Upper Thurne Broads and Marshes – Site Action Plan

Version 5

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Introduction

Stage 4 requires the Agency to affirm, modify or revoke permissions assessed within the Appropriate Assessment at stage 3 of the Habitats regulations process. Those

permissions that were found not to be having an adverse effect on site integrity at Stage 3 will be affirmed. However, for those that could not be shown to have no adverse effect, it is necessary to identify the most appropriate course of action to enable a conclusion of no adverse effect on site integrity to be reached. This Site Action Plan (SAP) details options identification and appraisal for all such permissions for the Upper Thurne Broads and Marshes and follows the principles and process outlined in the Agency Habitats Directive Handbook and TAG papers.

SECTION A

STAGE 3 OVERVIEW

Site description

The Upper Thurne Broads and Marshes SSSI is located approximately 5km southeast of Stalham (TG430210) and the site forms part of the headwaters of the River Thurne, approximately 4km from the coast.

There are four large, shallow Broads: Hickling Broad, Heigham Sound, Horsey Mere and Martham Broad; smaller water bodies; and extensive areas of flooded swamp and reedbed. The habitats of the Upper Thurne have a high proportion of open water. Agricultural areas to the north and east drain into the site, and there is an open connection with the tidal River Thurne in parts of the system to the south. The Broads and fens exhibit a slight brackishness due to their proximity to the coast and to the presence of deposits of estuarine clay.

The designated SAC and SPA features are:

- Molinia Meadows
- Fen Orchid
- Alluvial Forests
- Calcareous Fens
- Natural Eutrophic Waters
- Hard Oligo-Mesotrophic Waters
- Otter
- Desmoulin's Whorl Snail
- Bittern
- Marsh Harrier
- Hen Harrier
- Gadwall
- Shoveler
- Bewick's Swan
- Whooper Swan
- Great Crested Grebe
- Cormorant
- Wigeon

In addition there are sub-features important for the SPA bird species and these are swamp, fen, reedbed, wet woodland, open water and fen meadow with ditches and water bodies.

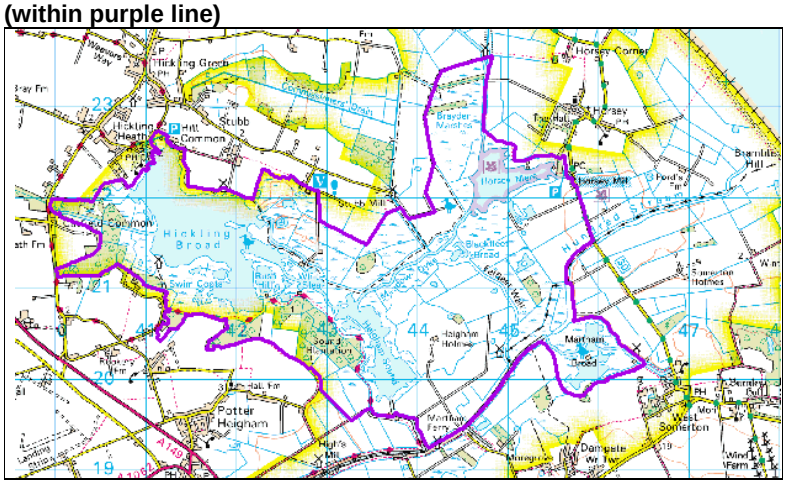
Summary of licenses / consents at end of stage 3

Table A1:

Function	No adverse effect on site integrity can be shown	No adverse effect on site integrity cannot be shown
Water Quality	29	15 (+1 new permission in-combination)
Water Resources	36 licences	12
Waste	1	0
PIR: discharges to water	0	0
PIR: discharges to air	0	0
Radioactive Substances Regulation	0	0

Map of site

Figure A1: Map showing location of Upper Thurne Broads ands Marshes SSSI (within purple line)



FUNCTIONAL SPECIFIC STAGE 3 OUTCOMES

A1 WATER QUALITY

At stage 3 specific targets were set by English Nature (now Natural England) for 4 of the SAC features that have a requirement for good water quality, these are Natural eutrophic lakes, Hard oligo-mesotrophic waters, Otter and Desmoulins Whorl snail. English Nature stated that if the site was delivering the targets for the eutrophic lakes and oligo-mesotrophic waters features it would be delivering the water quality targets for all the designated features.

The eutrophic lakes feature is comprised of Martham, Horsey, Hickling, and Heigham Broads, and some marsh dykes in the south of the site in the Hickling and Horsey areas. The hard oligo-mesotrophic waters feature is comprised of Martham, Horsey, Hickling, and Heigham Broads and some marsh dykes in the north east of the site in the Horsey area.

The stage 3 assessment concluded that only nutrients were having (or could have at fully consented conditions) an adverse impact on the features of the site.

At stage 3 the nutrients target for natural eutrophic lakes and SPA lakes (0.1mg/l total P (TP)), was met in all Broads and the river. The target for SAC lakes (0.05mg/l TP) was met in Martham Broad and Horsey Mere. The target for oligo-mesotrophic water (0.03mg/l) was only met in Martham Broad.

Detailed assessments and calculations at stage 3 were carried out for each of the 3 areas: Martham Broads; Horsey Broad; and Hickling / Heigham Broads.

For Martham the results indicated that both Broads are of good or high ecological status and both comply with all phosphorus targets. An in-combination investigation with water resource permissions indicates that there could be a considerable reduction in water flows to this area and TP targets may then be exceeded. The four discharges to this area are therefore taken to stage 4 for options appraisal.

For Horsey Mere the broad complied with the SAC lake target but not the target for oligo-mesotrophic waters. Five discharges having the potential to affect this area were taken through for options appraisal.

Results from Hickling Broad and Heigham Sound showed they did not comply with the SAC lake target or the target for oligo-mesotrophic waters. Eleven discharges were identified as having the potential to affect this area.

New consents were also examined for in-combination assessment. PRENF19055 is near the River Thurne at Candle Dyke and for this it could not be concluded that it will not have an adverse effect on the site in-combination.

Table A1.1: List of discharges taken forward to stage 4 for further consideration

Consent code	Consent name	Martham	Horsey	Hickling / Heigham
AW4NF55X	Repps with Bastwick STW			✔
PR4NF1175	Private STW at Hickling			✔
PRENF10631	Private STW at Repps with Bastwick			✔
PRENF11182	Private STW at Repps with Bastwick			✔
PRENF13229	Private STW at Potter Heigham			✔
PRENF10816	Private STW at West Somerton			✔
AW4NF1083X	Horsey STW		✔	✔
PRENF10152	Private STW at Horsey		✔	✔
PRENF10673	Private STW at Horsey		✔	✔
PRENF347	Private STW at Horsey		✔	✔
PR4NF1778	Private STW near Hickling		✔	✔
PRENF19055	Private STW (Reg. 48) considered in combination with those in review			✔
PR4NF1977*	Private STW at West Somerton	✔		
PR4NF2127*	Private STW at West Somerton	✔		
PRENF10809*	Private STW at West Somerton	✔		
PRENF8356*	Private STW at West Somerton	✔		

* in combination with groundwater abstractions

Figure A1.1: Map of site, showing location of permissions in Stage 4

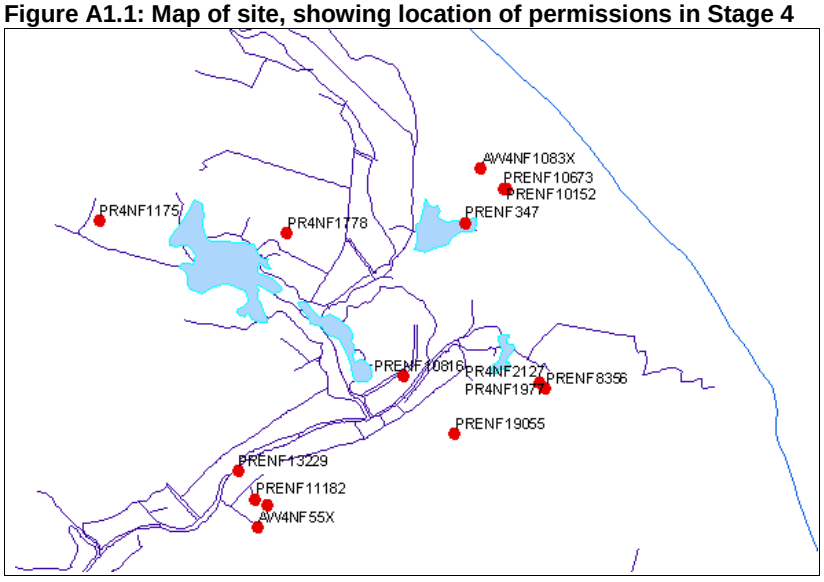


Table A1.2: Outcomes of Stage 3 Appropriate Assessment and issues identified for the Upper Thurne Broads and Marshes SSSI

Number	Discharges to	AEOI alone or in-combination	Known impact or perceived risk	Actual (A), Modelled (M) or Suspected (S) impact	Hazard posed	Permission relevant to another site?
AW4NF55X	River Thurne	In-combination	Known impact on water quality standards	A and M	Nutrients - phosphorus	No
PR4NF1175	Hickling area	In-combination	As above	A and M	As above	No
PRENF10631	R. Thurne	In-combination	As above	A and M	As above	No
PRENF11182	R. Thurne	In-combination	As above	A and M	As above	No
PRENF13229	R. Thurne	In-combination	As above	A and M	As above	No
PRENF10816	Heigham area	In-combination	As above	A and M	As above	No
AW4NF1083X	Horsey area	In-combination	As above	A and M	As above	No
PRENF10152	Horsey area	In-combination	As above	A and M	As above	No
PRENF10673	Horsey area	In-combination	As above	A and M	As above	No
PRENF347	Horsey area	In-combination	As above	A and M	As above	No
PR4NF1778	Hickling area	In-combination	As above	A and M	As above	No
PRENF19055	R. Thurne	In-combination				
PR4NF1977	Martham area	In-combination with groundwater abstractions	Possible impact on water quality standards at maximum abstraction	S	As above	No
PR4NF2127	Martham area	As above	As above	S	As above	No
PRENF10809	Martham area	As above	As above	S	As above	No
PRENF8356	Martham area	As above	As above	S	As above	No

Table A1.3: Known effects from other sources

Ref. to Table A1.1	Known effect	Another CA* responsible	No other CA* responsible, future regulation / management realistically achievable	No other CA* responsible, future regulation / management <u>not</u> realistically achievable
A1	Nutrient enrichment	Defra - Agricultural inputs		
A2	Nutrient enrichment		Phosphorus input from un-consented small diffuse sources – assessment and possible regulation	Phosphorus input from natural diffuse sources
A3	Nutrient enrichment	Broads IDB – modification of drainage system to reduce salinity and ochre will benefit nutrient attenuation in the catchment		

A2 WATER RESOURCES

A2.1 Outcomes of Stage 3 Appropriate Assessment and issues identified

Much of the information in this section of the Site Action Plan is taken from the Options Appraisal Report (OAR) for Upper Thurne Broads & Marshes SSSI (Entec, October 2009).

A.2.1.1 Hydro-ecological understanding

The Upper Thurne Broads & Marshes SSSI is located in the catchment of the River Thurne, which is part of the Broads Reporting Area within the Yare and North Norfolk Groundwater Resource Investigation Area (see figure 3.1 in the Options Appraisal Report, Entec, 2009). The site extends from from Catfield Common and Hickling Heath in the west to Horsey and West Somerton in the east. Covering an area of 1159ha, it extends to within 2km of the coast at its eastern margins. There are four large shallow lakes within the site; Hickling Broad, Heigham Sound, Horsey Mere and Martham Broad. These, together with several smaller water bodies, are thought to have been formed by the flooding of peat diggings prior to the 13th century. They are surrounded by extensive areas of reedbed and species-rich sedge fen, with significant areas of associated grazing marsh and fen meadow. There are also small areas of alder carr and drier deciduous woodland.

The Broads Reporting Area for the Yare North Norfolk regional groundwater model comprises the tidal sub-catchments of the Rivers Ant, Bure and Yare, and the catchments of the Rivers Thurne and Muck Fleet. The rivers are often at a higher level than the surrounding land, and consequently water levels in adjacent low-lying areas are controlled by an extensive network of managed ditches and dykes. Pumping stations are required to discharge water from the drainage network in areas where the main rivers are embanked.

The Chalk aquifer underlies the entire Broads Reporting Area, but only occurs at outcrop in the far west of the Area in parts of the River Yare and River Bure valleys. The Chalk dips below the Eocene London Clay Formation to the east of a north-south line that runs from near Happisburgh in the north-east, down the approximate line of the lower River Ant, to near Beccles in the south. Crag deposits are present throughout the majority of the Reporting Area. To the west of the western limit of the London Clay, Crag deposits directly overlie the Chalk, whereas to the east the Crag and Chalk are separated by Eocene Clay.

Crag deposits outcrop in places along the valley sides, and at higher elevations are overlain by glacial Till and glacial Sands and Gravels. More recent deposits include significant areas of peat along the valley bottoms and other low-lying areas.

The SSSI comprises three hydrological units; the Hickling Broad and Marshes unit occupies the western centre of the site, whilst the Horsey Mere and Marshes unit is to the east and Martham Broad and Fens, the smallest unit, is located in the south-eastern corner of the SSSI.

The topography of the site is generally flat but rises at the periphery of the site boundary, for example southwards from the southern boundary of the Martham Broad and Fens and southwards from the south-west corner of Hickling Broads and Marshes. Surface water fluxes through the Upper Thurne SSSI are very large because of the tidal influence on the River Thurne and the large quantities of water pumped in and out of the system by the IDB (Section 3.7 of the Options Appraisal Report). Hickling Broad is connected to areas of surrounding marshes by surface drains and, therefore is believed to provide a tidally fluctuating control of surface water levels in these areas.

The site is believed to be wet throughout, with the distribution of vegetation communities indicating differences in management and ground conditions (e.g. areas previously cut for peat, hover, pumped / drained areas and presence of estuarine clays etc.) rather than differences in wetness *per se*.
Ground levels in the marshes bordering the Broads are at levels of about 0.3-0.5 mAOD, and the drained marshes adjacent to them are approximately 1m lower. The drained areas are separated from the Broads by embankments ("walls"), the water within them draining to Internal Drainage Board (IDB) pumps through which it is raised to the higher level River Thurne and other watercourses that flow through the Broads (for more information please refer to the Water Level Management Plans published by the King's Lynn Consortium of IDBs, KLCIDB,1994, 2000, 2001a-d, and 2002).

The Broads themselves are shallow waterbodies, the flooded remains of peat diggings (Lambert & Jennings, 1960), with average depths ranging from 1.0-1.5m (Broads Authority data supplied to Entec). Entec (2001, 2004 & 2006) have previously described the site topography and drainage, and subdivided the SSSI into three hydrological sub-units:

1) Hickling Broad (including Meadow Dyke and Heigham Sound)
2) Horsey Mere (including Brayden Marshes and the grazed areas to the south around Mere Farm and Heigham Holmes)
3) Martham Broad.

