLOGY

The Strumpshaw Marshes are situated in the lower tidal reaches of the Yare Valley. The River Yare marks the eastern boundary of Strumpshaw Fen. In the west, the Fen is bounded by a railway line. The marshland is drained by numerous interconnecting dykes. Under natural conditions, flooding by the River Yare led to the formation of a reed swamp, whose decay resulted in peat deposits and a rise in surface elevation. As a result, the areas of open water have become progressively smaller, as indicated by topographic maps dating back to 1846, 1881 and 1946.

Embankments were built along the River Yare and the Strumpshaw Broad, and the River Yare was drained in the 19th Century by a windmill. A central embankment was built in 1881. The embankment was breached by the summer flood of 1916. Since

1975, the RSPB have been managing the site, which was divided into three "Management" parts:

(a) An area west of Lockford Run where the system of drains is open to the River Yare and Lockford Run, and strongly tidal;
(b) An area east of the Lockford Run and west of the central embankment; in 1978-1980 the RSPB restored the river banks and isolated this part from the River Yare in order to provide a suitable habitat for certain rare birds and flora which were adversely affected by the poor quality of the River Yare and Lockford Waters. Except for one sluice gate that can allow water to enter from the Yare, it is entirely dependent on rainfall;
(c) An area east of the central embankment, with water levels being controlled by a drainage pipe.

In 1985, the mud in Strumpshaw Broad was pumped out and the area of open water increased.

3.2 HYDROGEOLOGY

The hydrogeology beneath the wetland comprises:

- A near surface estuarine CLAY/MUD AQUITARD which is approximately 10 m thick near the River Yare, thinning to 3 - 4 m away from the River Yare, towards the railway embankment. Water levels in shallow (1 - 2 m deep) piezometers in October 1986 were 0.04 to 0.2 maOD with a hydraulic gradient toward the centre of the Fen.

- The mixed fen/brushwood PEAT SEMI-UNCONFINED AQUIFER, which is approximately 4 m thick thinning to 2 m away from the River Yare towards the railway embankment. The peat aquifer is in hydraulic continuity with the Crag Sands below. Water levels in deep piezometers (approximately 5 m deep) in October 1986 were 0.01 to 0.18 maOD, ie a few centimetres lower than the water levels of the overlying clays. The water level difference suggests downward flow from the aquitard into the peat and Crag below. Seasonal fluctuations can reverse this position.

- The SEMI-UNCONFINED CRAG SAND AQUIFER (15 m thick) occurs below the peat, except near the railway embankment and north of it where it crops out at the surface. Further north it is capped by Boulder Clay. It is in hydraulic continuity with the peat above and with the Chalk below. At the wetland, its piezometric head is around 0 m OD, and similar to that of the peat, but rises to 2 - 5 maOD in the northeast. Its regional direction of flow is similar to the Chalk, ie southwestward, toward the River Yare.

- The SEMI-CONFINED CHALK AQUIFER which occurs at a depth of 20 - 25 mbgl. Its regional piezometry indicates a water level of 0 m OD in the wetland rising to 5 m OD in the northeast. The cone of depression around the AWS PS has most probably modified the local piezometry in the Chalk. The drawdown at the marsh support borehole 700 m west of the PWS borehole showed a drawdown of 0.5 m after 17 hours pumping the PWS (M Martin, 1987). At the marshland borehole, the maximum water level (1986) was 0.5 mbgl. In the marshes, the Chalk water levels under natural conditions were probably above ground level, and therefore artesian. It appears that under natural conditions there was potential for upward flow of Chalk water via the Crag sand into the peat above. Under the 1986 conditions, groundwater levels in the Chalk were lower than those in the overlying peat/ ? top of the Crag, indicating downward leakage into the Chalk.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water comprises rainfall and flood waters from the adjacent River Yare. In historic times, this was probably the main source of water to the wetland. The building of embankments, drainage works, and management practices have over the years modified river water inputs.

Groundwater contributes to the wetland by upward leakage from the Chalk aquifer, but also from rain water retained in the past. The natural build up of the Fen in historic times, drainage works in the 19[th] Century and nearby abstraction from the Chalk since 1951, have all contributed to changes in groundwater supply to the wetland. In comparison to surface water, the groundwater component has probably been minor, except during periods of drought or in the Summer and Autumn.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Categories: 2

There is no reason to suppose that any of the vegetation present on this site, or that which used to occur (including the former *Cinclidium stygium* vegetation) *requires* groundwater input, though it is possible that this site naturally received some marginal groundwater discharge.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the wetland, there are licensed abstractions from dykes, streams and the River Yare.

Groundwater: Within 5 km from the wetland there are 17 groundwater abstractions from wells and boreholes. The most important is that operated by AWS for PS at Strumpshaw, 1.21 - 1.35 km from the centre of the wetland. It is licensed to abstract from the Chalk at 2000 tcma (63.4 l/s) and maximum daily at 7500 m^3/d (86 l/s). It comprises 3 boreholes, at TG 341 068 and 1 at TG 339 073.

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions are not considered to have any impact on the wetland. However, the construction of embankments adjacent to the Yare and the central embankment within the wetland have reduced the surface water component, particularly in the part of the wetland between east of the Longford Run and west of the central embankment, which now relies on rainfall. River water enters through dykes in other parts of the wetland.

Groundwater contributions, which reportedly used to derive from upward leakage from the Chalk, have possibly decreased as a result of abstraction from the AWS PS at Strumpshaw. Reported piezometries suggest that flow has now been reversed, ie downward leakage from the peat into the Chalk.

Though there appears to be little doubt that abstraction has lowered water levels in the Chalk, the natural hydraulic relationship of this aquifer with the near surface peat and overlying clays remains uncertain, especially in the light of historic natural changes in the fen topography and modifications of the surface water regime in the last two centuries, and more recently in 1978-1980. It is possible that groundwater contributions in the historic past have been small and that the wetland was primarily sustained by surface water incursions during flooding. It is also possible that the sealing off of part of the wetland by the RSPB in 1978-1980 deprived the wetland of its main source of water supply. In conclusion, given the nature of the vegetation, and the existence of some comparable changes at Wheatfen, where groundwater abstraction is not thought to have much influence on the water balance, there is little reason to suppose that groundwater abstraction is the proximate cause of the observed changes at Strumpshaw. It seems more likely that the changes relate partly to natural water deficits and to reduction of river inflows as part of a water management strategy.

The site has been assigned an AMP3 Water Abstraction Category 1. In this preliminary assessment, it has not been possible to confirm this. Moreover, indications are that a Category 2 may be more appropriate.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

RSPB monitor the main key species of birds (bittern, marsh barrier and bearded tit), marsh pea and swallowtail butterfly.

5.1.2 Proposed Monitoring

None proposed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: Not known, but possibly none.

Groundwater: Within the Fen: Not known, but possibly none. During 1986, eight shallow (2 - 3 m) and eight deep (5 m) piezometers were installed in the wetland and monitored during June - February 1986, as part of the borehole compensation Chalk borehole scheme (M Martin, 1987).

Outside the Fen: The Agency have monitored since 1977 one Chalk borehole at Strumpshaw 2.4 km northeast (TG 3528 0724).

5.2.2 Proposed Monitoring

Surface water: If appropriate, staff gauges in the drains and Strumpshaw Broad (assume 6 no).

Groundwater: If none exist, piezometers should be installed in clusters in the following approximate numbers at locations within the fen to be decided at a later date.

Organic Clay	:	10 no (1 - 2 m deep)
Peat	:	10 no (2 - 6 m deep)
Crag	:	10 no (3 - 12 m deep)
Chalk	:	1 no (35 m deep) adjacent to one of the cluster sites

In addition, 2 more Chalk boreholes (35 - 50 m deep) should be installed at the following approximate locations:

- 1 no approximately 100 NE of the 2 PS boreholes
- 1 no approximately 500 SE of the 2 PS boreholes
- 1 no approximately 500 SW of the 2 PS boreholes, close to the River Yare.

Note: This proposal should be seen in the context of further investigation.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

None proposed. The vegetation was surveyed as part of the Broadland Fen Resource Survey (Parmenter, 1995).

6.2.2 Hydrology

The following are proposed:

a) As a first priority, the water quality of the River Yare should be fully investigated (including that of the dykes, ponds, etc and of the AWS PS boreholes) in order to establish: (i) the hydrochemistry of all waters; (ii) any recent improvement in the quality of the River Yare, in relation to nutrient levels; and, (iii) the suitability of this water (it is understood that water quality has improved) for use in the now "sealed" part or other parts of the wetland.

b) A study as to the reasons why the compensatory marsh borehole has not been the appropriate solution.

c) After a) and b) have been completed, installation of piezometers as proposed in 1.6.2 above including groundwater sampling and chemical analysis.

d) A controlled long duration (120 days) pumping test using the 2 AWS PS boreholes and the proposed and existing boreholes (1 AWS PS and compensation borehole) for the monitoring of water levels and hydrochemistry. Prior to the test, the 3 AWS PS boreholes should be shut down for a minimum of 10 days, in order to establish near non-pumping conditions. The single AWS PS (TG 339 073) should be shut down during the test period. All data should be analysed and reported on with the objective of establishing the impact of the PS on groundwater levels and the wetland.

6.3 ALLEVIATION MEASURES

To await the results of the investigations. Various options could include:

a) Use of river water (raw), if water quality permits.
b) Use of treated river water to remove nutrients.
c) Compensation water comprising mixture of river water and groundwater.
d) Temporary cessation of abstraction or reducing AWS licence and monitoring of results.
e) Revoking of licence and relocation.

The options that probably have the greatest likelihood of success are a), b) and c). ← cost out

6.4 SITE MANAGEMENT

On-going vegetation management is required to prevent/control scrub invasion.

PART B

NON HABITATS DIRECTIVE SSSIs

Beetley & Hoe Meadows

Didlington Park Lakes

Kenninghall

Scoulton Mere

Whitwell Common

Dernford Fen

Sawston Hall Meadows

Cattawade

SITE: BEETLEY AND HOE MEADOWS (BEETLEY)

NGR: TF 982 174 **AREA: 6.74 ha (16.6 acres)**

1. DESCRIPTION OF SITE

Two more-or-less adjoining areas of fen, grassland and wood on opposite sides of a major tributary stream of the River Wensum. Most of the fen interest occurs in the northern meadow (Beetley) where there are some strongly flushed areas of fen, as well as fen meadow and wet grassland. The flush vegetation is of greatest interest at this site, with elements of both base-rich and more base-poor conditions (*Carex demissa* occurs rather than *C. lepidocarpa*). These are in proximity with a "heathy grassland", probably of similarly variable base-status.

The site is a Norfolk Wildlife Trust Reserve.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, but has no international designations. EN consider the main wildlife interest lies in the *Juncus subnodulosus–Cirsium palustre* fen meadow (M22) and other fen meadow/mire types.