Hickling Broad
Water levels in Hickling Broad exhibit daily variations of 5-10cm which are a result of a tidally induced backing up of water (and wind turbulence). Only in unusual conditions do saline waters from the Bure estuary proceed higher than Acle Bridge, downstream of where the River Thurne joins the River Bure at Thurne Mouth (Holman 1994). During the period 1998-2004, water levels in the Broad ranged from about 0.25-0.75 mAOD with the average level being between 0.4-0.5 mAOD (Entec, 2006). Consequentially there is a low hydraulic gradient between the Broad and the sea, 20km downstream. The Broad is largely surrounded by flood banks, which separate it from the surrounding drained land, and receives surface water from the Catfield IDB pump which discharges to Catfield Dyke. Due to the influence of tidal fluctuations, the Broad can also receive water via Heigham Sound and Meadow Dyke which provide connection to the Horsey Mere and Martham Broad areas.

At the western end of the Broad, south of Catfield Dyke, Mrs Myhill's Marsh is at an elevation of about 0.4-0.5 mAOD. It is separated from the surrounding uplands by a catchwater drain and is crossed by ditches with surveyed bases at about -1 mAOD, though by analogy with the surveys carried out at Ludham-Potter Heigham Marshes (Entec, 2007a), the ditch depths may appear on-site to be substantially less (e.g. about 0.6m). Nonetheless, the levels suggest the Marshes can be influenced by the water level in the Broad. Entec (2006b) notes that the drains in Mrs Myhill's Marsh are directly connected to the Broad.

To the south of Hickling Broad, beyond the flood bank, there are several areas of woodland including Piccamore Wood at its western end. This area is at a lower level than the Broad and surface water drains to the south, eventually reaching the Potter Heigham Pump from which it is discharged to the River Thurne.

To the north of White Slea and the adjacent Hickling Broad, a series of drained grazing marshes occur to the north of a flood bank which runs close to the Broad. These include Bygraves' Marsh and, to the west, White Slea Marshes. At White Slea Marshes, the ground surface averages about -0.4 mAOD, up to about a metre below the water level in the Broad. Norfolk Wildlife Trust (NWT) manage the site and is able to control inflow from the Broad and ouflow to the IDB drains at the north-west and north-east corners of the Marshes. Water then flows eastwards to Stubb Mill, where most water is discharged towards Meadow Dyke, with only minor flow progressing further north towards Eastfield Pump (John Blackburn, NWT warden, pers. comm.).

Horsey Mere
Horsey Mere is largely fed by pumped drainage water from agricultural land to the north, east and south, as well as gravity drainage water leaving Brayden Marshes. The drainage water from the north flows along Waxham New Cut and includes water from the Brograve Level where deep drains have intercepted saline waters. The topographic survey of levels in Brayden Marshes indicates levels of about 0.4 mAOD to the south of Waxham New Cut, and slightly higher levels of 0.6-0.7 mAOD further north, adjacent to the Cut, on the eastern margin of the Marshes. The higher levels may be due to spoil both from mud-pumping of Waxham New Cut and another dyke occurring close to the line of the transect on its west side (Steve Prowse, National Trust warden, pers. comm.).

Martham Broad
Martham Broad is separated by flood banks from naturally receiving drainage water from the uplands to the south. Such water can, however, enter the Broad after first draining into the agricultural land to the east and then being pumped into the Broad by the Old Somerton IDB Pump. The Broad also receives a tidal influx of surface water from the River Thurne (Entec, 2006). Topographic survey data indicates that the ground surface near the outflow from the Broad is about 0.4 mAOD, whereas to the south, within a drained area, the ground surface is as low as -0.4 mAOD before it rises to 22 mAOD further south, to the south of West Somerton.

For further information regarding flow in the broads and ditch system and variation in water levels and water chemistry please refer to Section 3.6 of the Options Appraisal Report (Entec, 2009).

The conceptual understanding of the site presented in this Site Action Plan focuses on the SSSI areas where the features of interest are located. These five areas comprise Mrs Myhill's Marsh, Piccamore Wood, White Slea Marshes (all within the Hickling Broad sub-unit), Brayden Marshes (within the Horsey Mere sub-unit), and Martham Broad.

Mrs Myhill's Marsh – Transition Mires (M5)
The marsh is surrounded by higher ground on three sides and is separated from it by a catchwater drain. Ditches drain land to the south and provide some input of surface water to the marshes. The marsh surface is at about 0.5 mAOD, within the range of surface water level fluctuations in Hickling Broad, and is wet, "still squelchy in an average summer" (John Blackburn, pers. comm.).
The Breydon Formation comprises peat overlying a clay or sandy clay layer, or layers, and appears to have a variable thickness. Three auger holes have encountered thicknesses varying from 0.75-2.0m. The Breydon Formation is underlain by the Crag and very possibly a thin layer of overlying clayey sandy Corton Formation. The groundwater levels within the Crag and Corton Formation are at about 1.0 to 1.7 mAOD, and since the shallow groundwater levels observed within the dipwells are at or close to ground level (c.0.5mAOD), there is the potential for upward groundwater flow to the Marshes. However, because of the presence of clay within the Breydon Formation, it is not certain what influence groundwater has on the body of the Marshes. It seems likely however that the catchwater drain that surrounds the Marsh at the break of slope, and possibly drains crossing the marsh, may have a groundwater component of flow, but in what proportion compared to rainfall and surface water input from the Broad, and runoff from the land and drains to the south, is not known.

Piccamore Wood – Alluvial Woodland
It is considered that this area may receive some Crag groundwater via lateral seepage into surface water drains, and there is the possibility of direct upward vertical flow from the Crag, but there is uncertainty regarding to what extent the presence, thickness, and clay content of the overlying Breydon Formation will significantly influence such seepage.

White Slea Marshes – Molinia Meadows
The hydrology of White Slea Marshes appears to be strongly controlled by site management undertaken by Norfolk Wildlife Trust. The Trust are able to draw water from the higher level Hickling Broad and to manage outflow to the IDB drain which runs along the northern boundary of the site. The presence or absence of clays within the Breydon Formation will influence whether there is any Crag groundwater discharge to the Marshes. It is not known whether the ditches fully penetrate the Breydon Formation or not, but if so there could be some groundwater discharge to them.

Brayden Marshes – Calcareous Fens
The Marshes are separated hydrologically from the surrounding IDB-drained areas, and are linked at their south-eastern end to Horsey Mere. The Breydon Formation underlies the area. Peat and clay have been recorded within the Breydon Formation at Horsey Mere, and in the Brograve Level to the north, deep drains have penetrated

through the Upper Peat and Upper Clay down into the Middle Peat. The presence of the Upper Clay may mean that there is little groundwater input to the site. Steve Prowse, the National Trust warden (pers.com.), considers the Marshes to be solely dependent on water levels in Horsey Mere.

Martham Broad – Hard Oligo-mesotrophic waters
The wetness of the marshes at Martham Broad is considered to be dependent on the river water level (John Blackburn, pers. comm.). Any direct groundwater input to the Broad is likely to come from the Corton Formation which is believed to form the base of the Broad towards the uplands. However, IDB dykes to the south of the Broad appear to intercept at least some, if not the majority, of this groundwater flow. Seepage of high quality groundwater to these dykes has been reported, and since this is subsequently pumped into the Broad by Old Somerton Pump, it provides an indirect groundwater input to the Broad. Direct groundwater input to the Broad from the Crag is unlikely as groundwater heads in the Corton Formation appear to be higher than in the Crag, and therefore there is potentially downward groundwater movement to the Crag, rather than upwards from it.

A.2.1.2 European features and Stage 3 targets

The wetland European features for which the site is included in the Broads SAC and Broadland SPA are presented in Table A.2.1.

At RoC Stage 3 the potential effect of abstraction on the features was assessed against targets derived from available information on the hydrological regimes required to maintain or restore the condition of those features on the site. At Upper Thurne Broads & Marshes, in the absence of any long-term dipwell data indicating the actual hydrological regime within the communities on-site, these targets were derived from Natural England's Favourable Condition Table for the site and the Ecohydrological Guidelines for Lowland Wetland Plant Communities (Wheeler, B.D.; Shaw, S.C.; Gowing, D.J.G.; Mountford, J.O.; and Money, R.P., 2004).

The hydrological targets used for the Stage 3 Assessment at Upper Thurne Broads & Marshes are presented in Table A.2.1. The hydrological targets used for the RoC Stage 3 Assessment at Upper Thurne Broads & Marshes SSSI are presented in Table 2.1. The targets for the Calcareous Fen, *Molinia* Meadows, Alluvial Forests, and Transition Mire communities were based on depth to water table, whereas the targets for the Natural Eutrophic Lakes and Hard Oligo-mesotrophic Waters features were based on a combination of flushing rates and water levels below the marsh ground surface for ditches, and on groundwater inflow for lakes.

Table A.2.1 European Features at Upper Thurne Broads & Marshes and Stage 3 Targets

European Feature	Stage 3 Target
Broads SAC	
Alluvial Forests With *Alnus glutinosa* and *Fraxinus excelsior*	Winter groundwater levels at or very near the ground surface, being maintained within 5cm of the ground surface in the spring. Summer

Represented by: **Parts of W2** (*Salix cinerea - Betula pubescens - Phragmites australis*)**, W5** (*Alnus glutinosa – Carex paniculata)* and **W6** *(Alnus glutinosa – Urtica dioica)* woodland NVC communities	maximum and minimum levels should be 5-45cm below the ground surface, optimal seedling growth occurring when levels are 10-30cm below ground level.
Calcareous Fens with Cladium mariscus and species of the Caricion davallianae Represented by: **S24** (*Phragmites australis-Peucedanum palustre*) tall herb fen and **S25** (*Phragmites australis – Eupatorium cannabinum)* tall herb fen	The target for S24 is that the summer water table (July-Sept) should be between 3cm above ground level and 36cm below ground level. Winter water levels are expected to be at the surface. The Stage 3 report notes that this target covers both communities (i.e. S24 & S25) that contribute to this feature.
Transition Mires and Quaking Bogs Represented by: **M5** (*Carex rostrata – Sphagnum squarrosum*)	Water levels should not fluctuate by more than 30cm annually.
Natural Eutrophic Waters	Feature targets have been developed related both to flushing flows and to ditch water levels. Regarding flushing flows, monthly flow should be twice the volume of the ditch system in summer (i.e. flushing rate of once every 2 weeks). When flushing rate < 6 weeks, the target is based on ditch water levels which are recommended by English Nature to be not more than 45cm below marsh level, year round. No target has been set for winter. It is considered that potentially adverse effects may occur if ditch water levels fall by more than 10% of the ditch depth in spring and summer (March-September), and if these reductions cause the water level to breach the 45cm limiting threshold. No generic targets were agreed with English Nature for these types of waters. The target proposed in the Stage 3 report was that the groundwater inflow to the hydrological sub-units of the site should not be reduced by more than 10%. This was considered precautionary as the estimated annual groundwater input to the site is about 1% of each tidal flux (which occurs twice daily).
Hard Oligo-Mesotrophic Waters with benthic vegetation of Chara spp. Represented by: Almost exclusively by type '4' of the GB Standing Waters classification, rarely types	The targets are the same as for Natural Eutrophic Lakes feature within ditches. The same targets are applied as for natural eutrophic lakes in the same situation.

'5' and '10' In Drainage systems In the Broads and Waters Linked Directly to the Broads	
Molinia Meadows on calcareous, peaty or clayey-silt-laden soils Represented by: **M24** (*Molinia caerulea – Cirsium dissectum*) fen meadow community	Water table should be between 10 and 41cm below ground level in the summer months (July-Sept).
Otter (Lutra lutra)	Targets are not required as they will be adequately covered by targets set for other features indicated above.
Broadland SPA	
Habitats for the populations of Annexe 1 bird species (Bittern, marsh harrier *Circus aeruginosus*, hen harrier *Circus cyaneus*, Bewick's swan *Cygnus columbianus,* whooper swan *Cygnus cygnus* and ruff *Philomachus pugnax*): Includes open water, fen, swamp, reedbed and lowland wet grassland with ditches and water bodies.	No target set - assumed to be adequately covered by SAC features
Habitats for the populations of migratory bird species (gadwall *Anas strepera* and shoveler *Anas clypeata*): Includes open water, fen, swamp, reedbed and lowland wet grassland with ditches and water bodies.	No target set - assumed to be adequately covered by SAC features
Habitats for the populations of waterfowl that contribute to the wintering waterfowl assemblage of European importance: Includes open water, fen, swamp, reedbed and lowland wet grassland with ditches and water bodies.	No target set - assumed to be adequately covered by SAC features

Distribution of features

- The natural eutrophic lakes and hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. features are widespread on site, associated with the broads and the dykes connecting them (see Figures 3.20 and 3.21 in the Options Appraisal Report, Entec, 2009).
- The calcareous fen feature is also abundant and occurs predominantly as large contiguous areas throughout the SSSI (Figures 3.20 and 3.21 in the Options Appraisal Report, Entec, 2009).
- Marsh dykes containing the natural eutrophic lakes feature are predominantly located within the Horsey Meres and Marshes hydrological unit.

- The alluvial forest and *Molinia* meadows features are predominantly located in the central section of the Hickling Broad and Marshes unit.
- The transition mires SAC feature occurs in one discrete area in the south-eastern corner of the Hickling Broads and Marshes unit at Mrs Myhill's Marsh.
- Records for otter indicate that they predominantly occur around Hickling Broad and associated woodland to the south.

A.2.1.3 Results of Stage 3 assessment

The Regulation 50 Appropriate Assessment was concluded in October 2006. For the 21 licensed abstractions included in the assessment, with regard to their effect on Upper Thurne Broads & Marshes SSSI, the following conclusions were reached:

- For surfacewater abstraction licences it was concluded that no adverse effect on site integrity could be shown
- For 17 groundwater abstraction licences it was concluded that no adverse effect on site integrity could not be shown when acting in-combination (five of these licences have been deregulated)
- A further 4 had been considered under regulation 48

Therefore: there is potential for adverse effect on the European interest features of Upper Thurne Broads & Marshes SSSI alone and in combination from water resource permissions.

The licences are presented in Table A2.2 below and are identified on Figure 2.1 in the Options Appraisal Report (Entec 2009).

The RoC Stage 3 analysis was undertaken using a layered radial flow model together with the Yare North Norfolk (YNN) regional groundwater model.
For the Horsey Mere and Martham Broad sub-units the analysis for full licence uptake indicated maximum draw downs of 0.005m (0.5cm) and 0.014m (1.4cm) respectively. These drawdowns were not considered to be of sufficient magnitude to result in an adverse impact on the features present.

In the Mrs Myhill's Marsh area of the Hickling Broad sub-unit a maximum draw down of 0.194m was predicted with radial flow analysis with abstraction licences 7/34/10/*G/0111 (HA Overton & Son) and 7/34/9/*G/0091 (AWS Ludham) making the largest contributions to the drawdown. The impact of groundwater abstraction to the south-west of the Mrs Myhill's Marsh area of the Hickling Broad hydrological sub-unit, mainly resulting from two abstraction licences, is considered to be of sufficient magnitude to result in an adverse effect on the transition mires feature present in the Marsh, and also possibly on the calcareous fen and alluvial woodland features located nearby. The reduction in inflow of groundwater to the open water areas of the sub-unit are of sufficient magnitude to potentially result in an adverse effect on the natural eutrophic lakes and hard oligo-mesotrophic water with benthic vegetation of Chara.

Table A.2.2 Outcomes of Stage 3 Appropriate Assessment for Upper Thurne Broads & Marshes SSSI

	Permission Name	Purpose	No adverse effect on site integrity cannot be shown		Impact (I) or a Risk (R) if cannot conclude there is no impact	Impact type: Actual (A), Modelled (M), or Suspected (S)	Nature of Impact	Permission relevant to another site? If Yes list site
			Alone	In-combination				
7/34/10/*G/0111 Base licence with Reg. 48 element	H A Overton & Sons	Spray Irrigation – direct		✓	RISK	M	>1mm in combination. Assessed under Regulation 48	Alderfen Broad, Ant Broads & Marshes, Ludham to Potter Heigham, Priory Meadows, Shallam Dyke Marshes
7/34/09/*G/0091 App. 21 misprints this licence number as 7/34/10/*G/0091 **Base licence with Reg. 48 element**	AWS Ludham	Potable Water Supply		✓	RISK	M	>1mm in combination. Assessed under Regulation 48	Bure Broads & Marshes
7/34/09/*G/0058	Simply Strawberries Ltd	General Farming & Domestic		✓	RISK	M	> 1mm in combination	Alderfen Broad, Ant Broads & Marshes, Broad Fen, Calthorpe Broad, Priory Meadows, Shallam Dyke Marshes
7/34/09/*G/0106	Ames	General Farming & Domestic		✓	RISK	M	> 1mm in combination	Ant Broads & Marshes, Broad Fen, Calthorpe Broad, Priory Meadows
7/34/10/*G/0015 (Deregulated)	Puxley	General Farming & Domestic		✓	RISK	M	> 1mm in combination. Deregulated under Water Act 2003	Alderfen Broad, Ant Broads & Marshes, Calthorpe Broad,

								Ludham to Potter Heigham , Priory Meadows, Shallam Dyke Marshes
7/34/10/*G/0121 (Deregulated)	West	General Farming & Domestic		✓	RISK	M	> 1mm in combination	Hall Farm Fen (dereg.), Ludham to Potter Heigham, Shallam Dyke Marshes, Trinity Broads
7/34/10/*G/0125 (Deregulated)	Nudd	General Farming & Domestic		✓	RISK	M	> 1mm in combination. Deregulated under Water Act 2003	Alderfen Broad, Ant Broads & Marshes, Bure Broads & Marshes, Ludham to Potter Heigham, Priory Meadows, Shallam Dyke Marshes
7/34/10/*G/0126 (Deregulated)	G A Tallowin & Co	General Farming & Domestic		✓	RISK	M	> 1mm in combination. Deregulated under Water Act 2003	Ant Broads & Marshes, Calthorpe Broad, Ludham to Potter Heigham, Priory Meadows, Shallam Dyke Marshes
7/34/09/*G/0066 (Deregulated)	Harris	General Farming & Domestic		✓	RISK	M	> 1mm in combination. Deregulated under Water Act 2003	Alderfen Broad, Ant Broads & Marshes, Broad Fen, Ludham to Potter Heigham, Shallam Dyke Marshes
7/34/09/*G/0102	Taylor	Spray Irrigation - Direct		✓	RISK	M	> 1mm in combination	Alderfen Broad, Ant Broads & Marshes, Bure Broads & Marshes, Ludham to Potter

								Heigham, Shallam Dyke Marshes, Upton Broad
7/34/10/*G/0061	Hirst Farms Ltd	Spray Irrigation - Direct		✓	RISK	M	> 1mm in combination	Burgh & Muckfleet Marshes, Hall Farm Fen, Trinity Broads
7/34/10/*G/0063	Simply Strawberries Ltd	Horticultural Watering		✓	RISK	M	> 1mm in combination	Burgh & Muckfleet Marshes, Hall Farm Fen, Ludham to Potter Heigham, Shallam Dyke Marshes, Trinity Broads,
7/34/10/*G/0096	Spinks	General Farming & Domestic		✓	RISK	M	> 1mm in combination	Burgh & Muckfleet Marshes, Hall Farm Fen, Ludham to Potter Heigham, Shallam Dyke Marshes, Trinity Broads
7/34/10/*G/0110	G W Daniels & Son Ltd	Spray Irrigation - Direct		✓	RISK	M	> 1mm in combination	Burgh & Muckfleet Marshes, Hall Farm Fen, Trinity Broads
7/34/10/*G/0114	P J Deane & Sons	Spray Irrigation - Direct		✓	RISK	M	> 1mm in combination	Ant Broads & Marshes, Broad Fen, Calthorpe Broad, Priory Meadows
7/34/09/*G/0139	Boardman	General Farming & Domestic		✓	RISK	M	> 1mm in combination	Alderfen Broad, Ant Broads & Marshes, Bure Broads & Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes

7/34/10/*G/0097	Wans Farms	Spray Irrigation - Direct		✓	RISK	M	Possible indirect impact on water quality in Martham Broad	
Permissions considered under Regulation 48 but considered at stage 3 in combination with those in the review								
7/34/09/*G/0141A Now 7/34/09/*G/0141C	Alston	Spray Irrigation - Direct					> 1mm in combination	Alderfen Broad, Ant Broads & Marshes, Upper Thurne, Bure Broads & Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes
7/34/09/*G/0144 Now 7/34/09/*G/0144B	Alston	Spray Irrigation - Direct					> 1mm in combination. Replaced licence 7/34/09/*g/0126.	Alderfen Broad, Ant Broads & Marshes, Broad Fen, Calthorpe Broad, Ludham to Potter Heigham, Priory Meadows, Shallam Dyke Marshes
7/34/09/*G/0147 Now 7/34/09/*G/0147B	Barton Hall Farms	Spray Irrigation - Direct					> 1mm in combination	Alderfen Broad, Ant Broads & Marshes, Broad Fen, Bure Broads & Marshes, Smallburgh Fen
7/34/10/*G/0149A Previously 7/34/10*G/0149	GW Daniels & Son Ltd and Burnley Group Partnership	Spray Irrigation - Direct					Possible indirect impact on water quality in Martham Broad	Trinity Broads

A.2.1.4 Actual Impact or Risk?

Natural England has assessed the site condition of the Upper Thurne Broads & Marshes SSSI as 41% of the site area is in 'favourable' condition, 20% of the area is classed as 'unfavourable no change' condition, and 39% in 'unfavourable declining' condition.

The areas considered to be in unfavourable condition are regarded as being affected by drainage, water abstraction, inappropriate water-level management, eutrophication, disturbance, siltation, and inappropriate agri-environment prescriptions. Water abstraction is the factor most prevalent across most of these areas.

This condition assessment has altered from the one reported in 2006. In 2006 the unfavourable condition was considered to be influenced by a range of issues including inadequate water levels associated with IDB drainage, ochre production through land drainage, excessive salinity, scrub invasion and disturbance of SPA refuge areas (Entec, 2006c). It is considered that the Water Resources RoC Stage 3 assessment has contributed to the changed assessment of the site rather than there being additional physical evidence of deterioration.

A2.1.5 Known effects from other sources

Previously licensed abstractions which are now deregulated, and abstractions which are exempt from regulations where these are known, were included in the Regional Groundwater Model at Stage 3.

A2.1.6 Other Agency regulated inputs for consideration as part of the prevailing environmental conditions

New licences assessed under Regulation 48 were included in the modelling as part of the prevailing environmental conditions at Stage 3. Currently exempt activities, e.g. trickle irrigation and dewatering, in the search area of the site, will be assessed as new consents under Regulation 48.

In addition there are a number of permissions which had already been assessed under Regulation 48 as new permissions and as such a conclusion cannot be reached under Regulation 50. Information from the Review and also up to date information gathered as part of the licensing process will be considered in any licence renewal under Regulation 48.

A3 WASTE PERMISSIONS

Rollesby Landfill (NFK/LS/077/0) was taken through to Stage 3 of the Review of Consents under a precautionary principle. The licence, held by the Highways Department of Norfolk County Council was for inert waste only but the landfill was never used.

In 2003 the licence was surrendered (Caroline Jeffery (Regulatory Waste pers.com).

Consequently, there will be no adverse impact on the European features of Upper Thurne Broads and Marshes SSSI and there will be no need for further assessment of the licence.

Natural England were consulted at Stage 3 and are in agreement with this conclusion.

SECTION B

OUTCOMES REQUIRED FOR UPPER THURNE BROADS AND MARSHES

Overall Environmental Outcome Statement
Natural England has put forward an environmental outcome for the Broads SAC and Broadland SPA (which includes the Upper Thurne Broads and Marshes SSSI) as follows:

Water Quality

Nutrients
The appropriate total phosphorus threshold for Broads natural eutrophic lakes, ditches and dykes is 50ug/l P as these waterbodies fall into the high alkalinity, very shallow (<3m mean depth) type. The ditches support the same features as the lakes and there is no evidence to suggest the ditch features are any less sensitive to eutrophication (Clarke S & Doarks C 2006 Local variation of ditch phosphorus targets: an interim approach).

There is a reasonably large body of data (water quality and biological) available for many of the Broads sites. These data have been investigated as a means of setting a 'Broads specific' threshold using the method being employed for Water Framework Directive. This local approach was considered worth investigating due to the availability of the data and an acknowledgement that the Broads have particular characteristics which may influence the relationship between phosphorus load and biological response. This analysis using Water Framework Directive methods supports a threshold value of 50ug/l. However, it does indicate that there may be some biological change at 40ug/l, further analysis and monitoring is required to determine the significance of this lower value and whether it reflects external (i.e. nutrient load) or internal (grazing) processes.

The total phosphorus threshold for hard oligo-mesotrophic waters with benthic vegetation of *Chara* formations remains unchanged at 30ug/l P.

Water Resources

Details regarding the component SSSIs and associated features that are affected by water resources licences are listed in the appendix 21 appropriate assessment for the Broads SAC and Broadlands SPA. Site descriptions and details of feature locations can be found in the site characterisation reports for the component SSSIs of the Broads SAC and Broadlands SPA.
Environmental outcomes for each feature are in the feature specific outcomes below.

Air Quality

No exceedence of the relevant critical loads and levels.

Feature / species specific environmental outcomes – Water Resources

Alkaline Fen
Functionality criteria underpinning environmental outcomes:

a) High groundwater table to support shallow rooting (*Carex* species) and mosses (with no or very limited functional water transport tissue) throughout the year

b) Continuous groundwater discharge in winter and summer (non-drought years); the supply of calcium rich often supersaturated groundwater needs to FLUSH the soil, so that the right chemical (i.e. redox and Ca) balance in the soils is maintained.

c) The competition processes that determine the required (M13) vegetation are dominated (Source Bryan Wheeler, Sheffield Uni.) by exclusion processes (exclude species) rather than inclusion (i.e. enough water to grow optimally). This exclusion process is mainly due to the anoxic – low REDOX soil conditions with high concentrations of toxins such as sulphide. This in its turn is dependent upon a continuous high water table throughout the year.

For M13 groundwater level targets have been used:

1) The average 'normal year' shallow groundwater table should throughout a normal year not drop more than 10cm below ground level.
2) The variability of the groundwater level in a 'normal year' should not drop under 1 SD from 10cm below ground level, e.g. -22.4cm.
3) The duration, frequency and intensity of drought periods should not be significantly increased by abstraction or surface water management.

Alluvial Forests
The generic water level target for alluvial woodland W5 and W6 is:

1) Winter water levels at or very near the ground surface
2) Spring water levels should be maintained within 5cm of the ground surface
3) Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level. This should maintain the typical canopy and under-storey species.

No data are available on the requirements of W2 woodland, which also contributes to the European feature. It is therefore proposed that the target regime described above applies to this community.

Calcareous Fen With Cladium spp.
For the S24, the target identified is:

1) Summer water table should be between 3cm above and 36cm below ground level in the summer months (July-Sept). This is the mean water level for S24 on a number of sites across East Anglia ±1SD (but curtailing

the maximum water table to water at 4cm above ground level as measured).
2) Winter water levels are expected to be at the surface

Note that the target for S24 covers both of the communities that contribute to the calcareous fen feature.

Natural Eutrophic Lakes in Drainage Systems
For this feature targets have been developed related both to flushing flows and levels.

1) For flushing flows the target is that the monthly flow through the ditch system should be twice the volume of the system (i.e. flushing rate of 2 weeks) in summer. However, where the flushing rate drops below 6 weeks, it is considered that there is greater potential for changes in water level, which are otherwise considered likely to be maintained at, or exceed, the level of an outfall when the flushing period is shorter than 6 weeks. Therefore, after this period, assessment of the effects on ditch water levels are also assessed. No target has been set for winter.
2) A water level regime that retains high water levels, not more than 45cm below marsh level, year round is recommended. With respect to the magnitude of effect that would be considered potentially adverse, whilst it is considered that plants are not highly sensitive to fluctuations in water level, it is suggested that the potential to affect species rooted in the ditch banks means that a conservative target is required to ensure that variation does not result in adverse effect.

Therefore it is suggested that mean reductions in level of up to 10% of ditch depth are acceptable in the spring and summer months (March-September) unless reductions of 10% would breach the 45cm threshold.

Natural Eutrophic Lakes
Level targets are not considered reasonable in large tidally influenced waterbodies and there are insufficient data for this site to identify a target with respect to the overall water-budget. However, it is possible to determine the effect of abstraction on the amount of groundwater flowing into the site. Therefore, it is proposed that the target should be that groundwater inflow to the site should not be reduced by more than 10%.

Hard Oligo-Mesotrophic Waters With Benthic Vegetation of Chara spp. in Drainage Systems
On Broadland sites the *Chara spp*. communities often occur in the same ditches as the natural eutrophic lakes feature. As a result, the water flow target for natural eutrophic lakes will also apply to the *Chara* spp. feature.

As a precautionary approach it is suggested that an effect will be considered adverse if it results in a change in level of more than 10% of the ditch depth, or water levels are lower than 45cm.

Transition Mires and Quaking Bogs

The transition mire community M5 occurs on the fen surface (not floating) and is thus potentially sensitive to water level fluctuations. Water levels should not fluctuate more than 30cm annually.

Molinia Meadows

The target for the M24, which is derived from the '*Ecohydrological Guidelines*' is that the summer water table should be between 10 and 41cm below ground level in the summer months (July-Sept.). This is the mean water level for M24 on a number of sites across East Anglia ±1SD (but curtailing the maximum water table to water at 10cm below ground level as measured)[1].

Desmoulin's Whorl Snail

The target requires the water table to remain within 0.2m of the ground surface for 9 months of the year, with a critical minimum level of -0.5m below ground level in the summer. Flooding to 0.6m depth is acceptable for limited periods in some locations.

Fen Orchid

This was also considered sensitive but where present was generally associated with either Molinia meadows or Calcareous fen habitat and therefore these habitat features targets are to be used.

[1] For normally distributed data this range will pick up 70% of the occurrences of situations for M24

B1 WATER QUALITY

B1.1 Features impacted & risk of impact

The designated features may be adversely affected directly (oligo-mesotrophic lakes) or indirectly (food for bird species) by elevated concentrations of phosphorus.

B1.2 Outcomes required

B1.2.1 Feature specific environmental outcomes

The environmental outcome is what must be achieved in order to conclude that there is no Adverse Effect On Integrity (AEOI) of the site (WQTAG152, section 5.2).

The table below summarises the Water Quality targets used at stage 3.

Table B1.1: List of water quality environmental outcomes

Feature	Water quality target
Natural eutrophic water (SAC lakes)	Total Phosphate concentrations 0.05mg/l or below
Natural eutrophic water (ditches and dykes)	Total Phosphate concentrations 0.1mg/l or below
Hard oligo-mesotrophic waters	Total Phosphate concentrations 0.03mg/1 or below
SPA lakes	Total Phosphate concentrations 0.1mg/l or below

As shown in table B1.1 a value of 0.1mg/l was used for ditches and dykes supporting natural eutrophic waters in stage 3. However in the environmental outcomes provided by NE at stage 4 a target of 0.05mg/l total phosphorus has now been given for all natural eutrophic waters. NE acknowledge that this is fairly precautionary and that it has been set by experts in this area. Information from EA National is that we should still use the 0.1 mg/l TP as further information has not been put forward to change this through TAG. Because of the uncertainty regarding these targets, both the 0.1mg/l and 0.05mg/l TP environmental outcomes will be considered for this feature.