This site has a range of grassland communities, from relatively dry grassland to marshy grassland, as well as some small areas of spring fed fen. Although there is a quite high species count overall, this site supports few rare wetland plants. Moreover, most of the wetland areas do not conform very well to established vegetation units, but tend to support rather esoteric species combinations. The reasons for this are not known.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain and enhance the extent and species composition of the grassland communities by cattle grazing.
2. Ensure adequate water flows and levels are sustained to maintain the strongly flushed areas of fen.
3. Control scrub, bracken and other invasive species, to maintain variety, but prevent loss of open grassland habitats.
4. Develop greater knowledge of invertebrate species, and take their needs into account in management.
5. Ensure the anthills are maintained.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

As far as has been ascertained, all data for this site are recent so it is not known to what extent changes have occurred. It is considered possible that the area of fen meadow/mire vegetation has contracted in response to perceived drying of the seepage slope, although there is no direct evidence for this.

3. WATER RESOURCES

3.1 HYDROLOGY

The southern boundary of Beetley Meadow is defined by a tributary stream of the River Wensum. The tributary runs northeastwards; irrigation reservoirs exist upstream and downstream. The site is drained by dykes which are overgrown and drain southwards into the stream. There are several indistinct seepages, with the wettest ground in the northern part of the site (1996).

3.2 HYDROGEOLOGY

Beetley Meadow is situated in a buried channel, approximately 500 m northeast of Hoe Meadow. The hydrogeology beneath the site comprises:

- A near surface (0 - 4 mbgl) PHREATIC SAND/GRAVEL AQUIFER which is underlain by Boulder Clay. In September 1997, water levels were approximately 2 mbgl (33.3 maOD) in the extreme north and 1 mbgl (27.1 maOD) in the south, 400 m north of the stream. Thus, groundwater flow is to the south, towards the tributary stream, which probably receives groundwater from the aquifer, especially at times of high water-table. The regional direction of flow is northeastward, along the stream valley, but locally converging into the valley.

  Water levels outside the wetland (near the Beetley and Dereham AWS PS) fluctuate seasonally by 2 - 2.5 m, and have fallen during the 1989-92 drought by 4 - 5 m.

- A BOULDER CLAY AQUITARD (11 m thick) which forms the base of the phreatic sand/gravel and the confining aquitard to the Chalk below.

- The SEMI-CONFINED UPPER CHALK AQUIFER which occurs at a depth of approximately 15 mbgl (20 maOD). In the northernmost part of the site, the groundwater level in September 1997 was approximately 3 mbgl (31.8 maOD), that is 1.5 m below the water-table of the sand/gravel aquifer. In the southern part closer to the stream, where topographic elevations are approximately 28 maOD (7 m lower than the northernmost part), the Chalk water levels are likely to be 3 - 4 m above ground level and therefore conditions would be artesian flowing, as is the case in Hoe Meadows. Thus, in the northern half of the meadow, there is minimal potential for upward leakage from the Chalk into the sand/gravel, though water may enter the lower part of the Boulder Clay. In the southern part, there is potential for upward leakage but the amounts would depend on the permeability of the Boulder Clay. In addition, to the vertical component, regionally groundwater in the Chalk moves to the northeast, converging locally into the stream valley.

  Water level fluctuations vary at about 1 m seasonally, but have fallen during recent drought by 2.5 - 3.0 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water comprises runoff generated during rainfall. The stream which runs along the southern boundary of the wetland may enter adjacent land during periods of high water levels in the winter months.

Groundwater is the main source of supply to the wetland. Seepages from the Sand & Gravel aquifer occur where the water-table intersects low lying ground. In the southern most part of the wetland, upward leakage from the underlying Chalk aquifer contributes to the Sand & Gravel and to the wetland. In the northernmost part, contributions from the Chalk aquifer would only occur during times of high chalk water levels, but not during the recent periods of low rainfall.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4

Some of the 'fenny' vegetation at this site has little dependence on groundwater inputs, but the more strongly flushed areas are groundwater dependent. The floristic composition of the seepage areas suggests that it is likely to be from drift rather than chalk.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: There are 4 licensed abstractions within 5 km from the wetland.

Groundwater: There are 60 licensed groundwater abstractions from boreholes, wells and groundwater seepages. The largest are by AWS for PS at:

a) Beetley Meadow: 2 Chalk boreholes at 1.49 km NE, 1100 tcma (34.88 l/s), daily 4000 m^3/d (46.3 l/s).
b) 2 Chalk boreholes at Hoe; 1.75 km SE, and 3 Chalk boreholes at E Dereham/Hoe 3.32 km SE; 1364 tcma (43.25 l/s); daily 3100 m^3/d (35.88 l/s) from Hoe and 100 m^3/d (11.57 l/s) for E Dereham.

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions are not considered to impact on the wetland.

The large number of groundwater abstractions from the Chalk have an overall impact in depressing groundwater levels, which together with recent low rainfall conditions, combine to reduce replenishment of the Sand & Gravel by upward flow from the Chalk. Also, low rainfall has meant less recharge by direct infiltration to the Sand & Gravel. The nearest AWS PS abstractions have probably been a factor in lowering water levels. However, at present the impact on the wetland groundwater regime has been mainly on the seepage slope in the northernmost part where the Sand & Gravel occurs at high ground and where seepages have apparently dried. In the remainder of the wetland upward leakage from the Chalk still occurs.

The site has been assigned an AMP3 Water Abstraction Category 3. The present preliminary evaluation agrees with this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

There is no known ecological monitoring at the site.

5.1.2 Proposed Monitoring

Carefully targeted annual vegetation monitoring on the seepage slope is proposed. Some permanent marker posts will need to be installed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None.

Groundwater: Within the wetland: There are 3 piezometers; 1 in Chalk and 2 in Sand & Gravel.

Outside the wetland: There are 9 observation boreholes within 5 km radius: 6 in Chalk and 3 in Sand & Gravel. Near Beetley AWS PS there are 2 piezometers (TF91/886A, B) in Chalk and Sand & Gravel, and similarly at 500 m NW of Dereham PS (TF91/864A,B).

5.2.2 Proposed Monitoring

Surface water: None.

Groundwater: 1 piezometer in Chalk (approximately 30 m deep) and 1 in Sand & Gravel between the wetland and the Beetley PS (TF 985 184) to establish the extent of the cone of depression.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

No ecological surveys are proposed. A detailed NVC survey of the site is available (Smart, !993).

6.2.2 Hydrology

Water level monitoring; hydrochemistry of groundwaters; and re-evaluation of hydrogeology using proposed boreholes.

6.3 ALLEVIATION MEASURES

The following are proposed:

a) Reduction/relocation of AWS PSs to await to results of monitoring.
b) Consideration to be given to using a compensation Chalk borehole to augment water supply in the northern part of the Fen.

6.4 SITE MANAGEMENT

On-going vegetation management is required.

SITE: DIDLINGTON PARK LAKES

NGR: TL 777 963 **AREA: 25.9 ha (62 acres)**

1. DESCRIPTION OF SITE

The site consists of three shallow artificial lakes, probably constructed in the nineteenth century. The marginal and swamp vegetation is well developed and diverse, including reed (*Phragmites australis*), meadowsweet (*Filipendula ulmaria*), lesser reedmace (*Typha angustifolia*), sweet flag (*Acorus calamus*), bogbean (*Menyanthes trifoliata*) and purple loosestrife (*Lythrum salicaria*) greater tussock sedge (*Carex* paniculata). The breeding and wintering bird populations are important, particularly breeding gadwall (*Anas strepera*).

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, but has no international designations. EN consider the main wildlife interest to be the "Eutrophic marl lake". The breeding and wintering bird populations are also important, including the RDB species, gadwall. The latter is also listed on the BAP long list of globally threatened/declining species.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Ensure suitable conditions for breeding gadwall are maintained.
2. Ensure that the water quantity and quality reaching the lakes adequately supports the notable features, especially breeding and wintering bird populations.
3. Achieve bank full water levels during the summer months, if bank condition allows.
4. Develop a broader information base concerning invertebrates present and birds using the lakes.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

Obvious changes have been observed as a result of lack of open water, for example, lack of water fowl etc.

3. WATER RESOURCES

3.1 HYDROLOGY

The Didlington Park Lakes consist of two man-made lakes, approximately 1.2 m deep, but shallower in places. The upper lake is believed to be clay lined and retaining water throughout the year. The lower lake has apparently no lining; it fluctuates seasonally and has been dry every summer since 1990. The upper lake is at an elevation of 8 - 10 maOD and the lower at 8 - 9 maOD. The southern boundary of the lower lake is bordered by the River Wissey.

The lakes are fed by the Moor Plantation Spring (approximate elevation 13 maOD) situated approximately 650 m NE, via a stream which discharges into the Upper Lake. In February 1997, the flow was 25 - 30 l/s. Water overspills into the lower lake across a weir. Two outfalls and seepages from the lower lake are the main outflows. Historically, the lakes were also fed by a "contour ditch", known as the Trout stream, which joins the Moor Plantation spring stream channel. In September 1997, no flow was observed. Drainage works have probably affected the flow of Trout stream, such that at present it does not contribute to the lakes.

3.2 HYDROGEOLOGY

The hydrogeology beneath the site is not well known. From regional information, it appears to consist of:

- Alluvial sediments which together with fine grained lacustrine deposits form a thin (? up to 10 m) low permeability AQUITARD. The alluvium extends in a thin strip along the valley of the River Wissey.
- The mainly UNCONFINED UPPER CHALK AQUIFER, which occurs at the surface in the northeast where the Moor Plantation spring issues. Northwest of the lakes, the Chalk is covered by Boulder Clay, a few metres thick. Groundwater levels in the Chalk are close to ground surface. In 1976, piezometric elevations were 7 - 8 maOD (Hydrogeological Map of Northern East Anglia). Groundwater flow is to the southwest, towards the valley of the River Wissey. A number of springs in the area emerge where the Chalk water-table intersects with the surface topography. The Moor Plantation Spring originates from the Chalk whilst the Trout Stream probably cuts through the Chalk water-table. There are no data on spring flows. Groundwater levels in observation boreholes fell in general by 2 - 5 m in 1989 - 1992, recovered in 1993 - 1994, and fell again in 1995 -1996. The decline in water levels coincides with both a variation in the AWS abstraction licence at High Ash and the onset of low rainfall. Seasonal fluctuation are 1 - 3 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Some surface water may enter the lower lake from the River Wissey.

Groundwater appears to be the main source of water. It is in the form of spring flow at the Moor Plantation which discharges into a stream and conveyed to the lakes. The chalk fed Trout Stream, which reportedly in the past discharged into the Moor Plantation stream, has had no flow for a number of years.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 3.

There is no reason to suppose that any of the vegetation present on this site *requires* groundwater input.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: There are 8 licensed abstractions within 5 km from the site, some from drains or dykes and others from the River Wissey.