B1.2.2 Methodology

To achieve the environmental outcomes appropriate action on all sources of phosphorus is required. To lead to no adverse effect on site integrity from the discharge consents, the proportion of P from point sources leading to the exceedence of this target must be removed – this results in a *Review of Consents (RoC) target* being set. When this RoC target is met then no adverse effect from Agency discharge consents can be concluded.

Guidance in WQTAG152 is that the year 2000 should be used as a base year, so that improvements delivered by AMP3 schemes can be acknowledged as contributing towards the delivery of the RoC target. In the Upper Thurne catchment there are no such schemes, therefore current / recent conditions can be used as a baseline.

Habitats guidance also states that all modelling should be done using fully consented conditions. This is because STWs often operate with headroom in their consented volumes, and at a lower P concentration than consented. For the Thurne site there are two water company and fourteen private STWs that have been brought forward for assessment at stage 4. These are discussed below.

Water company consents
These are Horsey, and Repps with Bastwick. The consented Dry weather flow (DWF) can be compared to that converted from the actual population equivalent (PE) for the works to give an estimate of any headroom in the volume of the works. This is shown in the table below.

Table B1.2: Water company STWs

Works	Consented DWF (m^3/day)	PE provided	Calculated actual DWF**
Repps with Bastwick	23	129	25.8
Horsey	3*	11	2.2

* maximum volume only available
** using 200 litres per person

The results show that overall there is no headroom in the consented volumes.

Both are descriptive consents and so have no P limits in their consent. Repps with Bastwick effluent has been sampled to provide data on the P concentrations for use in modelling.

The above information shows that there is no headroom in relation to volume or P concentration, for the water company STWs.

Private consents
There are fourteen small private STW consents for assessment. These are of domestic sewage and all have a maximum consented volume only. This volume estimates the volume of sewage that will be produced from information provided including the size of the property and number of people. Therefore these volumes will be taken to be close to the actual volumes released. There are no P limits in the consents, therefore no headroom relating to P concentrations.

Therefore current P concentrations in the site will be used as a good estimate of fully consented conditions, in calculating the RoC targets and in modelling.

B1.3 Identifying the relevant environmental outcome and RoC target

At stage 3 the assessment was made on the three areas of the site separately. These three areas will be used again at stage 4. For each area the relevant environmental outcome will be identified (depending on the location of features and discharges) and the RoC targets calculated.

Martham area
Discharges with the potential to affect this area (as assessed at stage 3) are shown in Figure B1.1 below.

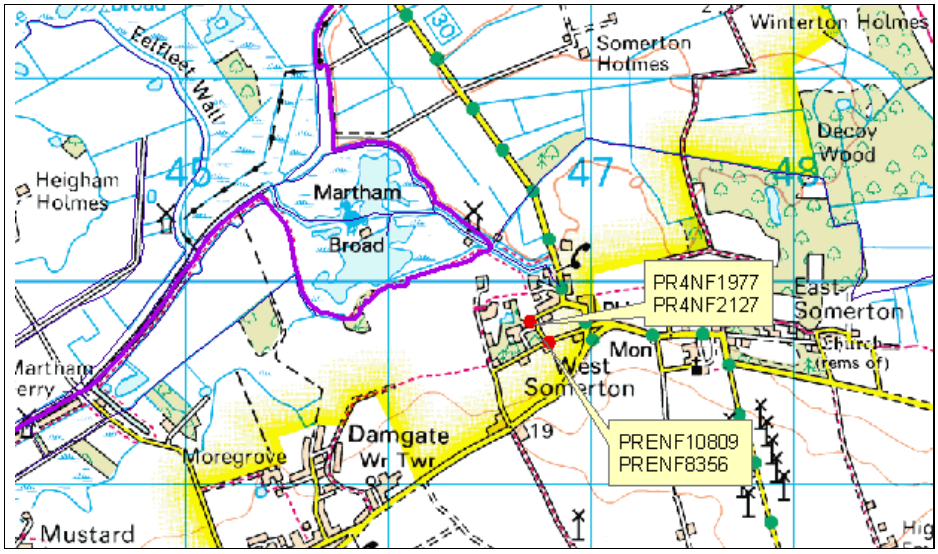


Figure B1.1: Location of discharges with potential to affect Martham area

All discharges have the potential to affect the Broad only, there are no other water quality features in this area. The relevant environmental outcome for Martham Broad is 0.03mg/l.

At stage 3 the broad was assessed as meeting the favourable condition targets, and meets the environmental outcome in recent years. Total P results are shown in the table below (mg/l).

Table B1.3: TP data for Martham Broad

	2005	2006	2007	Average 2005 - 2007
THR060 – Martham N Broad	0.045	0.022	0.019	0.030
THR061 – Martham S Broad	0.038	0.027	0.016	0.027

The discharges were brought forward because of possible in-combination effects with water resources licenses. At maximum licensed abstraction and subsequent reductions in flows to the broads, it could not be concluded that the environmental outcome would still be met.

Key points for Martham area

- The environmental outcome for Martham broad is 0.03 mg/l
- The environmental outcome is currently complied with and modelling and options appraisal at stage 4 is needed to assess the relationship between P concentration and flows, and to identify options that will enable the targets still to be met.

Horsey area

Discharges with the potential to affect this area (as identified at stage 3) are shown in Figure B1.2 below.

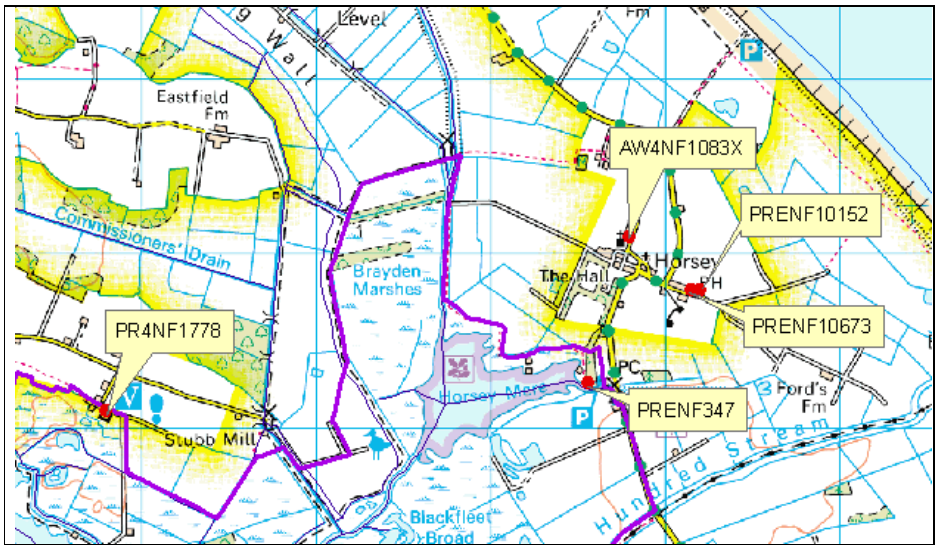


Figure B1.2: Location of discharges with potential to affect Horsey area

PRENF347 is direct to Horsey Mere. AW4NF1083X, PRENF10152 and PRENF10673 are to water courses where water is then pumped via the Horsey Mere or Brograve pumps to Horsey Mere. PR4NF1778 is to a watercourse where water is pumped via Stubbs Mill pump to the Brograve pump and then to Horsey Mere. Therefore all could impact on Horsey Mere. The relevant environmental outcome for Horsey Mere is 0.03mg/l.

There are oligo-mesotrophic features at Brayden Marshes but these are isolated from watercourses containing discharges so do not need to be considered here.

Therefore the relevant environmental outcome for this area is 0.03mg/l TP in Horsey Mere.

Recent / current data from Horsey Mere can be used to calculate the RoC target, as mentioned above in section B1.2.2. Total P concentrations (mg/l) are shown below.

Table B1.4: TP data at Horsey Mere

	2005	**2006**	**2007**	**Average 2005 - 2007**
THR020 – Horsey Mere	0.042	0.045	0.042	0.042

The P concentration here has been quite stable over the past few years. The overall average of 0.042 will be used in calculations of the RoC target. The other information needed for this calculation is the percentage of P from point sources. At stage 3 this was calculated as 21%. This is precautionary as it uses P budget calculations and these do not take into account any dilution / decay of the discharges. Calculation of the RoC target is shown below.

Table B1.5: RoC calculation at Horsey Mere

Details for THR020 (Horsey Mere), all calculations as mg/l TP	
Baseline (current concentration)	0.042
Environmental outcome	0.03
P to be removed	0.042 - 0.03 = 0.012
21% of the P removal should be achieved by point sources	0.012 x 21% = 0.0025
Therefore the RoC target is:	0.042 – 0.0025 = 0.040

The result shows that only a very small decrease is required in order to remove the point source contribution.

Key points for Horsey area

- The environmental outcome for Horsey Mere is 0.03 mg/l
- The RoC target for Horsey Mere is 0.040 mg/l

Hickling and Heigham area

Discharges with the potential to affect this area (as identified at stage 3) are shown in figure B1.3 below.

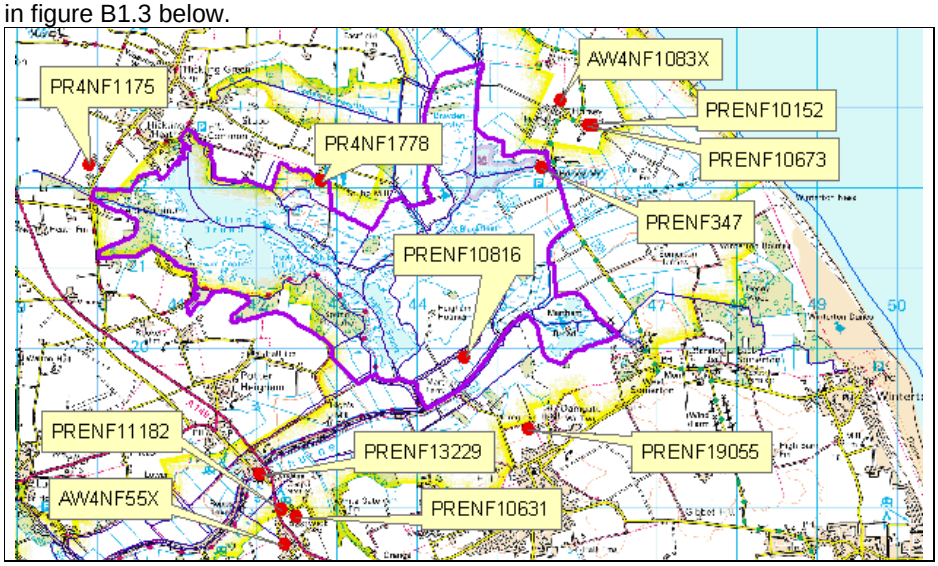


Figure B1.3: Location of discharges with potential to affect Hickling and Heigham area

As mentioned above PRENF347, AW4NF1083X, PRENF10152, PRENF10673 and PR4NF1778 go into Horsey before any water accesses Hickling / Heigham. Therefore the assessment of any potential impact on Horsey Mere will be appropriate to assess any effects of these.

PR4NF1175 will enter Hickling Broad therefore an assessment of any effect from these on Hickling Broad and Heigham will be made. The relevant environmental outcome for Hickling and Heigham Broads is 0.03mg/l.

PRENF10816 has an incorrect NGR and is to watercourses in Somerton at NGR TG469199. Therefore this will be considered in the assessment for Martham Broad.

PRENF19055, PRENF 13229, PRENF10631, PRENF11182 and AW4NF55X are to the River Thurne. Water from here can access Heigham Broad, and the ditches and dykes that are the natural eutrophic water feature. Effects of these on the P concentration in Hickling and Heigham Broad and in the river will be considered. The 0.03 mg/l outcome for Hickling and Heigham is still most appropriate to use. As mentioned above in section B1.2.1, both 0.1 and 0.05 environmental outcomes for natural eutrophic water will be considered, and these will be the environmental outcomes used for the river.

Therefore the environmental outcomes used are 0.03mg/l in Hickling Broad, 0.03mg/l in Heigham Broad, 0.1 mg/l and 0.05 mg/l in the River Thurne. Current / recent data is shown below.

Table B1.6: TP data at Hickling, Heigham and River Thurne

	2005	**2006**	**2007**	**Average 2005 - 2007**
THR030A – Hickling Broad	0.045	0.052	0.077	0.058
THR040 – Heigham Sound	0.058	0.057	0.057	0.057
THR065 – River Thurne at Martham Ferry	0.059	0.067	0.048	0.058

For all, the averages will be used in calculations of the RoC target. The other information needed for this calculation is the percentage of P from point sources. Information from the stage 3 assessment shows this is 19%. Calculation of the RoC targets is shown below.

Table B1.7: RoC target calculation at Hickling and Heigham

Details for THR030A (Hickling) and THR040 (Heigham), all calculations as mg/l TP		
	THR030A	THR040
Baseline (current concentrations)	0.058	0.057
Environmental outcome	0.03	0.03
P to be removed	0.058 - 0.03 = 0.028	0.057 - 0.03 = 0.027
19% of the P removal should be achieved by point sources	0.028 x 19% = 0.0053	0.027 x 19 = 0.0051
Therefore the RoC target is:	0.058 – 0.0053 = 0.053	0.057 – 0.0051 = 0.052

For the River Thurne, the 0.1 mg/l TP environmental outcome is already met (average of 0.058 mg/l at Martham Ferry), so only the 0.05 mg/l outcome needs to be considered.

Table B1.8: RoC target calculation at River Thurne

Details for THR065 (River Thurne at Martham Ferry), all calculations as mg/l TP	
Baseline (current concentration)	0.058
Environmental outcome	0.05
P to be removed	0.058 - 0.05 = 0.008
19% of the P removal should be achieved by point sources	0.008 x 19% = 0.0002
Therefore the RoC target is:	0.058 – 0.0002 = 0.0578, i.e. is 0.058

The concentration in the River Thurne is so close to the 0.05mg/l environmental outcome that removing the point source contribution means no real reduction in concentration is needed.

Key points for Hickling / Heigham area

- The environmental outcome for Hickling Broad and Heigham sound is 0.03 mg/l
- The RoC target for Hickling Broad is 0.053 mg/l
- The RoC target for Heigham Sound is 0.052 mg/l
- The environmental outcome for the River Thurne is 0.1 and 0.05 mg/l
- The 0.1 mg/l environmental outcome in the River Thurne is already met
- The 0.05 mg/l derived RoC target for the River Thurne means no real reduction in concentration is required to remove the point source contribution

Therefore modelling is required for the Martham area to assess the relationship between P concentration and flows, and identify options that will enable the targets to be met. Options for meeting the RoC targets in the Horsey and Hickling / Heigham areas need to be identified and modelled. This is detailed in section C1.

B2 WATER RESOURCES

B2.1 New information since Stage 3

Since the Stage 3 Appropriate assessment was completed additional information has been used to enhance the conceptual understanding, reduce uncertainties within numerical modelling of the site and in the identification of appropriate thresholds and criteria against which to assess acceptable levels of abstraction. This is detailed in Section 2.4 of the Options Appraisal Report (Entec, October 2009) and summarised below in Table B.2.1.

Table B.2.1: New information since Stage 3

Aspect	New information
On site investigations	
Topographic Surveys	Topographic surveys have been undertaken along six transects across parts of Upper Thurne Broads & Marshes. Two cross Mrs Myhill's Marsh, one crosses White Slea Marshes, one runs within Brayden Marshes close to and parallel to Waxham New Cut, a short transect crosses ground to the west of Martham Broad North, and a transect runs from Martham Broad south-east through West Somerton. These surveys support the interpretation of hydrological and ecological data, and they have been used in the construction of the regional groundwater model.
Water level monitoring	Dipwells and gaugeboards have been installed generally on or close to the topographic transects in the Mrs Myhill's Marsh and Catfield Dyke area, on White Slea Marshes and Brayden Marshes, and in the Martham Broad area. In addition three new observation boreholes have been drilled adjacent to Mrs Myhill's Marsh with the purpose of improving knowledge of the geology, groundwater levels, and vertical head gradients. All except for two dipwells and a gaugeboard at Martham Broad have been surveyed. For further information please see section 3 and Appenidx C of the Options Appraisal report (Entec, 2009).
Hydrochemical survey	A survey of the surface waters in the Mrs Myhill's Marsh, Catfield Dyke and Martham Broad areas was undertaken in September 2005 to provide information on the sources of water to the site (i.e. surface water and groundwater) (Ewan, 2005). For further information please refer to Section 3 of the Options Appraisal report (Entec, 2009).
Hydrological Modelling	
Yare & North Norfolk Regional Groundwater model	Local refinement of the regional model has been undertaken around the RoC sites including Upper Thurne Broads & Marshes SSSI within the Broads Reporting Area. A more detailed description of model construction,

	development and calibration is presented in Section 4 of the Options Appraisal report (Entec, 2009).
Licence Characterisation	Work has been carried out to ensure that licences are represented correctly and realistically in the groundwater model. In particular, for aggregated licences or sources within licences, abstractions from individual sources within the aggregate are weighted such that the maximum abstraction takes place from the sources in closest proximity to the site while remaining within the overall abstraction limit. The improved licence representations are provided by the Real Fully Licensed model run.
Criteria for deciding acceptable levels of abstraction	Generic targets from Stage 3 have been replaced by site-specific hydrological criteria to decide on acceptable levels of abstraction. The hydrological criteria are linked to the Environmental Outcomes for the site.

B.2.2 Environmental Outcomes required for the site

Natural England has advised that the conservation objectives provided on the 27th August 2004 for Stage 3 of the Review of Consents are still current for the Upper Thurne Broads & Marshes SSSI component of the Broads SAC.

Natural England's advice on functionality which is applicable to the Upper Thurne Broads & Marshes SSSI is as follows:

It is a widely supported view that the degree of natural functioning within the Broads should be increased. While historically the Broads would have functioned as a natural estuary / floodplain, man has intervened with the natural functioning over many centuries.

Where man's interventions on sites have been more recent or where a more-natural functioning has been maintained the environmental outcome should be to increase natural functioning, particularly where this is beneficial to the interests of Natura 2000 or makes the site more ecologically sustainable. Past actions on sites, such as isolation, damming, embankment and pumping have been undertaken to overcome the symptoms of eutrophication and adverse hydrological regimes. However it is now acknowledged that while these measures have been mostly effective at moderating the initial threats to the site, it has resulted in significant secondary impacts such as reduced natural functioning and resilience. For sites to again function with integrity both the initial impact and impact of the secondary measures need to be addressed. The following table identifies sites where such actions are required, the type of actions required and the resulting functional consequence.

In the Upper Thurne Broads and Marshes this involves the following action: Reduce or remove some flood embankments, remove dams to facilitate greater hydrological connectivity with the River Thurne. Target areas include Hickling, Martham and Heigham Holmes.

For the Water Resources function, feature-specific outcomes have been provided for *Molinia* meadows, Alluvial forests, Calcareous fens, Transition mires, Natural eutrophic lakes (in Broads and drainage systems), Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. in Broads and drainage systems. The features-specific outcomes are presented in Table B.2.2 below.

No feature specific outcome is provided for otter as it was agreed at Stage 3 of the RoC that provided the hydrology was suitable for the habitat features associated with dykes and Broads, that these conditions would be suitable for otter. No feature specific outcomes are presented for the SPA species as it was agreed at Stage 3 that provided the hydrological regime remained appropriate for the SAC features, conditions would be suitable for the SPA features.

Table B.2.2: Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Upper Thurne Broads & Marshes SSSI								
Interest Feature Location	**Description of Flora and Fauna under European Designation**	**Spatial Distribution / Quality / Historical Problems**	**Natural England Specific Environmental Outcomes (Broads SAC, Broadland SPA)**	**Hydrological Functioning**	**Model Cell(s) used at Stage 3**	**Model Criteria used to Assess Adverse Effect at Stage 3**	**Model Cell(s) used at Stage 4**	**Primary Model Criteria used at Stage 4**
White Slea Marshes	*Molinia* Meadows (M24)	Refer to map Figure 3.20-3.21 (OAR, Entec, 2009). No apparent problems in non-drought years under historical levels of abstraction.	Water table should be between 10 and 41cm below ground level in the summer months (July-Sept). Winter water levels to be nominally just sub-surface.	Shallow water table supported by upward groundwater flow from the Drift / Crag aquifers.	Hickling Broad hydrological subunit	Water table should be between 10 and 41cm below ground level in the summer months (July-Sept).	**Cell C R133C334**	For non-drought summers: Soil moisture content, kept above stress threshold. For drought summers: Water level in uppermost model layer above lowest historical water level.
Piccamore Wood	Alluvial woodland (W2, W5, W6)	Refer to map Figure 3.20-3.21(OAR, Entec, 2009). No apparent problems in non-drought years under historical levels of abstraction.	Winter water-levels at or very near the ground surface, being maintained within 5cm of the ground surface through the spring establishment period. Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level.	Shallow water table supported by upward groundwater flow from the Drift / Crag aquifers.	Hickling Broad hydrological subunit	Winter groundwater levels maintained within 5cm of the ground surface in the spring. Summer maximum and minimum levels should be 5-45cm below the ground surface.	**Cell B R138C331**	For non-drought summers: Soil moisture content, kept above stress threshold. For drought summers: Water level in uppermost model layer above lowest historical water level.
Brayden Marshes Martham Broad	Calcareous fen (S24, S25)	Refer to map Figure 3.20. 3.21(OAR, Entec, 2009)... No apparent problems in non-drought years under historical levels of abstraction.	Summer water table between 3cm above and 36cm below ground surface in the summer months (July to Sept). Winter water levels are expected to be at the surface.	Drains and shallow water table supported by upward groundwater flow from the Drift / Crag aquifers.	Hickling Broad hydrological subunit, Horsey Mere hydrological subunit, Martham Broad hydrological subunit.	Summer water table (July-Sept) should be between 3cm above ground level and 36cm below ground level. Winter water levels are expected to be at the surface.	**Cell D R125C342 and Cell E R139C351**	For non-drought summers: Soil moisture content, kept above stress threshold. For drought summers: Water level in uppermost model layer above lowest historical water level.

Table B.2.2 (continued): Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Upper Thurne Broads & Marshes SSSI								
Interest Feature Location	**Description of Flora and Fauna under European Designation**	**Spatial Distribution / Quality / Historical Problems**	**Natural England Specific Environmental Outcomes (Broads SAC, Broadland SPA)**	**Hydrological Functioning**	**Model Cell(s) used at Stage 3**	**Model Criteria used to Assess Adverse Effect at Stage 3**	**Model Cell(s) used at Stage 4**	**Primary Model Criteria used at Stage 4**
Mrs Myhill's Marsh	Transition mires (M5)	Refer to map Figure 3.20-3.21 (OAR, Entec, 2009). No apparent problems in non-drought years under historical levels of abstraction.	Water levels should not fluctuate more than 30cm annually.	Drains and shallow water table supported by upward groundwater flow from the Drift / Crag aquifers.	Hickling Broad hydrological subunit (particularly Mrs Myhill's Marsh).	Water levels should not fluctuate more than 30cm annually.	**Cell A R134C321**	For non-drought summers: Soil moisture content, kept above field capacity. For drought summers: Water level in uppermost model layer above lowest historical water level.
Hickling Broad Horsey Mere Meadow Dyke & Heigham Sound Martham Broad, Heigham Holmes Mere Farm	Natural Eutrophic Lakes and Ditches	Refer to map Figure 3.20-3.21 (OAR, Entec, 2009). Under normal conditions reduced flushing and water quality impact observed in ditch network - summer draw down in ditches observed - unknown if abstraction contributes significantly to this. No direct evidence of damage linked to site has been recorded under historical conditions.	Where this feature occurs in the Broads on site, level targets are not considered reasonable in such large tidally influenced water bodies. The target is therefore that groundwater inflow should not be reduced by more than 10%. Where the feature is present in drained marsh dyke systems mean reductions in level of up to 10% of ditch depth are acceptable in the spring and summer months (March – September) although the 45cm below marsh level is the threshold below which NE would indicate that targets are not being met irrespective of the level of abstraction. When flushing rate > 6 weeks, the target is based on ditch water levels which are recommended by NE to be not more than 45cm below marsh level, year round. No target has been set for winter.	Shallow water table supported by upward groundwater flow from the Drift / Crag aquifers and inflow from surface water via field drains.	Six layer regional groundwater model used. Turnover calculations in drained marsh areas. Assessment of reduction in groundwater inflow to hydrological sub-units in Broads.	Groundwater inflow to hydrological sub-units should not be reduced by more than 10%. For drained areas a 10% reduction in ditch depth will be allowed unless reductions of 10% would breach the 45cm threshold. When flushing rate >6 weeks, ditch water levels should be not more than 45cm below marsh level, year round. No target has been set for winter.	Discharge to stream flow over area of Zone budget for hydrological units Hickling Broad, Horsey Mere, Meadow Dyke & Heigham Sound, Martham Broad, Heigham Holmes, and Mere Farm.	Secondary Criteria only. For drought summers: Lowest historical discharge to stream. For non-drought summers: Lowest historical discharge to stream.

Table B.2.2 (continued): Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Upper Thurne Broads & Marshes SSSI								
Interest Feature Location	**Description of Flora and Fauna under European Designation**	**Spatial Distribution / Quality / Historical Problems**	**Natural England Specific Environmental Outcomes (Broads SAC, Broadland SPA)**	**Hydrological Functioning**	**Model Cell(s) used at Stage 3**	**Model Criteria used to Assess Adverse Effect at Stage 3**	**Model Cell(s) used at Stage 4**	**Primary Model Criteria used at Stage 4**
Martham Broad Horsey Mere Hickling Broad Heigham Sound	Hard oligo-mesotrophic waters with benthic vegetation of *Chara spp.*	Refer to map Figure 3.20-3.21 (OAR, Entec, 2009).. No direct evidence of damage linked to site has been recorded under historical conditions.	Same as for Natural Eutrophic Lakes for the feature in both Broads and ditches.	Shallow water table supported by upward groundwater flow from the Drift / Crag aquifers and inflow from surface water via field drains.	As for Natural Eutrophic Lakes in the Broads i.e. Martham Broad, Horsey Mere and Hickling Broad hydrological sub-units	Groundwater inflow to the hydrological sub-units of the site should not be reduced by more than 10%.	Discharge to stream flow over area of Zone budget for hydrological units Horse Fen and Potter Heigham Marshes.	Secondary Criteria only. For drought summers: Lowest historical discharge to stream. For non-drought summers: Lowest historical discharge to stream.

B.2.3 Model-based hydrological criteria

The Stage 4 assessment has moved away from the generic hydrological targets used at Stage 3 for assessment of risk of impact to European features. A standardised methodology for the assessment of abstraction-related impacts of groundwater-dependent habitats has been developed within Anglian region. The current methodology uses a refined regional groundwater model together with new information obtained since Stage 3. The approach adopted, using the regional groundwater model, is detailed in the Options Appraisal Report (Entec, October 2009).

The generic Environmental Outcomes and the site specific Environmental Outcomes provided by Natural England are based on typical groundwater levels at locations of specific vegetation communities as reported in the Ecohydrological Guidelines (Wheeler et al., 2004). The described groundwater levels, ditch levels and flushing rates cannot be directly used to define hydrological thresholds to assess acceptable levels of abstraction at the Upper Thurne Broads & Marshes SSSI because:

- The guidelines do not take into account the specific conditions that exist at Upper Thurne Broads & Marshes SSSI
- Where vegetation stands are less species rich, hydrological requirements are likely to be less exacting, in that water tables are likely to fluctuate more, probably leading to summer dry conditions.
- The modelled groundwater level in the top active layer represents a 200m x 200m area within which ground elevation, soil conditions, geology, water levels and flows can vary significantly.
- The modelled water levels in the uppermost layer of the regional model do not exactly represent the real water table
- The water levels observed in dipwells may not correspond with water levels reported in the Ecohydrological Guidelines because different methods are used to measure the water table
- Flushing rates through drainage systems will not be consistent across a whole drainage network, since some drains will be better connected than others.
- The model estimates of stream discharges (used to calculate flushing rates) may not exactly represent the real rate of leakage, because the routing network is based only on a 200m x 200m grid size and cannot represent detailed drainage networks.
- The water levels and flow through the drainage networks are influenced by tidal fluctuations, and this is not represented in the regional model.
- Turnover times using stream cell flows exiting Broads on site may be longer than the one month time-step and do not take into account lake dynamics or storage in upstream stream cells

Acceptable levels of abstraction for the Upper Thurne Broads & Marshes SSSI will be assessed using the groundwater model to appraise the effect of abstraction scenarios with regard to:

- Continued discharge of groundwater to the site - assessed by the relative volume of groundwater discharge to zone budget areas
- Maintenance of an upward hydraulic gradient from the Crag to the near surface deposits - assessed by the relative elevations of groundwater levels within the Crag (layers 3 and 4) and the top active layer in the model (layer 1 or layer 3)
- Maintenance of an upward flow of groundwater from the Crag to the near surface deposits - assessed by the relative volume of flow to the top active layer in the model
- Impacts on groundwater level in the top active layer of the model as an indicator of abstraction effects on the depth to the water table
- Impacts on soil moisture characteristics, especially with regard to ooziness thresholds, stress thresholds and winter saturation, for features dependent on maintenance of a shallow water table.

For the RoC process it is essential that the Environmental Outcomes for the Broads SAC can be translated into one or more quantitative criteria specific to the Upper Thurne & Marshes SSSI that can be predicted with the groundwater model. This is the only way in which options to achieve the Environmental Outcomes can be quantitatively assessed.

The approach to defining hydrological thresholds for Upper Thurne Broads & Marshes SSSI takes into account the approach adopted for other similar sites in Anglian Region but also site-specific issues relating to the hydrological functioning of the site and to the current uncertainties in the model representation. This is described more fully in the Options Appraisal report for Upper Thurne Broads & Marshes SSSI (Entec, 2009). The general methodology developed for deciding acceptable levels of abstraction for Inland sites (Ursula Buss 2009) is applicable to sites where it can be agreed that historical levels of abstraction have not resulted in any long term adverse effect on the site. Natural England have confirmed that this interpretation of their Environmental Outcomes and the general approach is acceptable.