Groundwater: There are 28 licensed abstractions, all from the Chalk aquifer. They are mostly small (mainly for irrigation) except for 3 operated by AWS for PS. They are:

a) 2 boreholes at High Ash, 2.94 km ENE, licensed at 675 tcma (21.4 l/s), daily 3500 m^3/d (40.5 l/s).
b) 2 boreholes at Mundford, 3.64 km SE, licensed at 159.11 tcma (5.05 l/s), daily 436.4 m^3/d (5.05 l/s).
c) 4 boreholes at Wellington, 3.96 - 4.38 km, S, licensed at 1000 tcma (31.7 l/s), daily up to 15000 m^3/d (17.36 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the lakes.

Regional groundwater fluctuations have declined in the period 1988-1992, and more recently in 1994 - 1995, as a result of low rainfall. Water levels in 1993-1994 rose to the same level as before 1988. The water-level fluctuations do not indicate a fall in the Chalk water-table that can be directly linked with the AWS PS abstractions. Of course, abstraction for both PWS and for irrigation, has an effect on the water-table, and by extension, on spring flows, but the recent low water levels are not thought to have been the direct result of abstractions. As spring flows have not been monitored, it is not possible to ascertain whether a decrease in their flows has occurred.

The site has been assigned an AMP3 Water Abstraction Category 2. The present preliminary study tends to suggest that drainage works in the Trout Stream, low rainfall in recent years and considerable seepages through the walls of the lower lake, perhaps enhanced by desiccation cracks, are the main factors that have adversely affected the hydrology of the lakes. The lower lake is also quite silted up and shallow, which means that falling water levels expose the 'base' more rapidly than previously. Thus, PS abstractions might have had only a minor effect, which suggests a Category 3.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None is known.

5.1.2 Proposed Monitoring

Annual count of breeding birds, especially gadwall, including repeated site visits during breeding season.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None.

Groundwater: None in the proximity of the site.

4 regional Chalk boreholes at distances of 1 - 4 km from the lakes, the nearest approximately 1 km east.

5.2.2 Proposed Monitoring

Surface water: (Per Agency report, September 1997)

a) weir in stream to measure Plantation Spring flows.
b) gaugeboards in upper and lower lakes.
c) weir to measure flow in ditch south of River Wissey.

Groundwater:

a) 2 Chalk piezometers (10 - 15 m deep): one near the Moor Plantation Spring, and a second near the lower lake.
b) 6 shallow drift piezometers (3 - 5 m deep), in the lower lake and downstream of the lakes, to determine of seepage rates.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

None is required.

6.2.2 Hydrology

The following are proposed:

a) Auger holes (12 no) in lakes to determine the nature of lake deposits.
b) Topographic survey to determine lakes profile and assist in establishing rate of seepages.
c) Field inspection of seepages and hydrochemical survey.
d) Hydrological balance of lakes.

6.3 ALLEVIATION MEASURES

To await the results of the investigations. Available options include (as per Agency Report, September 1997):

a) Provision of additional water to the lakes by means of a Chalk borehole close to the lake.
b) Works to reduce seepages from the lower lake including lining and/or construction of a bund in the lake southern periphery.
c) Deepening of the lower lake by removal of accumulated sediment, and maintaining lower water levels.
d) The preferred option could be a combination of supplementary water supply (a) and deepening of the lake (c).

6.4 SITE MANAGEMENT

Not required.

SITE: KENNINGHALL AND BANHAM FENS

NGR: TM 041 875 **AREA: 48.9 ha (120.8 acres)**

1. DESCRIPTION OF SITE

A large valley fen complex in the River Whittle valley, containing a deep (10 m), natural mere (Quidenham Mere). Kenninghall Fen and Banham Great Fen are situated on the eastern side of the valley, while Quidenham mere is situated in the valley centre. Higher ground rises to the south-west, north and east of the site.

Quidenham Mere is largely surrounded by fen carr, including wet ashwood and wetter alder carr. Kenninghall Fen is south of the mere and some of the slopes are obviously spring fen, supporting extensive areas of fen meadow with smaller patches of *Schoeno-Juncetum* {~M13}, with some patches of *Carex elata* "swamp" and some areas of *Cladium* and *Phragmites* dominance. By contrast, Banham Great Fen, to the north of the mere has extensive, rather dry, beds of sedge and reed, with some marginal *Cirsio-Molinietum* (~M24).

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, but has no international designations. EN consider the main wildlife interest of the site to be *Schoenus nigricans–Juncus subnodulosus* mire (M13), *Juncus subnodulosus–Cirsium palustre* fen meadow (M22), *Cladium mariscus* sedge swamp (S2) and reed swamp.

Banham Fen supports communities of international importance (S2, M24), and some nationally-rare species.

According to Dr Wheeler, the site contains a range of vegetation-types and, overall, has quite high diversity, but individual components tend to be rather disappointing and not very good examples. The (mostly small) examples of M13 do not support many of the rarer species that are often associated with this community, but the reason for this is not known. Nor is it known if these stands were once richer (their present character is similar to that in the late 1970s).

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Ensure ground water flows, drain levels and water quality are maintained to fully support the wetland communities.
2. Maintain the extent and species diversity of the notifiable swamp and mire communities.
3. Control invasive vegetation, especially scrub, to the advantage of the open fen/grassland/mire communities, particularly on Banham Great Fen.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

There is some evidence of loss of diversity on both Kenninghall Fen and Banham Great Fen, but a sparsity of appropriate records constrains assessment. EN have reported a marked change of reed/sedge bed vegetation on Banham Great Fen towards *Arrhenatherum* / thistle / nettle-dominated grass sward. Banham Great Fen was once mown for sedge and its current impoverished state may well relate partly to dereliction. Groundwater abstraction has been suggested as a cause of deterioration, though in the early 1980s, when this area was quite wet in the summers, its vegetation was that of species-poor *Cladium* beds of limited floristic value. Kenninghall Fen has also suffered from a reduction of grazing although this has been re-instated within the last few years, resulting in considerable improvements to the vegetation (SR, pers. comm).

[Another major problem on the site is the high percentage of effluent flow in the summer months direct into Quidenham Mere which also affects Kenninghall Fen.]

3. WATER RESOURCES

3.1 HYDROLOGY

The site is characterised by the Quidenham Mere, a natural deep depression at the centre of the Fen. The Mere is fed by flow (5 - 10 l/s in May 1995) from the River Wittle which enters the Mere in the south. The main outlet is also via the River Wittle which flows to the northwest towards Quidenham. Downstream of the Mere but within the Fen, the flow of the Wittle may be augmented by piped water from two Groundwater Developmnet Scheme boreholes, one at Banham (TM08/091), at 1.1 km southeast of the site, and a second at Kenninghall Place (TM08/90), 3.5 km also southeast of the site. A dam at the Mere outfall prevents fresh groundwater flowing into the Mere.

3.2 HYDROGEOLOGY

Regionally, the geology consists of Upper Chalk, which is overlain by Boulder Clay in the south (0 - 10 m thick) and outliers of Brick Earth in the east and west. There is probably a buried channel north of the Fen, which is filled with 10 - 15 m of Brick Earth. In the Fen, alluvial deposits and peat overlie the Chalk.

The hydrogeology beneath and in the proximity of the site comprises:

- A near surface ALLUVIAL PEAT/SILT/SAND & GRAVEL AQUITARD which occurs beneath the Fen and has a thickness of up to 12 m. The aquitard consists of near surface peat (approximately 3 m thick) underlain by silt/clay and sand & gravel layers. Groundwater levels are a few centimetres above the ground surface at 25.2 - 25.3 maOD (December 1997). Water level monitoring since 1992 at drift piezometer TM08/163 at the southwestern boundary of the Fen shows seasonal fluctuations of 0.1 - 0.3 m, coincident with adjacent Chalk piezometer TM08/162. However, in late 1995, Chalk water levels were 1 - 1.5 m lower than those in the Drift, though this may be due to the drift piezometer drying up.

- The UNCONFINED-SEMICONFINED AQUIFER. Except for the eastern and western borders of the Fen, the Chalk within the Fen is semi-confined by the alluvial aquifers. Regionally, Brick Earth and the Boulder Clay form the upper confining layer. Within the Fen, groundwater levels are just above the ground surface at 25.2 maOD (December 1997) and coincident with or marginally higher than those of the overlying alluvial aquitard. Outside the Fen the Chalk is unconfined. The general direction of groundwater movement is from east to west converging in the west, south of the valley of the River Wittle. Piezometric elevations in the east are 27.5 maOD, in the west 22.5 maOD, and in the Fen at 24 - 26 maOD. The Chalk aquifer and the overlying alluvial aquitard are in hydraulic continuity. Thus, the water levels in the aquitard and in the Quidenham Mere are dependent on Chalk levels. Average annual water level fluctuations in the Chalk are approximately 0.5 m at TM08/011, 800 m north of the centre of the site; 2 - 4 m at TM08/14, 1800 m south; 2 - 3 m at TM08/104, 800 m east, with fluctuations of more than 5 m in 1989-1992 and 1994-1995, caused by the nearby Banham borehole abstraction; 0.5 m at TM08/162 at the southwestern border of the Fen (400 m southwest of the centre). In 1989-1992 and in 1994-1996, low rainfall has caused water levels to fall by 1 - 3 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water contributions are minor and mainly from runoff entering the River Wittle, following periods of rain.

Groundwater is the main source of water to the fen, the Quidenham Mere and observed seepages. It most probably forms the base flow to the River Wittle which discharges into the Mere. Groundwater originates from the underlying Chalk aquifer. It enters the Fen and Mere by upward leakage into the alluvial aquitard and by lateral flow from the east.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 4

The M13 stands are probably critically dependent upon groundwater inputs, almost certainly including a substantial chalk water component. Groundwater supply may also have some importance in determining the water balance in other parts of Kenninghall Fen where it is not critical to the character of the vegetation. It has been suggested that groundwater abstraction has been detrimental to Banham Great Fen, but the evidence for this is not known to the Consultants. Groundwater supply is not critical to the vegetation that currently occupies this area but could be important to the water balance.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the wetland, there is one licensed source from drains and ditches at 4 - 5 km east.

Groundwater: Within 5 km from the wetland, there are 20 licensed sources, of which all except one abstract from the Chalk. Abstractions for irrigation and domestic supply are small, generally less than 50 tcma. The main abstractors are the Environment Agency and AWS, the former for use as compensation water, and the latter for public supply.

The Agency have two combined licences for the purpose of augmenting the flow of the River Thet (and Little Ouse) to provide water for the Ely Ouse to Essex transfer. Licence 6/33/42/G/074 is licensed for 10,500 tcma (333 l/s) from 18 boreholes (not all operational) 4 - 5 km southeast of the wetland. Licence 6/33/44/G/137 is for 13,070 tcma (414 l/s) from 23 boreholes (not all operational), of which the closest to the wetland are at Banham, TM08/91, 1.1 km southeast of the wetland and TM08/90 at Kenninghall Place, 3.5 km also southeast. The water from the Banham borehole is used for augmenting the flow of the River Wittle, downstream of the Quidenham Mere, and when operational, yields 7700 m^3/d (89.1 l/s).

AWS is licensed to abstract from two boreholes at 1410 tcma (44.7 l/s), daily 4900 m^3/d (56.7 l/s). The boreholes are located at Denham /Quidenham, 1.7 km west of the site. AWS also abstract from a borehole at Quidenham, licensed at 1250 tcma (39.6 l/s) daily 4546 m^3/d (52.6 l/s) at 2.1 km, west of the site.

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the wetland.

Groundwater abstractions from the Chalk aquifer contribute to the lowering of water levels and therefore, have the overall effect of reducing lateral and upward flow to the wetland and the Mere within it. Low rainfall in recent years has had a profound effect, which to a large extent over-rides that of abstractions. The AWS PS boreholes are situated at some distance downgradient of the wetland, and therefore their impact is likely to be small. The Agency Banham compensation borehole is much closer, 1.1 km or so, and being situated upgradient of groundwater flow, would cause a depression of water levels at the wetland and also divert lateral flow from it. The suspected drying up of seepages east of the site, is probably connected with this abstraction, though the contributory effect of the drought cannot be ruled out.

The site has been assigned an AMP3 Abstraction Category 2. The present preliminary evaluation agrees with this Category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None known.

5.1.2 Proposed Monitoring

Carefully targeted vegetation monitoring, including the installation of some permanent marker posts.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: There are 7 gaugeboards, 2 in the River Wittle, 2 in the Mere and ponds, and 3 in drains.

Groundwater: Within the wetland: There are 7 observation boreholes: 4 in the alluvium and 3 in Chalk. Of these, one in the alluvium and one in the Chalk have been monitored since 1993, while the remainder were installed in 1997.

Outside the wetland: Within a distance of 5 km, the Agency have been monitoring 35 boreholes; 3 in drift and 32 in Chalk. Most have been monitored since 1977 and a few since 1982, 1992 and 1993.

5.2.2 Proposed Monitoring

Surface water: None is proposed.

Groundwater: None is proposed.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

A base-line vegetation survey would be useful.

6.2.2 Hydrology

The following are proposed:

a) A depth survey of Quidenham Mere.
b) Hydrochemical survey of groundwaters, and mere/drain/stream waters.
c) A controlled (150 day) pumping test is proposed over the period April - October using the Agency's compensation borehole at Banham, east of the site (TM08/91). The existing boreholes and staff gauges in the Fen and within a 2 km radius should be monitored, and the results with those of a) and b) above analysed and evaluated. The objective would be to determine the cone of influence and the hydraulic behaviour of the alluvial aquitard and of the Mere.

6.3 ALLEVIATION MEASURES

To await the results of the investigation. Should a link between the Agency's borehole and the wetland hydrology be established, the quantity abstracted would need to be reduced; alternatively the borehole may need to be relocated 1.5 - 2.0 km downgradient of the wetland.

6.4 SITE MANAGEMENT

Some work on vegetation management is required on Banham Great Fen.

SITE: SCOULTON MERE

NGR: TF 988 015 **AREA: 15 ha (37 acres)**

1. DESCRIPTION OF SITE

A quite large and shallow (approximately 1.25 m) mere at the head of a long tributary valley of the River Wissey. It contains a large island (Scoulton Heath) which is mainly birch woodland and willow scrub, with a surprisingly extensive carpet of bog moss (*Sphagnum*). This area supports (or, at least, once supported) the nationally-rare fern, *Dryopteris cristata*. The fringes of the island and mere are flanked by swamp and tall fen. There are particularly extensive areas of *Phragmites* / *Typha* wet fen and swamp at the north end of the island.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, but has no international designations. The main interest is considered to be the birch and fern woodland on oligotrophic peat. The crested buckler fern *Dryopteris cristata* is nationally-rare, but there seems to be some doubt as to whether this still occurs at this site.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Ensure water flows, levels and quality are maintained.
2. Ensure the W2b NVC community (to be confirmed) is maintained.
3. Maintain and expand the populations of RDB and NS plants.
4. Obtain further information on invertebrates and manage accordingly.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

No direct evidence.

3. WATER RESOURCES

3.1 HYDROLOGY

Scoulton Mere is man-made and was constructed prior to 1797. It comprises a central island surrounded by shallow water. It is situated at the head of the Watton Brook which runs from the Mere eastwards to eventually discharge into the River Wissey. Flow data are restricted to monthly current meter gaugings at TF 904 102, 7.5 km west of the Scoulton Mere. Gaugings at this location indicated a base flow of less than 20 l/s (1989-91). Baseflow is thought to derive from drift seepages. The Watton Brook, which extends northwards by 1 km to the Long Plantation, flows into the Mere. A few drains northwest of the Mere also discharge into the Mere. Outflow from the Mere is into the Watton Brook.

3.2 HYDROGEOLOGY

There are no boreholes at or very close to the Mere. Regional information suggests an east-west buried channel, which more or less follows the Watton Brook Valley and is filled with Boulder Clay, overlying Upper Chalk. The hydrogeology in proximity to the Mere comprises:

- Locally a PHREATIC SAND AQUIFER (3 - 5 m-thick) perched on Boulder Clay below. Water levels are not known but are probably close to the surface. Seepages from this aquifer may form the baseflow of the Watton Brook.

- A BOULDER CLAY AQUITARD consisting mainly of clays, clay-with-chalk fragments, and locally thin sands near the surface. It confines the Chalk aquifer below. The thickness of the Boulder Clay below the mere is not precisely known. Approximately 1.1 km east, borehole TF90/104, penetrated 86.23 m of Boulder Clay. Borehole TF90/005, 1.5 m west, penetrated 13.7 m of Boulder Clay. At Carbrooke Hall, 2.4 km southwest boreholes TF90/74(79), penetrated approximately 22 m of Boulder Clay.

  If the mere is located within the buried channel, the Boulder Clay is likely to be more than 60 m thick.

- The CHALK CONFINED/SEMI-CONFINED AQUIFER occurs at depths of more than 40 mbgl (10 maOD) along the buried channel. At the Mere, it is probably at 60 mbgl (-20 m OD). The mere is situated at a groundwater divide from where groundwater flow diverges southwestwards to Carbrooke and northwestwards to Cranworth. Lowest groundwater levels (1993) were approximately 50 maOD, and on average around 52 - 53 maOD. As the topographic elevation at the Mere is approximately 53 maOD, Chalk groundwater levels are likely to be only a few metres below surface and possibly artesian. Therefore, there is potential for upward flow from the Chalk aquifer into the Boulder Clay aquitard, but whether such flow reaches the near surface or enters the Mere and phreatic sands is uncertain. Lithological evidence west of the Mere suggests a clay thickness of more than 30 m, which would preclude significant upward flow.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water from the Watton Brook discharges into the northern edge of the wetland. The rate of flow is not known. Outflow is also via the Watton Brook.

Groundwater seepages from the phreatic sand aquifer/Boulder Clay aquitard appear to be the source of baseflow to the Watton Brook. There is potential for upward leakage from the Chalk aquifer into the overlying strata, but whether this reaches the near surface or is an indirect source of water to the Mere is not known. Because recharge of the phreatic sands is by infiltration of rainfall, stream baseflow and flow into the Mere, must be susceptible to changes in rainfall.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: 2/3?

There is no reason to suppose that any of the vegetation present on this site *requires* groundwater input. The relationships between vegetation and water levels on this site are not known - it is possible that the *Sphagnum* community may be associated with floating rafts, which can therefore accommodate some variation in water level.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: There are no licensed abstractions within 5 km from the Mere.

Groundwater: There are 34 licensed abstractions within 5 km from the Mere. They are mostly small, for domestic use and irrigation, except for two Chalk sources operated by AWS for PS:

a) Carbrooke Source: 2 boreholes 4.86 - 4.93 km WNW, licensed at 829.645 tcma (26.3 l/s), daily 2273 m^3/d (26.3 l/s).
b) East Watton Source; 2 boreholes 4.26 km WSW, licensed at 1346.85 tcma (42.7 l/s), daily 4840 m^3/d (56.02 l/s). This is a relatively new licence and was granted in 1989 for a ten year period. Abstraction commenced in 1990.

4.2 IMPACT OF ABSTRACTIONS

Clarke (1922?) (TNNNS article) states that the Mere was "quite dry in the late summer of 1921, when the expanses of mud were covered with large specimens of the freshwater mussel, from which the molluscs had been extracted, presumably by herons." By October 1921, water covered about a quarter of the area, to a depth of a few inches.

EN have stated that the Mere now has consistently low water levels, which was not the case prior to the establishment of the East Watton borehole and the 1990/91 drought. It is suggested that this indicates drying out of the peat (which is 1 - 2 m deep) on the island, which would be detrimental to the conservation interest. Evidence is based on observations (but no hard data), and representations from local landowners (anecdotal), that farm wells have been affected by lower water levels.

The AWS PS groundwater sources are located at some distance downgradient of the Mere. A 23-day pumping test of the Chalk boreholes at East Watton in May-June 1988, indicated a significant drawdown in an east-west direction along the valley of Watton Brook. At approximately 7.8 km southwest from the Mere the drawdown was 1.35 m. Drawdowns at the Mere are likely to be very small, probably less than 1 m. The impact on the Mere as a result of PS abstractions is not likely to be significant, particularly since a hydraulic connection with the Chalk is probably severely impeded by the Boulder Clay. The fact that the Mere was dry in the 1920's, and low water levels have been observed since 1990, are probably more indicative of low rainfall rather than abstraction.

This site has been assigned in AMP3 Water Abstraction category 3. The present preliminary evaluation agrees with this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None known.

5.1.2 Proposed Monitoring

Monthly monitoring of peat surface using "peat anchors".

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: 1 staff gauge in the Mere.

Groundwater: Within the Mere: There are 13 observation boreholes east of the Mere, all are in Chalk except two which are in Drift. The nearest to the Mere are:

TF90/004 in Chalk, 600 m E
TF99/147 in Chalk, 2800 m SW

5.2.2 Proposed Monitoring

Surface water: 2 no weirs at the inflow and outflow sections of the Watton Brook; alternatively staff gauges with monthly current metering.

2 no staff gauges in the Mere water.

Groundwater:

a) Cluster of 3 no piezometers close or within the Fen; 1 no in Chalk (depth ?> 50 m), 1 no in Boulder Clay (15 - 20 m); 1 no in superficials (3 - 5 m). 2 clusters of Chalk and adjacent drift piezometers at distances of 500 m and 1000 m from the East Watton Source on a line between the Mere and the Source. Depths: 30 - 50 m in Chalk; 10 - 20 in Boulder Clay; 3 - 5 m in superficials.
b) 3 - 5 shallow piezometers (1 - 3 m deep) in the peatland (with adjacent peat anchors).