Taking into account the generic approach applied at other RoC sites, the current limitations of the model representation, the hydrological understanding of the site and the perception that historical abstraction has not had an adverse effect on the site, the site specific criteria for assessing acceptable levels of abstraction in 5 locations (Model cells A through to E) within the Upper Thurne Broads & Marshes SSSI are presented in Tables B.2.3a and B.2.3b below. A brief description of the model behaviours within each of the assessment cells is given below.

1) Cell A (R134, C321) - Mrs Myhill's Marsh - represents transition mires (M5)

- The model represents the conceptual understanding of the site well, reproducing the small upward groundwater gradient between the lower Crag

and the upper Crag with historical levels in the Crag (layer 4) being similar or equal to those in the top active layer.

- Differences in calculated soil moisture content between the historical and naturalised scenarios are subtle, noticeable changes only becoming apparent in drought summers. Moisture content always recovers to full saturation each winter, even after severe drought.
- Discharge from groundwater to the stream cell at Mrs Myhill's Marsh is pre-dominantly maintained throughout the modelled period for both the naturalised and historical scenarios during the winter months only. During summer months in both the historic and naturalised scenarios the stream appears to be losing water to the aquifer (ca. <20 m^3/day).

2) Cell B (R138, C331) - Piccamore Wood - represents Alder woodland (W2, W5 and W6)

- The modelled data reproduces an upward groundwater gradient between the Crag and the Drift with historical levels in the Crag (layer 4) above or equal to those in the top active layer. Positive upward flow to the top active layer (Layer 1) from Layer 2 is not maintained throughout each year with a period in the eighties and since 2000 showing a significant negative downward flow between the Drift and Glacial Till (layer 2), though comparison between the upflow and groundwater levels plots show that the Crag aquifer (Layer 4) is feeding the drift even when the heads in Layer 2 drop.
- There are only subtle differences in soil moisture content between historical and naturalised scenarios and recovery to full saturation each winter.
- Discharge from groundwater to the stream cell at Piccamore Wood is maintained throughout the modelled period for both the naturalised and historical scenarios during most winter periods but generally not summer and not the winter of drought years 1991 and 1992.

3) Cell C (R133, C334) - White Slea Marshes - *Molinia* meadows (M24)

- The modelled data reproduces an upward groundwater gradient between the Crag and the Drift with historical levels in the Crag (layer 4) above or equal to those in the top active layer. Positive upward flow to the top active layer is maintained throughout each year from Layer 2.
- There are only subtle differences in soil moisture content between historical and naturalised scenarios and recovery to full saturation each winter.
- Discharge from groundwater to the stream cell at White Slea Marshes is maintained throughout the modelled period for both the naturalised and historical scenarios during most winter periods but generally not summer and not the winter of drought years 1973, 1996 and 1997.

4) Cell D (R125, C342) - Brayden Marshes - Calcareous Fen (S24)

- The modelled data reproduces an upward groundwater gradient between the Crag and the Drift with historical levels in the Crag (layer 4) above or equal to those in the top active layer. Positive upward flow to the top active layer is maintained throughout each year from Layer 2.
- Soil moisture content recovers to full saturation each winter.

- Discharge from groundwater to the stream cell at Brayden Marshes is maintained throughout the modelled period for both the naturalised and historical scenarios during winter periods and summers.

5) Cell E (R139, C351) – Martham Broad - Calcareous fen (S24).

- The modelled data reproduces a downward groundwater gradient between the Drift and the Crag for most of the 1970-2006 period with historical levels in the Crag (layer 4) above those in the top active layer only during wetter periods (1988)
- A positive upward flow to the top active layer from Layer 2 is maintained throughout winter seasons but a downward gradient from layer 1 to layer 2 is the dominant pattern during summer periods
- There are only subtle differences between historical and naturalised scenarios and soil moisture content recovers to full saturation each winter
- Discharge from groundwater to the stream cell at Martham Broad loses water to the aquifer throughout the modelled period for both the naturalised and historical scenarios during winter and summer periods. The rate of loss to the aquifer decreases during known wetter years such as 1988.

Table B.2.3a: Summary of assessment thresholds for features associated with model cells A through to E

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Transition Mires at Mrs Myhill's Marsh (Assessment Cell 'A', r134_c321) – see Figs 7.9 and 7.10 in Entec (2009)				
Non-drought summer	**> field capacity**	> lowest historical in non-drought summers = August 1993 = 0.453 mAOD	August 1993 = -17.84 m^3/d	August 1993 = +22.52m^3/d
Drought summer	**> field capacity**	**> lowest historical in drought summers = September 1974 = 0.275 mAOD**	September 1974 = -17.10 m^3/d	September 1974 = +5.77m^3/d
Non-drought winter	Return to saturation	> lowest winter peak in non-drought winters = March 2005 = 0.84 mAOD	March 2005 = -13.74 m^3/d	March 2005 = +19.34m^3/d
Drought winter	Return to saturation	> lowest winter peak in drought winters = February 1973 = 0.55 mAOD	February 1973 = -5.67m^3/d	February 1973 = +0.44m^3/d
Alluvial Woodland at Piccamore Wood (Assessment Cell 'B', r138_c331) – see Figs 7.11 and 7.12 in Entec (2009)				
Non-drought summer	**> stress threshold**	> lowest historical in non-drought summers = September 2003 = -0.62 mAOD	September 2003 = +7.01m^3/d	September 2003 = 0 m^3/d
Drought summer	**> stress threshold**	**> lowest historical in drought summers = July 1976 = -0.81 mAOD**	July 1976 = +7.44m^3/d	July 1976 = 0 m^3/d
Non-drought winter	Return to saturation	> lowest winter peak in non-drought winters = February 2005 = -0.20 mAOD	February 2005 = -0.89m^3/d	February 2005 = 0 m^3/d
Drought winter	Return to saturation	> lowest winter peak in drought winters = February 1973 = -0.42 mAOD	February 1973 = +2.52m^3/d	February 1973 = 0 m^3/d

	= **Primary criteria**
	= Secondary criteria

Note: The 'zero' thresholds for modelled discharge to stream cell imply that no discharge is taking place during any of the four determined periods in time.

Table B.2.3a (continued): Summary of Criteria and Thresholds

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
***Molinia* Meadows at White Slea Marshes (Assessment Cell 'C', r133_c334) – see figs 7.13 and 7.14 in Entec (2009)**				
Non-drought summer	**> stress threshold**	> lowest historical in non-drought summers = September 2003 = -1.19 mAOD	September 2003 = +12.34m^3/d	September 2003 = 0 m^3/d
Drought summer	**> stress threshold**	**> lowest historical in drought summers = July 1976 = -1.32 mAOD**	July 1976 = +12.41m^3/d	July 1976 = 0 m^3/d
Non-drought winter	Return to saturation	> lowest winter peak in non-drought winters = February 2005 = -0.68 mAOD	February 2005 = +1.45m^3/d	February 2005 = -3.71 m^3/d
Drought winter	Return to saturation	> lowest winter peak in drought winters = February 1973 = -0.87 mAOD	February 1973 = +6.51m^3/d	February 1973 = 0 m^3/d
Calcareous Fen at Brayden Marshes (Assessment Cell 'D', r125_c342) – see figs 7.15 and 7.16 in Entec (2009)				
Non-drought summer	**> stress threshold**	> lowest historical in non-drought summers = October 1998 = -1.77 mAOD	October 1998 = 2.67m^3/d	October 1998 = -2.20m^3/d
Drought summer	**> stress threshold**	**> lowest historical in drought summers = September 1976 = -1.78 mAOD**	September 1976 = 2.41m^3/d	September 1976 = -1.38m^3/d
Non-drought winter	Return to saturation	> lowest winter peak in non-drought winters = June 1998 = -1.76 mAOD	June 1998 = 2.11m^3/d	June 1998 = -2.51m^3/d
Drought winter	Return to	> lowest winter	April 1973	April 1973

	saturation	peak in drought winters = April 1973 = -1.77 mAOD	= 1.96m^3/d	= -2.05m^3/d
Calcareous Fen at Martham Broad (Assessment Cell 'E', r139_c351) – see figures 7.17 and 7.18 in Entec (2009)				
Non-drought summer	**> stress threshold**	> lowest historical in non-drought summers = October 1998 = -0.70 mAOD	October 1998 = -3.52m^3/d	October 1998 = 12 m^3/d
Drought summer	**> stress threshold**	**> lowest historical in drought summers = September 1976 = -0.82 mAOD**	September 1976 = +9.36m^3/d	September 1976 = 12 m^3/d
Non-drought winter	Return to saturation	> lowest winter peak in non-drought winters = May 1998 = -0.63 mAOD	May 1998 = -13.39m^3/d	May 1998 = 12 m^3/d
Drought winter	Return to saturation	> lowest winter peak in drought winters = February 1973 = -0.70 mAOD	February 1973 = -14.32 m^3/d	February 1973 = 12 m^3/d

	= **Primary criteria**
	= Secondary criteria

Table B.2.3b: Secondary Criteria - Stream Discharge to Zone Budgets - Thresholds for Natural Eutrophic Lakes (Broads) and Ditches – see figures 7.19 to 7.24 in Entec (2009)

	Modelled Stream Discharge in Hickling Broad Zone Budget Area	**Modelled Stream Discharge in Horsey Mere Zone Budget Area**	**Modelled Stream Discharge in Meadow Dyke and Heigham Sound Zone Budget Area**	**Modelled Stream Discharge in Martham Broad Zone Budget Area**	**Modelled Stream Discharge in Heigham Holmes Zone Budget Area**	**Modelled Stream Discharge in Mere Farm Zone Budget Area**
Non-drought summer	lowest historical discharge in non-drought summers: = August 2003 = 479.61 m^3/d	lowest historical discharge in non-drought summers: = October 1972 = 144.27 m^3/d	lowest historical discharge in non-drought summers: = September 2003 = 146.81 m^3/d	lowest historical discharge in non-drought summers: = August 1975 = 193.83 m^3/d	lowest historical discharge in non-drought summers: = November 2003 = 209.03 m^3/d	lowest historical discharge in non-drought summers: = November 2003 = 29.33 m^3/d
Drought summer	lowest historical discharge in drought summers: = July 1996 = 524.24 m^3/d	lowest historical discharge in drought summers: = August 1976 = 149.72 m^3/d	lowest historical discharge in drought summers: = August 1976 = 179.01 m^3/d	lowest historical discharge in drought summers: = July 1976 = 236.96 m^3/d	lowest historical discharge in drought summers: = November 1991 = 237.13 m^3/d	lowest historical discharge in drought summers: = September 1976 = 30.00 m^3/d
Non-drought winter	N/A	N/A	N/A	N/A	N/A	N/A
Drought winter	N/A	N/A	N/A	N/A	N/A	N/A

	= **Primary criteria**
	= Secondary criteria

B.2.4 Results of groundwater modelling

Since the completion of the Stage 3 Assessment in October 2006, a standardised methodology for the assessment of abstraction-related impacts on groundwater-dependant habitats has been progressively developed within Anglian region for the Review of Consents process. This has employed the use of regional groundwater models that weren't available during Stage 3 or that have since been further refined, plus new information about each site derived from continued monitoring activity. This new approach is more risk-based, taking account of the effects of historic abstraction regimes, site condition and professional judgement.

The regional groundwater model has been used to simulate the effects of abstraction under several abstraction scenarios for the 35 year period from 1970 to 2004. The basic scenarios were "naturalised", "historical" and "real fully licensed (RFL)" abstraction. The modelling scenarios are described in detail in section 7.2 of the Options Appraisal Report (Entec, 2009). The RFL scenario includes abstractions at fully licensed rates but takes account of aggregate limitations within the licence conditions. The abstractions from individual sources within the aggregate are weighted such that the maximum abstraction takes place from the sources in closest proximity to the site.

The criteria detailed in Tables B2.3a and B2.3b above, based on soil moisture content or lowest modelled historical groundwater levels, are used for comparison with time series modelled for different abstraction scenarios which are all based on the same climatic time series for the 35 year period from 1970 up to the end of 2004. The results of the assessment are summarised in tables B.2.4a, B.2.4b and B.2.4.c.

Table B.2.4a: Results for Abstraction Scenarios against Model-based Hydrological Criteria

Historical Model-based Hydrological Criteria	**Historical (YNN318tr)**	**Real Fully Licensed (YNN319tr)**
Mrs Myhill's Marsh (Model Cell A: r134_c321, Model Layer 3) See Figures 7.9 and 7.10		
Non-drought summers: **Soil moisture content above field capacity** August 1993 lowest water level (0.45 mAOD); and associated regimes of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled soil moisture content does not drop below field capacity in any non-drought summers** Water level breaches the threshold in six non-drought summers, maximum breach of 8.5cm in August 1993. Lowest stream discharge flow threshold is breached three times in '85, '99 and '00.
Drought summers: **September 1974 lowest water level (0.275 mAOD)**, and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled water levels fall below the threshold in five drought years by a maximum of 13cm (1974)** Lowest upward flow breaches the threshold five times in '74, '76, '92, '96 and '97; lowest stream discharge flow threshold is breached in all but one drought summer (not 1973).

Non-drought winters: Return to saturation; March 2005 lowest peak water level (0.84 mAOD) and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level is achieved in all but one non-drought winter. Upwards flow and stream discharge are maintained in all non-drought winters.
Drought winters: Return to saturation; February 1973 (0.55 mAOD) lowest peak water level and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all but 2 drought winters (not 1973 & 74). Upwards flow and stream discharge are maintained in all non-drought winters.

Table B.2.4a (continued): Results for Abstraction Scenarios against Model-based Hydrological Criteria

Hydrological Criteria	Historical (YNN318tr)	Real Fully Licensed (YNN319tr)
Piccamore Wood (Model Cell B: r138_c331, Model Layer 1) See Figures 7.11.and 7.12 (Entec, 2009)		
Non-drought summers: **Soil moisture content above stress threshold** September 2003 lowest water level (-0.62 mAOD); and associated regime of upward flow to top active layer.	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches the threshold in one non-drought summer (2003). Lowest upward flow remains below the threshold eight times in '71, '78, '82, '85, '87, '00, '04 and '05.
Drought summers: **July 1976 lowest water level (-0.81 mAOD)**, and associated regime of upward flow to top active layer.	No problem by definition	**Modelled water level falls below threshold in one drought year by a maximum of 1cm in (1976)** Upward flow drought summer threshold breached once in '73
Non-drought winters: Return to saturation; February 2005 lowest peak water level (-0.20 mAOD); and associated regime of upward flow to top active layer.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters.
Drought winters: Return to saturation; February 1973 (-0.42 mAOD) lowest peak water level; and associated regime of upward flow to top active layer.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973. The lowest upwards flow is reached in all drought winters.
White Slea Marshes (Model Cell C r133_c334, Model Layer 1) - See Figures 7.13 and 7.14 (Entec, 2009)		
Non-drought summers: **Soil moisture content above stress threshold** September 2003 lowest water level – (1.19 mAOD); and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches threshold in one non-drought summer (2003). Lowest upward flow breaches the threshold in all non-drought summers.
Drought summers: **July 1976 lowest water level (-1.32 mAOD)**, and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled water levels fall below the threshold in one drought year by a maximum of <0.5cm (1976)** Lowest upward flow remains below the drought summer threshold four times in '73, '74, '92 and '97
Non-drought winters: Return to saturation; February 2005 lowest peak water level (-0.68 mAOD); and associated regime of upward flow to top active layer.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters

Drought winters: Return to saturation; February 1973 (-0.87 mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973. The lowest upwards flow is reached in all drought winters
Brayden Marshes (Model Cell D r125_c342) See Figures 7.15 and 7.16 (Entec, 2009)		
Non-drought summers: **Soil moisture content above stress threshold.** October 1998 lowest water level (1.77 mAOD); and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches the threshold in one non-drought summer (1972). Lowest upward flow breaches the threshold in all but 4 non-drought summers; lowest stream discharge flow threshold is breached in 2 non-drought years (1972, 1998).
Drought summers: **September 1976 lowest water level (-1.78 mAOD)**, and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled water levels do not fall below the threshold in any drought year.** Lowest upward flow falls beneath the threshold in all drought summers; lowest stream discharge flow threshold is breached in two drought years (1976 and 1996).
Non-drought winters: Return to saturation; June 1998 lowest peak water level (-1.76 mAOD); and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all non-drought winters. Upwards flow and stream discharge threshold are maintained in all non-drought years.
Drought winters: Return to saturation; April 1973 (-1.779 mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all drought winters. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973.
Martham Broad (Model Cell E: r139_c351, Model Layer 1) See Figures 7.17 and 7.18 (Entec,2009)		
Non-drought summers: **Soil moisture content above stress threshold.** October 1998 lowest water level (-0.70 mAOD); and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer.** Water level breaches threshold in one non-drought summer (1972). Lowest upward flow breaches the threshold in all non-drought summers.
Drought summers: **September 1976 lowest water level (-0.82 mAOD)** and associated regime of upward flow to top	No problem by definition	**Modelled water levels fall below the threshold in one drought year by maximum of 1cm (1976)**

active layer and stream discharge.		Lowest upward flow remains below the threshold in all drought summers except 1974 and 1976.
Non-drought winters: Return to saturation; May 1998 lowest peak water level (-0.63 mAOD); and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 1993 and 1998. Upwards flow reaches the threshold in all years.
Drought winters: Return to saturation; February 1973 (-0.70 mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge.	No problem by definition	Return to saturation in all winters. Lowest winter peak water level achieved in seven drought winters. Upwards flow reaches the threshold in all drought winters.