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

There is a need to establish the relationship between water levels in the Mere and in the peatland, and between water levels, the peat surface and plant communities:

i) Topographic survey of the peat surface (and of water levels) across the land.
ii) Base-line vegetation mapping, in particular recording of the extent and location of the Sphagnum communities and open fen, with investigation of the nature and depth of the associated substratum.
iii)Monitoring of the vertical movement of the peat (?raft) beneath the *Sphagnum* areas in relation to water level variation in order to establish whether there is sufficient accommodation of such variations. This will involve installation of 'peat anchors' (levelled to Ordnance Datum) and dipwells at approximately 3 - 5 strategic points (See 5.2.2 above) with regular monitoring (at least monthly) of levels for a minimum of one year.

6.2.2 Hydrology

Controlled long duration (90 day) pumping test using the East Watton PS source and the proposed and existing boreholes for water level measurements. The objective is to establish the extent of the cone of depression and the hydraulic relationship between the Boulder Clay and Chalk.

6.3 ALLEVIATION MEASURES

To await the results of the investigations. An option to be considered is to provide compensation water from a Chalk borehole at the Mere. The revocation or reduction of the AWS licence is unlikely to have an immediate beneficial effect under the recent conditions of low rainfall or the present regime of regional abstractions.

6.4 SITE MANAGEMENT

Water level management is a major issue (the site is used by fishermen and wildfowlers), although in recent years manipulation to prevent flooding has not been required because of low water levels.

SITE: WHITWELL COMMON

NGR: TG 088 206 **AREA: 19.17 ha (47.36 acres)**

1. DESCRIPTION OF SITE

A quite large valley fen alongside a tributary stream of the River Wensum, draining from Booton Common, which receives some drainage from a small number of ditches across the fen. In the north the fen is largely wooded (alder carr) and is fairly narrow, but it broadens southwards into a flattish expanse of open fen, with wet hollows and with somewhat flushed slopes. A strip of raised ground, supporting dry oak woodland extends into the low areas of the SW common. There is a very obvious pan-like depression immediately east of this.

Part of the site lies at the confluence of a southerly and an easterly flowing stream and as a result the main area of adjacent higher ground is situated to the north-west of the site.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, and, while not a SAC site, formerly supported the internationally-important M13 community (*Schoenus nigricans–Juncus subnodulosus* mire).

Dr Wheeler considers that it is undoubtedly a degraded site, which has shown considerable change during the last two decades, though it still supports a fair range of species. Areas that, in the 1970s, were (fairly low-grade) examples of M13 are now mainly a (species-rich) form of M22.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain ground water levels that create the calcareous flushes.
2. Maintain an open fen area.
3. Maintain the species/community diversity.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

This site has shown a considerable quantitative reduction in vegetation diversity and some qualitative loss and species. This site has some very interesting early plant records, none of which appear to persist. Interest has always probably attached to a *Schoeno-Juncetum* {~M13} vegetation of seepage slopes and sumps (old peat pits ?) (these latter probably once had *Acrocladio-Caricetum* {~M9}). Much of the known interest was still present in 1974, though 'notable' species were then mostly restricted to small areas in shallow depressions close to the 'neck' of the Common. Since that time there has been a substantial loss of characteristic species from these areas, through dereliction and perhaps dehydration, though a few (e.g. *Epipactis palustris, Gymnadenia conopsea Schoenus nigricans*, *Parnassia palustris*) persist in small quantity. Interestingly, some wet tufa-depositing springheads persist, though without species-rich spring fen vegetation. All references to the southern area, currently dominated by tall herb fen and

Arrhenatherum grassland, seem to report it as drying out, even in 1962. This, coupled to the lack of proper peat, may suggest that this area has only ever been poorly drained, rather than true fen (though the absence of peat could, of course, be because it has been removed).

Whitwell Common appears to have deteriorated more than some other valleyhead fens during the last two or three decades, but the reasons for this are not really known and the site is puzzling. The most likely simple explanation is that the changes are a consequence of dereliction, but other possibilities include some nutrient enrichment and; in the case of the former M9 stands, overgrowth of the former (small) turf ponds. There is little reason to suppose that there has been a material reduction of water levels across the site.

3. WATER RESOURCES

3.1 HYDROLOGY

Whitwell Common lies at the confluence of three tributaries of the River Wensum. The northeastern tributary marks the southern boundary of the site. It extends to the northeast, towards Booton Common, which is situated in the same valley at a distance of approximately 2.5 km. The northern tributary marks the eastern boundary of the site. A small western tributary, at the southwestern boundary, joins the northeastern tributary at the southernmost edge of the site. The northern boundary of the site is defined by a road. Within the wetland, there are a number of drains and some permanently wet hollows.

3.2 HYDROGEOLOGY

The regional geology consists of alluvium in the valley, Boulder Clay (0 - 20 m thick) probably underlain by Brick Earth and Sand & Gravel (0 - 15 m). The precise hydrogeology beneath the site is not known. Regional information suggests the following hydrogeological units:

- A 2 - 4 m thick ALLUVIAL /? BRICK EARTH CLAYAQUITARD which probably impedes somewhat upward flow from the Chalk aquifer below.
- Away from the wetland, a BOULDER CLAY AQUITARD, up to 20 m in thickness, which semi-confines the Chalk aquifer.
- The UPPER CHALK UNCONFINED/SEMI-CONFINED AQUIFER which occurs at a few metres below ground within the wetland, and is exposed immediately south. Away from the wetland, the Chalk is probably in hydraulic continuity with overlying sand & gravel.

The regional piezometry suggests that groundwater moves to the south towards the valley of the River Wensum, but possibly with a component converging into the tributary valleys. The water level elevation at the site is not known, but is probably at approximately 20 maOD. As the topographic elevation at the site is less than 20 maOD, water levels are likely to be near or just above ground level. Therefore, there is potential for upward movement of Chalk groundwater into the wetland, via the thin alluvial cover. Moreover, the tributary stream that borders the southern boundary probably receives water from the exposed Chalk, immediately to the south.

The range of fluctuations of groundwater levels at the site are not known. Observation boreholes at Sparham and Great Witchingham, 2 -3 km, southwest of the site indicate seasonal fluctuations of 0.5 - 1.0 m, and a decline in the drought periods of 1989 - 1992 and 1995 - 1996 of 1 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water probably enters the wetland from the tributary streams, during periods of high water levels. Some runoff from the adjacent higher ground may also reach the wetland, following periods of rain.

Groundwater appears to be the main source of water to the wetland. It derives from the Chalk aquifer by lateral flow and upward leakage through the overlying thin alluvial deposits.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Categories: 3, 4

The former M13 stands were probably critically dependent upon groundwater inputs, almost certainly including a substantial chalk water component. Most of the current vegetation is not critically dependent on groundwater discharge, though it seems likely that this important in maintaining the water balance of the site. Moreover, some tufaceous springheads are dependent on calcareous groundwater.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the site there are 9 licensed surface water abstractions from dykes, the Rivers Wensum, Aisne, and Blackwater, mainly for general agriculture and spray irrigation.

Groundwater: Within 5 km from the site, there are 68 licensed abstractions. Most are from the Chalk for domestic and agricultural and spray irrigation use, at less than 5 tcma (0.16 l/s). The nearest is at White House Farm: 1 Chalk borehole 200 m N of the site, licensed at 1.9 tcma (0.06 l/s), daily 6.8 m^3/d (0.08 l/s).

AWS are licensed to abstract for public supply from:

a) Sparham: 2 Chalk boreholes in Chalk at 1.7 - 1.8 km SW at 400 tcma (12.7 l/s), daily 1500 m^3/d (17.36 l/s).
b) Lyng; 2 (and 3) Chalk boreholes at 3.55 km SW, at 1095 tcma (34.7 l/s), daily 3000 m^3/d (34.7 l/s).

c) Lyng, Richmond Place: 1 Chalk borehole at 3.25 km SW, at 30 tcma (0.95 l/s), daily 100 m^3/d (1.15 l/s).

Industrial abstraction by Bernard Matthews & Matthews Norfolk Farms.

a) 4 Chalk boreholes at Great Witchingham, approximately 2.8 km SW at 550 tcma (17.4 l/s), daily 1818 m3/d (21.7 l/s).
b) 2 Chalk boreholes at Great Witchingham, approximately 2.8 km SW, at 237 tcma (7.5 l/s), daily 650 m^3/d (7.5 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the wetland.

Groundwater abstractions could have an overall impact on water levels, especially those situated to the north-northeast of the site, upgradient of the direction of groundwater flow. However, all are very small, and even the closest one (200 m NW) at White House Farm (0.06 l/s) is unlikely to have a significant impact. The AWS PS boreholes and the Bernard Matthews industrial boreholes are situated downgradient of the prevailing direction of groundwater flow, 2 - 3 km southwest of the site. Any impact on the groundwater table at the site is therefore considered to be negligible.

The site has been assigned an AMP 3 Water Abstraction Category 3. This preliminary evaluation confirms this category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

Vegetation monitoring has been undertaken since 1994 under conditions imposed at the time of the AWS abstraction licence application, and will continue for a further two years.

5.1.2 Proposed Monitoring

Continue existing vegetation monitoring.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None is known within the wetland.

Groundwater: None is known within the wetland.

Outside the wetland: At Booton, 2.5 km NE of the site (see Booton Report). The Agency have monitored since 1988 Chalk borehole TG01/787 at Sparham Hill, 1.8 km SW, and Chalk borehole TG01/990 since 1952, at Great Witchingham, 2.8 km SW.

5.2.2 Proposed Monitoring

Surface water: 2 - 3 staff gauges in the drains and streams within and at the boundaries of the wetland (if appropriate).

Groundwater: 2 piezometers within the wetland in one cluster; one shallow (2 - 5 m) in drift and a deep (10 - 15 m) in Chalk.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

At the end of the current licensing agreement, the existing vegetation monitoring data, together with the hydrological data, should be fully analysed and interpreted in order to ascertain whether a link between conditions on the site and the abstraction has been shown. Recommendations for further monitoring will depend on the outcome.

6.2.2 Hydrology

The following are proposed:

a) Field survey of site including private abstractions in the vicinity.
b) Hydrogeological evaluation after installation of proposed piezometers and staff gauges.

6.3 ALLEVIATION MEASURES

None required at present; to await the results of the proposed investigation.

6.4 SITE MANAGEMENT

Further action is required with regard to vegetation management/scrub removal. EN suggest fencing off at least part of the site to allow for more sustainable management by grazing.

SITE: DERNFORD FEN

NGR: TL 472 504 **AREA: 10.5 ha (25.8 acres)**

1. DESCRIPTION OF SITE

A rather dry area of fen along the bottom of the River Cam valley. The fen is now separated from the river by a railway, and represents a relic of a once much larger area of rough fen and carr. The vegetation ranges from dry calcareous grassland and scrub to *Juncus subnodulosus* fen meadow, reedbed and alder carr. Areas of open pools within the site, together with ditches and the chalk stream enhance the diversity. The variety of vegetation types and open water provide valuable habitat for fauna, in particular for amphibians and reptiles. The area is also noted for its breeding warblers.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, but has no international designations. The main wildlife interest lies in the fen meadow and alder carr which are considered of regional importance.

The nationally-uncommon fragrant orchid (*Gymnadenia conopsea* ssp. *densiflora*), marsh helleborine (*Epipactis palustris*) and saw sedge (*Cladium mariscus*) occur on the site. There are also 10 Lepidoptera of national importance.

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain and enhance the features for which the site was primarily notified, namely the fen meadow, tall fen, alder carr and chalk grassland communities.
2. Maintain and enhance additional features of nature conservation interest, particularly the broadleaved woodland and mixed scrub areas.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

There are comparatively few old species records for the site, which makes it impossible to determine whether the present rather impoverished nature of the fen vegetation is 'natural' or a result of species losses, though some species such as Butterwort (*Pinguicula vulgaris*) and black-beaked sedge (*Schoenus nigricans*) are known to have disappeared (but seemingly last recorded in the 1950's). Considerable scrub clearance was carried out in 1980s, with re-instatement of mowing, which seems to have improved the condition of the fen / fen meadow.

EN have stated that "There has been a decline in the diversity of aquatic and wetland species", based on observations from members of the British Butterfly Conservation Society. [The level of evidence remains to be assessed.]

There was a suggestion in 1985 that scrub clearance had caused a general rise in water level over the site. [S. Lambert, *site visit,* 1985], and in 1986, the site was reported as wetter than in 1985.

3. WATER RESOURCES

3.1 HYDROLOGY

Denford Fen is situated 400 - 700 m west of the River Cam (Granta) and 2 km northwest of Sawston Meadow. In the west it is bordered by a railway embankment. In the south, a northwest-southeast drain or stream originates from Nine Wells Spring (50 m outside the Fen) and flows northwestwards, emerging on the west side of the railway embankment, where it is probably culverted. The southern boundary is also a drain or stream. A northeast-southwest drain, linked with secondary small drains, in the eastern part of the site flows into the "Nine Wells drain". All drains eventually flow into the River Cam.

3.2 HYDROGEOLOGY

The precise hydrogeology of the site is not known, as no studies appear to have been carried out. Based on regional information the hydrogeology beneath and in the proximity of the site comprises:

- The UNCONFINED LOWER CHALK AQUIFER which may be weakly confined by any overlying alluvial silts and clays. The regional direction of groundwater flow is to the northwest. The elevation of the water-table in the autumn of 1976 (BGS, 1994, Hydrogeological Map of the Area between Cambridge and Maidenhead) was approximately 18 maOD or approximately 1 - 2 mbgl. The spring at Nine Wells has a topographic elevation of approximately 19 maOD, and the drains 18 - 19 maOD. It appears, therefore, that the springs and drains are fed from the Middle Chalk aquifer, and as such are susceptible to water-table fluctuations. Water level fluctuations in the Fen are not known. Monitored boreholes by the Agency are at some distance: TL44/20B and TL44/335 in Lower Chalk are at 5 km SW of Denford; they have been monitored since 1984, and show seasonal fluctuations of approximately 0.5 m, and a decline of 1 m during the low rainfall periods of 1989/1992 and 1995-1996. TL44/289 in Middle Chalk is at 5.5 km SSE, and has been monitored since 1980. It is less than 500 m from the Ciba Chemicals abstraction, and shows seasonal fluctuations 1 - 2 m, and a decline in 1989-1992/1995-1996 of approximately 2 m. The influence of the Ciba abstraction is evident.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water contributions are from rainfall and surface runoff after periods of rain. According to the EN's Wetland Questionnaire (27/7/1994) the site still floods in the winter, probably from runoff from the elevated ground in the northeast. (However, any influence of flooding from the River Cam entering the site via drains should be checked; the 1:10,000 map shows the drains east of the site and the railway draining into the river).

Groundwater replenishment to the fen is in the form of springs (Nine Wells), and seepages into the ditches. The aquifer provides soil moisture to vegetation when water-tables are close to the ground surface. Contributions are probably seasonal and susceptible to drought.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: Uncertain

It seems likely that this may once have been a GDC 4 site (*i.e.* groundwater discharge is a significant component of the water balance and is critical to the character of the vegetation), but this is not known with certainty.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the site, there are 8 licensed surface water abstractions, mainly from the River Cam..

Groundwater: Within 5 km radius, there are 43 licensed groundwater abstractions. Most of them are small, less than 100 tcma, for irrigation and domestic supply. The largest are as follows:

1) CWC have 5 licences at distances of 1.1 to 4.6 km from the wetland. They are:
   a) Sawston 2 boreholes at 1.83 km SW, 545.2 tcma (6.3 l/s), daily 654.62 m^3/d (7.6 l/s)
   b) Sawston Mill 1 borehole at 1.1 km S and Hinxton Grange 2 boreholes, 4.6 km SE; 2104.884 tcma (66.7 l/s), daily 6819 m^3/d (78.9 l/s)
   c) Babraham 2 boreholes at 3.34 km NE, 3318.653 tcma (105.2 l/s), daily 9092 m^3/d (105.2 l/s)
   d) Abington Farm, 2 boreholes at 3.34 km SE, 364.998 tcma (11.6 l/s), daily ? 4546 m^3/d (?52.6 l/s)
   e) Duxford 2 boreholes at 4.3 km SSW, 2259.526 tcma (71.6 l/s), daily 7319.56 m^3/d (84.7 l/s) (2 licences).

2) The Environment Agency have 1 combined licence at 7645 tcma (242.4 l/s), daily 33910 m^3/d (461.9 l/s) from 13 boreholes. All are at distances greater than 5 km except 1 borehole at Whittlesford, at 2.5 km SW.

3) Ciba Chemicals, 2 boreholes (linked licence) for cooling/industrial, at Duxford, 5 km SSE, 4891.496 tcma (155 l/s), daily 1818 m^3/d (210 l/s).

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the wetland.

Groundwater licensed abstractions less than 5 km from the site amount to 8593.261 tcma (272.5 l/s) from CWC; probably 588 tcma (18.6 l/s) from the Agency; and, 4891.496 tcma (155 l/s) from Ciba; that is a total of 14073 tcma (446 l/s). This is a considerable quantity which would potentially have an effect on the wetland water levels and water supply. However, any direct effects would mainly be from the sources immediately upgradient of the wetland, which are those of CWC at Sawston and Sawston Mill, and to a lesser extent from Hinxton Grange, Abington Farm and Babraham.

The site has been affected by direct drainage, and there is a suggestion that building of the railway may have led to a fall in the water-table[1]. A water control sluice was installed in 1984, with the aim of flooding the site between February and April, by backing-up stream spring water onto the site. However, there is now very little open water on the site.

The site has been assigned an AMP3 Abstraction Category 2. The present preliminary evaluation confirms this Category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None is known.

5.1.2 Proposed Monitoring

Carefully targeted vegetation monitoring on an annual basis, including the installation of some permanent marker posts.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: Weir for summer flows in the stream/drain in the southern border of the wetland.

Groundwater: 2 dip-wells in the wetland, but no water levels have been measured.
3 boreholes in Chalk at 5 - 6 km SSW of the wetland.

5.2.2 Proposed Monitoring

Surface water: Gaugeboards/V-notch weir in flowing stream or drains (if found to be needed, after site visit).

[1] in: A Survey of Demford Fen Sawston, Cambridgeshire 1950–58. Bishop Stortford College Natural History Society, pp. 1–52.

Groundwater: Within the wetland: 2 piezometers; 1 in the river alluvials (5 m), and 1 in Lower Chalk (10 m).

Outside the wetland: 2 piezometers in Chalk between the wetland and Babraham PS (10 - 20 m in depth); 1 piezometer in Chalk between the wetland and Sawston PS.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

A detailed ecological site survey and the preparation of a vegetation map are proposed.

6.2.2 Hydrology

The following are proposed:

a) A detailed hydrological/hydrogeological field survey of site.
b) Water level observations for 1 year, using proposed monitoring.
c) Evaluation of results.

6.3 ALLEVIATION MEASURES

To be defined following investigations and to be considered in conjunction with Sawston Hall. Options could be:

a) Revocation/Reduction of CWC licences at Sawston Mill and Sawston.
b) Provision of compensation water from nearest CWC source, probably Sawston.

6.4 SITE MANAGEMENT

Further management (including scrub removal) is required to enhance the fen habitats.

SITE: SAWSTON HALL MEADOWS

NGR: TL 491 491 **AREA: 7.4 ha (18.2 acres)**

1. DESCRIPTION OF SITE

The meadows overly spring-fed peat, and are a relic of a pasture type formerly more widespread at the margins of the East Anglian fenland. The grassland communities range from sedge-rich marshy grassland into drier calcareous grassland. Thick belts of scrub and areas of open water provide additional habitat and further enhance the value of the site for the fauna, in particular invertebrates.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, but has no international designations. The site is noted for the presence of the nationally-rare (RDB and Schedule 8) umbellifer, Cambridge Milk-parsley (*Selinum carvifolia*), now only recorded from Cambridgeshire. Saw-wort (*Serratula tinctoria*) and great fen sedge (*Cladium mariscus*) are nationally uncommon. There is one RDB2 Dipteran (*Erioptera meijerei*), and nationally notable Hemiptera (6), Coleoptera (1) and Diptera (1).

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Maintain and enhance the nature conservation interest of the site, namely Fen Meadow and other unimproved grassland communities, together with the population of *Selinum carvifolia*.
2. Maintain, and where appropriate, enhance other features of nature conservation value, namely ditches, open water, locally rare species, periglacial soil features and hedges.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

The ditches which once drained (or irrigated) the site have become occluded, and provide a habitat for some 'wetter' fen plant species than present in the meadows (e.g. *Cladium mariscus*). However, there have been no recent records for species such as *Anagallis tenella*, *Parnassia palustris* and *Ophioglossum vulgatum* (last recorded 1970's).

The EN proforma states that "the drying out is said to have caused a decline in the diversity and extent of the wetland and aquatic vegetation", although the evidence is apparently anecdotal.

A former pond (marked as open water in 1982) is now completely covered with pond sedge *Carex acutiformis*, but it is unclear whether this is a natural successional process or response to drying out, or a combination of both.

Scrub invasion threatens the special interest of the site.

3. WATER RESOURCES

3.1 HYDROLOGY

The site is situated at approximately 1 km west of the River Cam. Within the Meadow, there is a central east - west ditch linked in the middle to two other east-west ditches and an old fish pond. Outside the Meadow, approximately 100 m southeast of its southern boundary, is the Lady's Wash Spring (TL 493 489). It discharges into a drain, which flows to the southeast and east into a series of old fish ponds, and also to the north into a ditch which forms the western boundary of the Meadow. All flows eventually reach the River Cam.

1.2 HYDROGEOLOGY

The hydrogeology at and in the area of the Meadow is only known from regional information. In the westernmost part of the site, river deposits including sand & gravel overlie Lower Chalk. Most of the site, however, is underlain by Middle Chalk which is overlain by peat. Sawston is situated at the junction between the Middle and Lower Chalk, which is marked by the hard (often fissured) Melbourne Rock. The junction runs NE-SW, and along it there are a number of springs, at Fowlmere, Thriplow, Whittlesford (all on a line southeast of Sawston), Sawston itself and Babraham in the northeast.