Note: Primary Criteria indicated in **bold** text

Table B.2.4b: Results Abstraction Scenarios against Model-based Hydrological Criteria - Hickling Broad Zone Budget Area and the Horsey Mere Zone Budget Area

Hydrological Criteria	**Historical (YNN318tr)**	**Real Fully Licensed (YNN319tr)**
Hickling Broad Zone Budget Area. See Figure 7.19.		
Non-drought summers: August 2003 lowest stream discharge (479.61 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in two non-drought years (1975 and 2003)
Drought summers: July 1996 lowest stream discharge (524.24 m^3)	No problem by definition	Lowest stream discharge flow threshold is not breached in any drought year
Non-drought winters: N/A	N/A	N/A
Drought winters: N/A	N/A	N/A
Hydrological Criteria	**Historical (YNN318tr)**	**Real Fully Licensed (YNN319tr)**
Horsey Mere Zone Budget Area. See Figure 7.20.		
Non-drought summers: October 1972 lowest stream discharge (144.27 m3)	No problem by definition	Lowest stream discharge flow threshold is breached in one non-drought year (1972) by 0.06 m3
Drought summers: August 1976 lowest stream discharge (149.72 m3)	No problem by definition	Lowest stream discharge flow threshold is breached in one drought year (1976) by 0.01 m3
Non-drought winters: N/A	N/A	N/A
Drought winters: N/A	N/A	N/A

Note: During dry periods at Hickling Broad the modelled heads in the majority of stream cells within the zone budget area fall below the stream stage. This allows for discharge of water from the stream into the aquifer through the affected stream cells. Flows into these stream cells (and consequently those into the aquifer through the stream cells) may be very limited, and under such circumstances, any model scenario that simulates surface water discharges may have more water available to

discharge into the aquifer than those that do not simulate discharges at all. This has the implication that discharges would lead to a rise in modelled heads in a model scenario with discharges, relative to naturalised conditions. The consequent reduction in downward gradient would have the effect that scenarios effectively 'flip' during such dry periods making it look as though naturalised conditions have the largest 'impacts' on groundwater levels.

Table B.2.4c: Comparison of Abstraction Scenarios against Model-based Hydrological Criteria - Meadow Dyke & Heigham Sound Zone Budget Area

Hydrological Criteria	Historical (YNN318tr)	Real Fully Licensed (YNN319tr)
Meadow Dyke and Heigham Sound Zone Budget Area. See Figure 7.21.		
Non-drought summers: September 2003 lowest stream discharge (343.33 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in one non-drought year (2003) by 0.40 m^3
Drought summers: August 1976 lowest stream discharge (407.71 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in one drought year (1976) by 0.50 m^3
Non-drought winters: N/A	N/A	N/A
Drought winters: N/A	N/A	N/A
Martham Broad Zone Budget Area. See Figure 7.22.		
Non-drought summers: August 1975 lowest stream discharge (193.83 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in one non-drought year (1975) by 1.82 m^3
Drought summers: July 1976 lowest stream discharge (236.96 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in one drought year (1976) by 0.88 m^3
Non-drought winters: N/A	N/A	N/A
Drought winters: N/A	N/A	N/A
Heigham Holmes Zone Budget Area. See Figure 7.23.		
Non-drought summers: November 2003 lowest stream discharge (209.03 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in one non-drought year (2003) by 0.81m^3
Drought summers: November 1991 lowest stream discharge (237.13 m^3)	No problem by definition	Lowest stream discharge flow threshold is breached in one drought year (1991) by 0.44m^3
Non-drought winters: N/A	N/A	N/A
Drought winters: N/A	N/A	N/A
Mere Farm Zone Budget Area. See Figure 7.24.		
Non-drought summers: November 2003 lowest stream discharge (29.33 m^3)	No problem by definition	Lowest stream discharge flow threshold is not breached in any non-drought year
Drought summers: September 1976 lowest stream discharge (30.00 m^3)	No problem by definition	Lowest stream discharge flow threshold is not breached in any drought year
Non-drought winters: N/A	N/A	N/A
Drought winters: N/A	N/A	N/A

B.2.5 Summary of Anglian Region's Technical Approach for "Inland Sites"

This approach is detailed in Buss (2009) and summarised here.

For sites where we judge that historical levels of abstraction have been considered acceptable we use thresholds for model-based hydrological criteria which are based, for example, on the lowest modelled historical water level in the top active layer of the numerical model. The use of thresholds which are based on the historical time series and lowest historical groundwater heads and flows inherently results in at least one breach since fully licensed abstraction is generally greater than historical abstraction in most catchments. In addition to the one 'default' breach, there is often only a very small number of breaches (if any) and most of the breaches may only be in the order of millimetres or a few centimetres, a few percent of soil moisture content or a few litres per day of flow.

The historical time series is used as a baseline because this is the only 'scenario' which has been experienced in the past and therefore can be compared with ecological and hydrological observations. In reality, adverse effects on site integrity may only start to occur once water levels and flows are somewhat lower than experienced in the past. Since this situation is outside of the range of our experience it is difficult to identify absolute thresholds when adverse effect will start to occur. Licence modifications may therefore not be necessary if hydrological impacts from fully licensed abstraction are greater than under the historical scenario by only an insignificant amount, i.e. if the number and scale of breaches is small, and if the risk of adverse effects on the site integrity actually occurring is judged to be sufficiently low.

We are therefore applying a risk-based approach that scales the need for licence modifications according to the risk to the site and a decision table (or "risk matrix") has been developed as a generic tool.

The 'risk-matrix' is applied by assigning a 'risk category' to each site (generally component SSSIs if a SAC / SPA consists of more than one SSSI). The risk matrix takes into account the scale and frequency of breaches to primary criteria thresholds, in the context of the conceptual understanding and the model representation, changes to the overall hydrological functioning, the general level of fully licensed and historical abstraction in the catchment surrounding the site and uncertainties around the ecological 'evidence' available. Professional judgement will be applied to the interpretation of the risk matrix and in deciding on the appropriate risk category.

There is a presumption that, for sites which are assigned a 'low risk category', no abstraction licence modifications will need to be investigated through the options appraisal process. The assumption is that for those sites, the risk that adverse effects on site integrity would occur and the Environmental Outcomes cannot be achieved is sufficiently low despite some (small and infrequent) breaches of thresholds.

For sites in the 'medium risk' and 'high risk' categories abstraction licence modifications will be investigated during the options appraisal process. The

presumption is that licences would need to be modified so that the site then falls into the 'low risk' category.

The difference between 'medium risk' and 'high risk' is the scale of abstraction licence modification. Most of the 'medium risk' sites may only require some restriction to actual abstraction in years with exceptionally dry conditions, whilst 'high risk' sites may require a general reduction in licensed quantity. However, the scale and detail of any modification will depend on the individual site and the licences implicated.

For SAC / SPAs with more than one component SSSI, the application of the risk matrix will direct the options appraisal work with regard to individual component SSSIs but does not preclude the overall Stage 4 conclusion for the European site. If necessary, sites in the 'low risk' category could be reconsidered at a later stage, although this is not expected to happen in general.

Natural England were consulted on our technical approach to inland sites at a meeting on 25th July 2008 and agreed with the approach for the Broads SAC on 15th December 2008.

B.2.5.2 Conclusions from the risk matrix

A Site Option Plan decision table (or "risk matrix") for Mrs Myhill's Marsh, listing the hydrological criteria and the degree to which they are met for each scenario, is presented in Table B.2.5. The modelling results which are most relevant are found in Figures 7.9 and 7.10 of the Options Appraisal report (Entec, October 2009) and the threshold breaches are summarised in Tables 7.9 – 7.19 of the Options Appraisal report (Entec, October 2009). The conclusions drawn from application of the new model-based hydrological criteria to the abstraction scenarios, in conjunction with the "Risk Matrix" decision table, below are that;

- Environmental outcomes are **achieved** under recent historical abstraction (by definition)

- There is a **medium** risk associated with real fully licensed abstraction scenario that environmental outcomes for Mrs Myhill's Marsh will **not be achieved** but a **low** risk for other parts of the site that environmental outcomes will **not be achieved**.

Therefore options appraisal is required to identify the most suitable action with regard to modification and or revocation of abstraction licences so that the Environmental Outcomes for the site can be met under a fully licensed abstraction scenario.

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Table B2.5: Risk Matrix for Upper Thurne and Marshes - Assessment Cell A - Mrs Myhill's Marsh (Appraisal based on RFL model run YNN319tr)

	Risk Category					
Criteria	**Low**	***Site details***	**Medium**	***Site details***	**High**	***Site details***
1) Performance against model-based hydrological criteria						
Scale of breach for water levels (related to threshold for drought summers)	≤ 5cm		≤ 10cm		> 10cm	*up to 13cm*
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)		≤ 3 out of 10 (= ≤ 9 out of 35)	*5 out of 35*	> 3 out of 10 (= > 9 out of 35)	
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5%	*none*	≤ 10%		> 10%	
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	*none*	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Timing of breaches	droughts only	*droughts only*	non-droughts only		droughts AND non-drought periods	
Soil moisture returning to saturation in winters	always	*always*	not in a few winters		not in most winters	
Impact on overall hydrological functioning	not significantly impacted		impacted in some years	*sometimes impacted*	significantly impacted in most years	
2) Appraisal of resources and abstraction scenarios						
Modelled water level under fully licensed scenario similar to naturalised / historical or close to 50% LTA recharge scenario	similar to naturalised or historical		between historical and 50% LTA recharge abstraction scenario	*yes*	close or above 50% LTA recharge abstraction scenario	

Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%	*2.4% (groundwater abstractions)*	20-40%		> 40%	
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	small		medium	*medium*	large	
Sensitivity to water table fluctuations indicated by field data (site generally wet?)	small	*Yes, (in Aug. 2006 water table only 20cm below GL)*	medium		large	
3) Uncertainties						
Evidence to allow judgement of no ecological change available and clear?	available and clear		available but not clear	*yes*	not available	
Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	~ stable or decreasing	*yes*	slightly increasing		increasing	
Model representation adequate?	adequate	*yes*	less adequate		not adequate	
Ecohydrological conceptual understanding clear and agreed?	clear and agreed	*yes*	less clear, not agreed		not clear, not agreed	
Field data available and sufficient?	available and sufficient		available but not entirely sufficient	*dipwell data only since July 2006*	not available and not sufficient	
Further considerations that may influence the overall risk category:						
Add site specific considerations as appropriate…						
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?				*agricultural and PWS*		

SECTION C

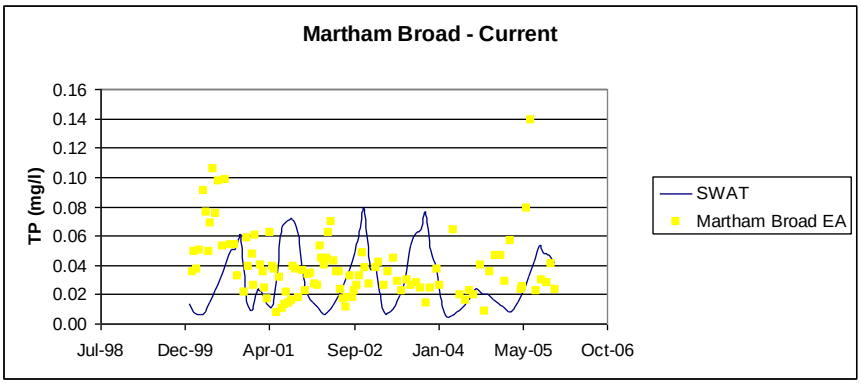
OPTIONS AVAILABLE

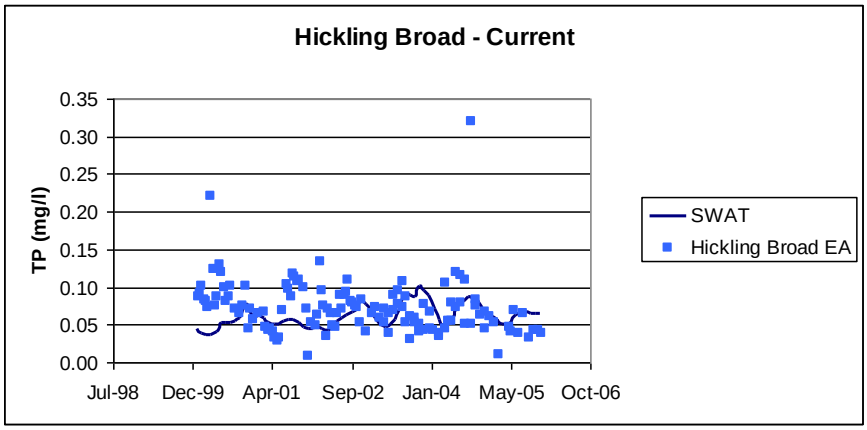
C1 WATER QUALITY

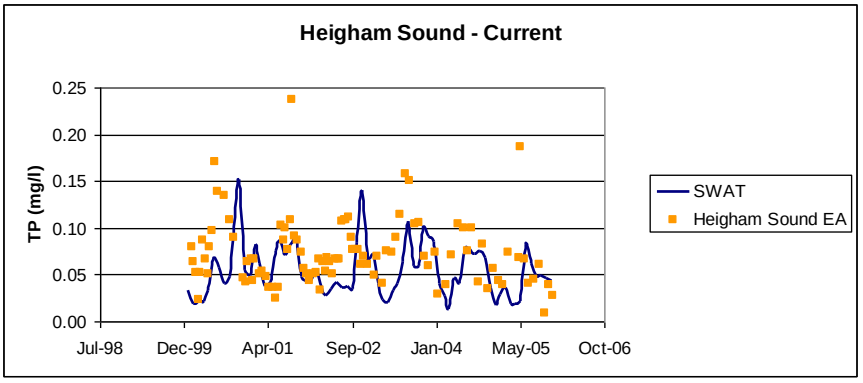
C1.1 Modelling

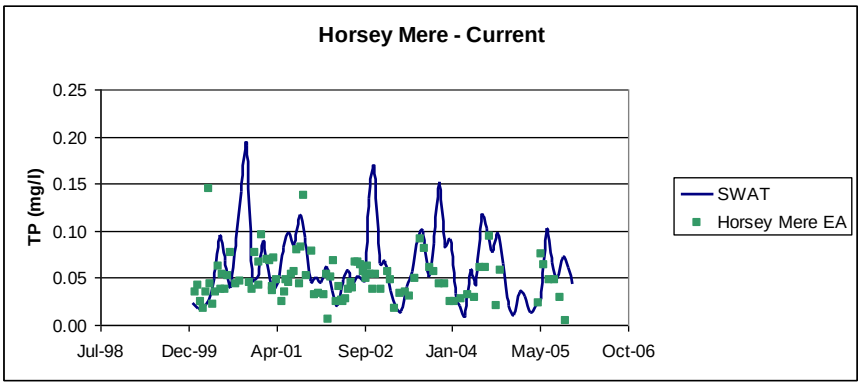
For this catchment, which is complex with artificially drained and pumped surface waters, a SWAT (Soil and Water Assessment Tool) model has been used at stage 4. This is an updated version of one developed at Cranfield University in 2006 for a PhD project, to replicate the hydrological behaviour of the Upper Thurne system. The model uses details of discharges, soil and agricultural information, weather data and monitored P results to model the functioning of the system. The model adequately represents the flows and Total Phosphorus concentrations in the land drainage discharge waters and within the surface water bodies. The model was calibrated and validated using monitored P data and then scenarios involving changes to the discharges, and changes to land use were run. At stage 3 of the Review of Consents, diffuse inputs were calculated to be important in this catchment therefore it was concluded that land use change scenarios would provide additional useful information. Details of this model and the scenarios run are in the SWAT modelling report (Holman and Deeks, 2007).