Beneath the site, the hydrogeology consists of:

- A PHREATIC ALLUVIAL AQUIFER/AQUITARD in the extreme west, which is most likely in hydraulic continuity with the underlying Chalk. The thickness of the aquitard is probably small, about 5 - 10 m.

- The UNCONFINED CHALK AQUIFER which underlies the alluvial aquitard/aquifer in the western edge of the site, but exposed throughout most of the site. Springs issue at the junction between the Middle and Lower Chalk. The regional groundwater movement is to the northeast, with some flow discharging into the River Cam. Piezometric elevations in the Middle Chalk in the autumn of 1976 (Hydrogeological Map of the Area between Cambridge and Maidenhead, BGS, 1984) were just below 20 maOD. In the summer of 1985, piezometric levels beneath the Meadow were approximately 21 maOD. Water level fluctuations in boreholes within 1 km from the Meadow in 1970-72 were approximately 1 - 2 m (Gilman, 1985). Monitoring of two boreholes by the Agency since 1984 at Thriplow (approximately 6 km SW of the wetland, TM44/335 in Lower Chalk and TM40/20B also in Lower Chalk) showed seasonal fluctuations of approximately 0.5 m, with a fall during the drought periods of 1989-1992 and 1995-1996 by approximately 1 m. A third borehole at Duxford (approximately 5 km SSW of the wetland, TM44/289, in Middle Chalk) has been monitored since 1980. It shows larger seasonal fluctuations of 2 m, probably the result of abstraction from the nearby Ciba Chemicals boreholes, and again a fall in 1988-1992 and 1995-1996 by about 2 m.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water contributions appear to be minor and consist of mainly rainfall.

Groundwater from the Middle Chalk aquifer is the main source of water to the Meadow. It discharges in the form of springs and seepages, and provides moisture to vegetation when water-tables are close to the surface.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: Uncertain (1, 2 or 3).

There is no evidence that the vegetation present necessarily *requires* groundwater inputs.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km from the site, there are 7 licensed abstractions, mostly from the River Cam but some from ditches and drains.

Groundwater: Within 5 km from the site, there are 43 licensed abstractions. Most are small, less than 50 tcma and used for irrigation and domestic supply. The largest are as follows:

1) CWC have 5 licences at distances of 0.8 to 4.27 km from the wetland. They are:
    a) Sawston 2 boreholes at 0.83 km NNW, 545.2 tcma (6.3 l/s), daily 654.62 m^3/d (7.6 l/s)
    b) Sawston Mill 1 borehole at 2.01 km WNW and Hinxton Grange 2 boreholes, 2.36 km SE; 2104.884 tcma (66.7 l/s), daily 6819 m^3/d (78.9 l/s)
    c) Babraham 2 boreholes at 2.78 km NNE, 3318.653 tcma (105.2 l/s), daily 9092 m^3/d (105.2 l/s)
    d) Abington Farm, 2 boreholes at 3.22 km SE, 364.998 tcma (11.6 l/s), daily ? 4546 m^3/d (?52.6 l/s)
    e) Duxford 2 boreholes at 4.27 km SW, 2259.526 tcma (71.6 l/s), daily 7319.56 m^3/d (84.7 l/s) (2 licences).

2) The Environment Agency have 1 combined licence at 7645 tcma (242.4 l/s), daily 33910 m^3/d (461.9 l/s) from 13 boreholes. All are at distances greater than 5 km except 1 borehole at Whittlesford, at 4 km W.

3) Ciba Chemicals, 2 boreholes (linked licence) for cooling/industrial, at Duxford, 3.6 km SW, 4891.496 tcma (155 l/s), daily 1818 m^3/d (210 l/s)

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions do not impact on the wetland.

Groundwater licensed abstractions less than 4 km from the site amount to 8593.261 tcma (272.5 l/s) from CWC; probably 588 tcma (18.6 l/s) from the Agency; and, 4891.496 tcma (155 l/s) from Ciba; that is a total of 14073 tcma (446 l/s). This is a considerable quantity which would potentially have an effect on the wetland. However, any direct effects would mainly be from the sources upgradient of the wetland (ie in the south-southeast), which are those of CWC at Hinxton Grange and Abington Farm, both licensed to abstract less than 2470 tcma (78 l/s); and also from sources in Sawston, which, although to the NNW, is fairly close (0.83 km) to the wetland, but has a low abstraction 545.2 tcma (6.3 l/s). At present, the evidence of adverse effects are the loss of spring flows for many years (since 1980) and continued drying out of the site.

The site has been assigned an AMP3 Abstraction Category 2. The present preliminary evaluation confirms this Category.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

The important population of Cambridge milk parsley (*Selinium carvifolium*) is monitored by English Nature.

5.1.2 Proposed Monitoring

None proposed.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: None in the wetland.

Groundwater: None in the wetland

3 boreholes in Chalk at 5 - 6 km SSW of the wetland.

5.2.2 Proposed Monitoring

Surface water: Gaugeboards/V-notch weir in flowing stream or drains (if found appropriate, after site visit).

Groundwater: Within the wetland: 3 piezometers; 1 in the river alluvials (5 - 10 m), 1 in Lower Chalk (10 m) and 1 in Middle Chalk (10 m).

Outside the wetland: 2 piezometers at Pampisford 1 km SE, 1 in Middle Chalk, 10 m, and 1 in Lower Chalk 30 m; 2 piezometers at Whittlesford Station, 2 km SSW, 1 in Middle Chalk (10 m) and 1 in Lower Chalk (30 m).

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

A vegetation survey was undertaken in 1982, although this was not to NVC level. It is recommended that a detailed site description (plus map) is produced. More detailed, targeted vegetation monitoring would be desirable, but may be inappropriate in the current context if management problems are not addressed.

6.2.2 Hydrology

The following are proposed:

a) A detailed hydrological/hydrogeological field survey of site.
b) Water level observations for 1 year, using proposed monitoring.
c) Evaluation of results.

6.3 ALLEVIATION MEASURES

To be defined following investigations in conjunction with Denford Fen. Options could be:

a) Revocation/Reduction of CWC licences at Hinxton/Abington and Sawston.
b) Provision of compensation water from nearest CWC source, probably Sawston.

6.4 SITE MANAGEMENT

The management requirements of the site need to be addressed, including scrub control.

SITE: CATTAWADE MARSHES

NGR: TM 090 329 **AREA: 88.2 ha (217.9 acres)**

1. DESCRIPTION OF SITE

Cattawade Marshes lie at the head of the Stour Estuary, between freshwater and tidal channels of the River Stour. These grazing marshes, with associated open water and fen habitats, are of major importance for the diversity of their breeding bird community, which includes species that have become uncommon throughout lowland Britain as a result of habitat loss. The site has benefited from a sympathetic management regime aimed at enhancing the ornithological interest. The marshes are also of value as a complement to the adjacent Stour Estuary SSSI where breeding habitats for birds are relatively scarce.

2. ECOLOGY

2.1 CONSERVATION INTEREST

The site is an SSSI, although without international designations. Two nationally-scarce plants are recorded: marsh mallow (*Althaea officinalis*) and Dittander (*Lepidium latifolium*). The site is considered of national importance for the diversity of the breeding bird community, which includes RDB species (redshank, oystercatcher, ringed plover, shelduck, shoveler, teal) and others that have become uncommon throughout lowland Britain as a result of habitat loss (e.g. lapwing, tufted duck, water rail).

2.2 ENGLISH NATURE (EN) CONSERVATION OBJECTIVES

1. Manage the site to maintain the appropriate balance of habitat types including open water, *Phragmites* reed bed, Sea Club-rush swamp, grasslands and scrub.
2. Maintain the characteristic flora and fauna of grassland habitats by appropriate levels of cutting and grazing management.
3. Manage for the whole range of vegetation structures within the ditch systems for the benefit of the associated flora and fauna.
4. Maintain/increase the populations of key lowland grassland bird species by enhancing the existing areas of suitable habitat.
5. Monitor, and control water levels and quality to preserve the integrity of wetland and open water habitats.
6. Survey the site plant communities using NVC techniques as well as recording the localities and populations of any rare species.
7. Survey the site's invertebrate fauna, as there is apparently no information available for this site.
8. Produce an agreed management plan for the site, taking into consideration the established ESA plans.

2.3 EVIDENCE OF ECOLOGICAL CHANGE

The former salt marsh became overgrown following the construction of the tidal barrage in the 1960's, but subsequent grazing management (now under an ESA agreement) has restored the area to 'good' grazing marsh. However, in recent years, the grass production has declined, and grazing levels are now considered to be too high.

The breeding bird community has declined in the past 3 - 5 years, both in terms of diversity and absolute numbers. This decline, together with that of grass production have been attributed to an increasing lack of water on the site in recent years.

3. WATER RESOURCES

3.1 HYDROLOGY

The site lies at the head of the Stour estuary. Its northern boundary is defined by the freshwater channel of the River Stour, and its southern boundary by a tidal drain (Pathdrain). The site was formerly a salt marsh subjected to tidal incursions. The construction of the Cattawade barrage in the 1960s has led to a reduction in tidal influences, and the formation of the present bird breeding marsh. Within the site, there are drains which flow into the main channels. Recently water levels in the River Stour have been low so that drains which previously carried water into the marsh are no longer flowing.

3.2 HYDROGEOLOGY

The detailed geology of the marshes is not known. Regional information suggest estuarine deposits (peat, organic clays, and sand/gravel lenses) and possibly valley gravels in the extreme south. The Crag which occurs to the north has probably been eroded away at the site. Therefore, the Chalk which is at -15 m OD (approximately 15 mbgl) directly underlies the estuarine alluvium. The hydrogeology beneath the site probably comprises:

- An estuarine UNCONFINED TO SEMI-CONFINED ALLUVIAL AQUIFER /AQUITARD, possibly up to 15 m thick and consisting of peat, organic clays, sand/gravel layers and Valley Gravel. Water levels are probably 1 - 3 m below ground level and controlled by the channels and drains within and at the periphery of the site. Groundwaters are probably brackish, though some fresh water lenses may exist.

- The CHALK SEMI-CONFINED AQUIFER at a depth of approximately 15 mbgl. Groundwater levels in August-September 1976 were approximately 10 mbgl (-10 m OD). A groundwater low around the estuary suggests a cone of depression, possibly the result of nearby abstractions (BGS, 1981, Hydrogeological Map of Southern East Anglia). There is convergence of groundwater flow into the Stour estuary. Observation boreholes in the general area, of which some have been monitored by the Agency as far back as 1966, indicate seasonal groundwater level fluctuations of 0.5 - 1.0 m. Declines during the drought periods of 1989 - 1992 and 1995 - 1996 have been small, but in the wet period of 1993 - 1994, water levels rose by 1 - 2 m above the long term average.

3.3 WATER SUPPLY TO THE WETLAND

3.3.1 Surface Water And Groundwater Supplies

Surface water in the form of rainfall, freshwater runoff from the River Stour, and tidal flows entering via the southern drain, are the main sources of water to the site.

Groundwater inputs are not known, but is thought that they may comprise seepages from the near surface estuarine alluvial aquitard and possibly from the Valley Gravel aquifer.

3.3.2 Relationship Of Vegetation To Water Supply

Groundwater Dependency Category: Uncertain.

The current vegetation at Cattawade Marshes does not have a specific dependence upon groundwater discharge, but the role of groundwater discharge in keeping the site wet remains to be determined.

4. WATER ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 LICENSED ABSTRACTIONS

Surface water: Within 5 km radius from the site, there are 29 licensed surface water abstractions. Most of them are small, less than 100 tcma (3.2 l/s), mainly for irrigation and anti-frost. The largest is from the River Stour by ESWC for public supply at 116,070 tcma (3.631 m^3/s), daily 31,800 m^3/d (3.681 m^3/s). This is a linked licence comprising:

a) Langham intake (123,000 m^3/d or 1.424 m^3/s), approximately 9 km W.
b) Stratford-St-Mary intake (189,000 m^3/d or 2.183 m^3/s) approximately 5 km NW.
c) Cattawade intake (102,000 m^3/d or 1.181 m^3/s) at the eastern boundary of the site.

Groundwater: Within 5 km radius from the site, there are 79 licensed groundwater abstractions; 7 from Chalk and the remainder from Sand & Gravel. Most are small, less than 50 tcma (1.6 l/s) for general agriculture, spray irrigation and some for industrial use.

The largest abstractor is the Tendring Hundred Water Co. who abstract from the Chalk for public supply from 7 locations at a combined rate of 26,097.5 tcma (827.5 l/s). Boreholes are located 1.9 - 4.0 km west and south of the site, the nearest being at Lawford (1.9 km S) licensed to abstract 9500 m^3/d (109.9 l/s).

4.2 IMPACT OF ABSTRACTIONS

The tidal barrage, constructed in 1960, cut off the salt marsh from tidal influences and led to a reduction of water levels in the marsh. There is anecdotal evidence of a continuing decline in water levels, and despite the installation of water control measures, there has been no open water on site for the last 5 - 8 years.

Surface water abstractions from the River Stour upstream of the site by ESWC in combination with the recent period of low rainfall, are considered to be the main reason for the lowering of water levels in the Stour. As a result, the water supply to the marshes via the existing channels has been seriously reduced.

Groundwater abstractions from the Chalk have resulted in the formation of a cone of depression in the general area of the marshes. It is not known whether this has led to downward leakage from the overlying estuarine deposits, and thus, by implication, to adverse effect on the prevailing water-table.

The site has been assigned an AMP 3 Water Abstraction Category 2. This preliminary evaluation confirms this category. Repeated site visits during breeding season will be required.

5. EXISTING AND PROPOSED MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing Monitoring

None is known.

5.1.2 Proposed Monitoring

Annual survey of the breeding bird community to substantiate reports on the reduction of numbers and diversity of birds. Repeated site visits during breeding season will be required.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: There appear to be no surface monitoring installations in the site.

Groundwater: There appear to be no groundwater monitoring installations within the site. The Agency, as part of their regional monitoring, have been measuring groundwater levels at 8 boreholes (5 in Chalk and 3 in gravels); in two boreholes as far back as 1966.

5.2.2 Proposed Monitoring

Surface water: a) Staff gauges at suitable locations in the various drains (up to approximately 6 no).

b) If appropriate, gauging weirs (3 no).
c) Hydrochemical monitoring of waters (EC, pH) monthly, and full chemical analyses (6 monthly) at selected locations.

Groundwater: a) 4 piezometer clusters at selected locations within or outside the marshes, depending on access. At 3 of the clusters, there should be 2 boreholes; one to penetrate the shallow alluvials (3 - 4 m deep) and a second to penetrate sand/gravel or Valley Gravel (10 - 15 m deep). At one of the clusters, there should be 3 boreholes; the third to penetrate the Chalk (30 - 40 m deep).
b) Hydrochemical monitoring of the groundwaters including full chemical analyses every 6 months.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 5.1.2 and 5.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

It is understood that EN intend to carry out baseline surveys of vegetation and invertebrates. This could form part of the AMP3 submission.

6.2.2 Hydrology

The following are proposed:

a) Hydrological, hydrogeological, and hydrochemical study of the site including field surveys and installation of monitoring structures.
b) Evaluation report to provide baseline conditions including the effects on the site of Chalk abstractions.
c) Monitoring of installations, initially for a period of 5 years.
d) Annual interpretational reports using monitoring data.

6.3 ALLEVIATION MEASURES

a) Maintenance and modifications of existing structures in order to enhance flow from the Stour to the site.
b) Following the baseline evaluation report, consideration with regard to modifying the existing ESWC surface water abstraction licence; also, if relevant, modification of Chalk abstractions by the Tendring Hundred Water Company.
c) Examination of the possibility of utilising Chalk water to augment the water supply to the site. This would depend on groundwater availability, compatibility of the quality of groundwater with the ecology of the marshland, and on the assumption that such abstraction would have no potential impact on site hydrology.

6.4 SITE MANAGEMENT

A Management Plan is in preparation.

APPENDIX 1

THE IMPORTANCE OF GROUNDWATER TO FEN SITES AND VEGETATION

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THE IMPORTANCE OF GROUNDWATER TO FEN SITES AND VEGETATION

There has been, and probably still is, considerable confusion as to the nature of the interaction between groundwater supply and the character and composition of fen sites and vegetation. This will not be reviewed fully here, but some salient points will be made.

GROUNDWATER DEPENDENCY CATEGORIES FOR FEN SITES AND VEGETATION

It is possible to identify different degrees of dependence of fen sites and vegetation upon groundwater supply. These can be categorized as:

1. Groundwater supply is (±) absent;
2. Groundwater discharge occurs, but is of negligible importance to the water balance or the character of the vegetation;
3. Groundwater discharge is a significant component of the water balance but is not critical to the character of the vegetation;
4. Groundwater discharge is a significant component of the water balance and is critical to the character of the vegetation.

It is also possible that in some circumstances groundwater discharge may be critical to the character of fen vegetation without being a major component of the water balance, but this appears to be unusual and is probably of little importance in an East Anglian context.

These categories may apply both to sites and parts of sites, and to specific types of vegetation. Not only do they intergrade, they also vary in their intensity, just as different types of fen vegetation vary in the degree of their dependence upon specific conditions. However, they provide a useful conceptionalisation, not least because they point to different solutions to any problems of low groundwater levels, viz (using the four categories identified above):

1. reduction of groundwater supply unimportant;
2. reduction of groundwater supply unimportant;
3. need to compensate for reduced groundwater supply, but does not have to be with groundwater;
4. compensation for reduced groundwater supply at least requires groundwater and, depending upon the nature of the vegetation requirements, such supplementation may not provide an adequate substitute for the original groundwater discharge.

Because of these varied consequences, it is clearly important to distinguish to which categories specific sites and vegetation types belong. It is also important, for vegetation-types which have a dependence upon groundwater discharge to consider the nature of this dependence, because this may determine the options for ameliorating reduced groundwater supply.

IMPORTANCE OF GROUNDWATER DISCHARGE TO VEGETATION-TYPES THAT REQUIRE IT

The association of particular plant species and vegetation-types with groundwater discharge has long been recognised but its causation has received only limited study. However, it is important to recognise that groundwater does not have 'magical' properties. Its effects on vegetation are primarily determined by the hydrochemical conditions it generates in the rooting zone. However, generalisation is complicated by the facts that:

- different species and vegetation have different intensities of dependence upon groundwater discharge;
- the relationship of different species and vegetation to groundwater supply can be modified by independent variables (e.g. management regime, substratum fertility);
- different types of groundwater (varying in chemical composition) are associated with different types of vegetation;
- different types of fen and fen vegetation have rather different relationships to groundwater.

Fortunately, in the East Anglian context, the discrete range of conditions encountered means that the inter-relationships are not as complicated as they could be. It is, however, important to recognise, and appreciate the importance of, the differences between the two main types of fens into which groundwater discharge occurs: soligenous and rheo-topogenous fens.

Soligenous Fens

Soligenous (= 'soil-made') fens are those which experience much lateral water movement derived from the mineral ground. The water table, and usually the site as well, is strongly sloping and is maintained primarily by groundwater discharge. If consideration is restricted to systems dependent on base-rich discharges (and all of the fen sites in the current review fall into this category) it may be noted that some of the key features of groundwater discharge in relation to some, or all, of the species and vegetation types that depend on it in soligenous fens are:

- fairly high and constant summer water tables; absence of protracted or deep winter flooding;
- absence of strongly reducing conditions in the rooting zone (caused by water flow and, often, by subsurface water tables);
- specific hydrochemical processes (especially calcite precipitation associated with degassing of discharging groundwater and concomitant P adsorption).

Rheo-Topogenous fens

As this term and concept has received only limited use in Britain, a brief explanation is necessary. The concept of 'topogenous fen' has long been used, more-or-less as an opposite to 'soligenous fen'. In its classic concept a topogenous (= 'topography-made') fen has a more-or-less level water table in which the primary direction of movement is vertical. However, where there is a hydraulic gradient across a topogenous fen, some lateral water movement is likely to occur and in some sites this is of sufficient magnitude to have an important and distinctive effect upon the composition of the vegetation. Such systems are effectively topogenous fens with lateral water flow and share some of the properties of both strictly topogenous and soligenous systems. The term 'rheo-topogenous' seems appropriate for this sort of the fen and is used here ('stagno-topogenous' can be applied to topogenous fens sensu stricto).

Some of the key features of rheo-topogenous fens are:

- fairly high to very high summer water tables; sometimes protracted or deep winter flooding;
- water levels less constant than in soligenous fens but more constant than in stagno-topogenous fens;
- vegetation frequently forms as a semi-floating raft; the vertical mobility of this can much reduce water level fluctuations relative to the vegetation surface and can help prevent both drying and deep flooding;
- less strongly reducing conditions in the rooting zone compared to stagno-topogenous fens (caused by water flow) but more strongly reducing than in soligenous examples (except where rafting occurs when conditions immediately below the surface are often not strongly reducing);
- some hydrochemical processes (such as calcite precipitation and flow-induced aeration) are generally less important than in soligenous fens, though others (such as denitrification) may be more important. In general, the hydrochemical characteristics of rheo-topogenous fens are less critically dependent on specific water sources than are those of soligenous fens (e.g. providing the water is of the correct quality (such as being base-rich and relatively nutrient poor), its precise source is not important to the vegetation of rheo-topogenous fens.

Lateral water movement in rheo-topogenous fens can be induced by groundwater discharge (in some cases from soligenous slopes adjoining a rheo-topogenous basin), but flow patterns can also be generated from other water sources. Because of this, such systems and their vegetation are sometimes less critically dependent upon groundwater discharge than are soligenous systems.