Data back to 1990 was used to calibrate and validate the model and a comparison of modelled with actual recent data was made. A comparison of actual against modelled concentrations is shown in Figures C1.1 to 1.4 below.









Figures C1.1 to C1.4: Observed and predicted Total Phosphorus in Martham Broad, Hickling Broad, Heigham Sound and Horsey Mere

The model is simulating the monthly mean concentration of Total P within the water body, whilst the monitoring sample is a single sample taken at a moment of time for a single point within the water body, therefore an exact match between simulated and observed data sets cannot be expected. However the results show that SWAT is simulating realistic concentrations.

C1.2 Targets

Scenarios have been run to provide information to help to identify any options to meet the targets identified in section B1. These targets are summarised below in table C1.1.

Table C1.1: Summary of targets identified in section B1

Broad	Baseline (actual) conditions	RoC target
Martham (THR060 and THR061)	Environmental outcome met at current flow conditions	Identification of flow conditions to meet RoC target
Horsey (THR020)	0.042 mg/l TP	0.040 mg/l TP
Hickling (THR030A)	0.058 mg/l TP	0.053 mg/l TP
Heigham (THR040)	0.057 mg/l TP	0.052 mg/l TP

C1.3 Discussion of scenarios run and results from the model

Many scenarios were run in this model. These scenarios included switching discharges off, reducing P concentrations in the discharges and changing arable land to pasture. These are all detailed in the modelling report (Holman and Deeks, 2007), and the water quality appendix WQ2 gives details of the loads used. A summary of the scenarios is given below and results discussed in relation to the RoC or other targets for each area.

Martham Broad

Martham Broad was brought forward to stage 4 only because of concerns that at fully abstracted conditions with reduced groundwater flow to this area, the target could be exceeded. Monitored results indicate that the environmental outcome is currently met (Table B1.3).

The HIA report at stage 3 (Entec 2006), stated that abstractions near the site can reduce the flow at the Somerton south pump. This pump takes water from the surrounding catchment, including groundwater, to the Martham Broads. Abstraction at fully licensed conditions represents 11% in an average year and 23% in a dry year of potential inflows (surface and groundwater) to the Martham Broads catchment. This is comparing naturalised to fully licensed, and on average for a year. Calculations have been carried out to compare this with historic / current flows and this concluded that there could be a reduction of between 10% and 12% of the historic amounts at the pump. A reduction of 12% to Somerton south pump was therefore modelled in the scenarios and additionally 5% and 20% reductions in case of any changes in these estimates resulted when the new groundwater model was used.

The new model for use at stage 4 suggests a reduction on flows at fully licensed is likely to be up to 6% (pers. com. Geoff Mason, Entec 2008). This is less than originally suggested. The scenarios run cover this new value – the result for the 5% reduction will give a good estimate of this.

The scenarios run to investigate this use the groundwater reductions modelled as reduced flows of water to the Somerton pump, but the same loadings from point sources are used. This simulates the reduced dilution in the Broad. Results are shown below.

Table C1.2: Results of reduced flow scenarios at Martham

Scenario number	Details of scenario	Predicted result
1a	Discharges at current conditions. 5% reduction in flow volume from Somerton south pump.	*<2 µg/l increase in annual average Total P concentration in Martham Broad*
1b	Discharges at current conditions. 12% reduction in flow volume from Somerton south pump.	*<3 µg/l increase in annual average Total P concentration in Martham Broad*
1c	Discharges at current conditions. 20% reduction in flow volume from Somerton south pump.	*<5 µg/l increase in annual average Total P concentration in Martham Broad*

This predicted change at 5% is not significant and means that the environmental outcome currently met in the Broad will not be exceeded at fully licensed abstraction. Therefore the discharges brought forward to stage 4 and that have the potential to affect Martham broad (PR4NF1977, PR4NF2127, PRENF10809, PRENF10816 and PRENF8356) will be affirmed.

Hickling Broad, Heigham Sound and Horsey Mere

These broads are exceeding their RoC targets and so scenarios to look at changes to point sources were required to identify any which would lead to the target being met. Effects of land use changes were also considered as a substantial proportion of the P in this catchment is from agricultural sources. All discharges brought forward to stage 4 are in the model. Scenarios 2 to 9 look at changes to the discharges, and 12 to 15 at changes to land use.

Table C1.3: List of scenarios run

Scenario number	Details of scenario	Reasons
2	All discharges at half consented loadings	To assess the effects of reducing P loads from discharges
3	All discharges switched off – loads and flows	To identify effects when no consented discharges are operating
3b	All discharges switched off – loads only, flows left the same	
4	All discharges at consented loadings except PR4NF1778, PRENF347 and PRENF10816 switched off	To assess the effects of removing P loads from some discharges which are closest to the features *(though now know that PRENF10816 is in the Martham area)*

9	All discharges at consented loadings except AW4NF55X switched off	This is to assess any changes in river concentration downstream of this discharge as this could impact on upstream broads because of tidal conditions. This largest discharge to the River Thurne (59m³/day) is used to examine this scenario. All the rest of the discharges here are between 1 and 10m³/day.
12a	All discharges at consented loadings Half arable land with 2m buffer strip around fields	To determine the effects of diffuse source P changes
12b	As 12a but all arable land with 2m buffer strip around fields	
13	All discharges at consented loadings. Sugar beet changed to oilseed rape	
14a	All discharges at consented loadings. 5% lower inorganic fertiliser application to arable	
14b	As 14a but 10% lower fertiliser application	
14c	As 14a but 10% lower manure application to grassland	
15	All discharges at consented loadings. Arable land use on silty clay marine alluvial soils changed to pasture	

The results can be shown graphically. Figure C1.5 shows the results for Hickling, those for Heigham and Horsey show a very similar pattern.

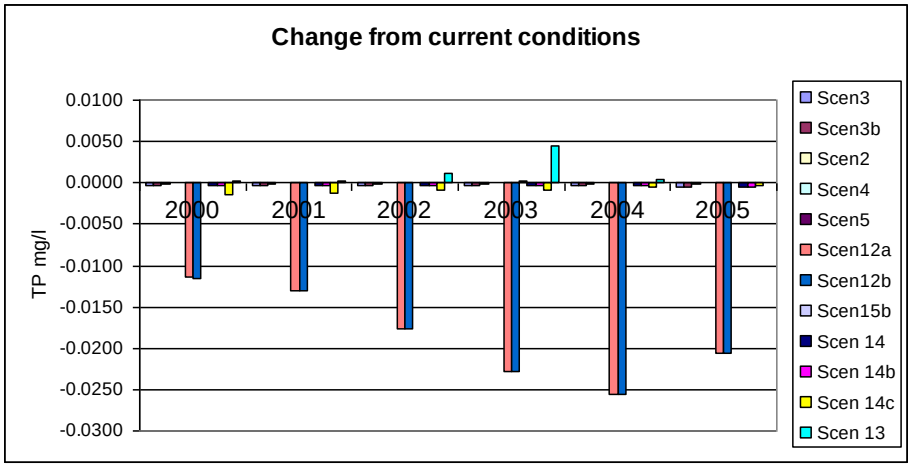


Figure C1.5: Results of scenarios at Hickling

The results above indicate only scenarios 12a and 12b are having a big effect on P concentrations.

Scenario 9 does not appear in the above graph as effects on the river were assessed separately. This is shown in figure C1.6 below.

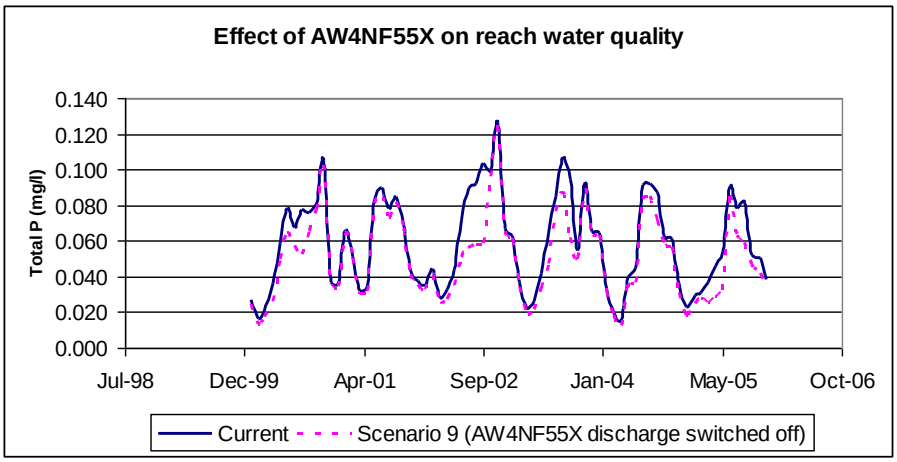


Figure C1.6: Results for scenarios involving AW4NF55X (the largest discharge to the river)

The result shows little change in concentration in the river as a result of the largest discharge being switched off.

These results can be shown in details for each Broad and this is shown in Table C1.4. All are as annual average Total P. Results where the change in concentration is significant are highlighted.

Table C1.4: Results of scenarios at Horsey, Hickling and Heigham

Scenario number	Horsey	Hickling	Heigham
2	<2 µg/l decrease	<1 µg/l decrease	<2 µg/l decrease
3	<3 µg/l decrease	<1 µg/l decrease	<3 µg/l decrease
3b	<3 µg/l decrease	<1 µg/l decrease	<3 µg/l decrease
4	<2 µg/l decrease	<1 µg/l decrease	<2 µg/l decrease
9	Reduction of 8µg/l on average downstream, but insignificant effect on concentrations within the upstream Broads.		
12a	<1 µg/l decrease	>11 µg/l decrease	>3 µg/l decrease
12b	>12 µg/l decrease	>12 µg/l decrease	>11 µg/l decrease
13	No trend seen: <1µg/l decrease to <4µg/l increase	<4µg/l increase	<3µg/l increase
14a	<1 µg/l decrease	<1 µg/l decrease	<1 µg/l decrease
14b	<1 µg/l decrease	<1 µg/l decrease	<1 µg/l decrease

14c	<1 µg/l decrease	<2 µg/l decrease	<2 µg/l decrease
15	<2 µg/l decrease	<1 µg/l decrease	<3 µg/l decrease

The results show that all the scenarios involving changes to point sources (scenarios 2 to 9) have no significant effect on the P concentrations within the Broads. The small changes predicted (<3 µg/l) are well within the variation inherent in the model.

The scenarios involving changes to land use (scenarios 12a to 15) have significant effects on the P concentrations within the Broads in some cases, though the simple representation of buffer strips in SWAT probably represents a best case.

C1.3 Conclusion from modelling work

A large proportion of TP to this catchment comes from agricultural / diffuse sources and this is reflected in the results from the modelling work. Changes to discharges does not have a significant impact on Horsey, Heigham and Hickling Broads and therefore discharges being considered under regulation 50 affecting these areas can be affirmed.

Changes to land use has the potential to affect TP concentrations considerably in these Broads.

For Martham Broad the results indicate that reduced flows will not have a significant impact on the Broad therefore discharges to this area can also be affirmed.

C1.4 Assessment of Available Options for point sources

All Options available have been assessed against the RoC Stage 4 Options Appraisal principals checklist in table C1.2 below.

Table C1.2: Options Appraisal – compliance with principles checklist

Option	Detail	Able to conclude no adverse effect on site integrity?	Compliance with principles checklist				
			Fair and reasonable	Accounts for Impacts from all inputs	Reg. 51(3)	Consistency	Other sites
THWQ option 1	Affirm all consents and set monitoring in place	Yes – modelling showed no significant effects of discharges in this catchment on the TP concentrations	Y	Y (all point sources)	Y	Y	N/A

THWQ option 2	Revoke, modify or move discharges	Yes – modelling showed no significant effects of discharges in this catchment on the TP concentrations	N	Y (all point sources)	Y	N	N/A

Based on the Options Appraisal, Option THWQ option 1 is the only one that allows a conclusion of no adverse effect on site integrity from point source contribution and is also compliant with all items on the principles checklist.

C1.5 Conclusion of options appraisal and preferred option

It is concluded:

- **The majority of TP to this catchment is from agricultural / diffuse inputs**
- **Modelling of point sources showed that changes to consents have no significant effects on concentrations in Horsey, Hickling and Heigham**
- **Modelled flow reductions to fully licensed conditions in the Martham area will have no significant effect on concentrations in Martham Broad**
- **Therefore the preferred option is that all consents are affirmed**

C1.6 Other Actions

Diffuse sources of nutrients have been highlighted as contributing significantly to the total nutrient loads in the catchment (79 to 85%). Attempts to reduce diffuse inputs of phosphate to the catchment have been initiated, however further effort and resources are required. Implementation of Codes of Good Agricultural Practice can be promoted in the short term, in the future, further reductions may be available using a range of instruments (e.g. regulation, advice, incentives) and a range of management measures (e.g. soil management plans, nutrient management plans). The Upper Thurne is a priority area under the Catchment Sensitive Farming initiative, and WFD will also target diffuse inputs here.

C1.7 Future plans and projects

Currently in the area new discharges would not be consented above the headroom of the existing STWs, therefore a spreadsheet has been developed to keep account of small discharges and calculate their combined volumes. The spreadsheet is now used by the National Permitting service who have responsibility for authorising these small discharges. Additionally the monitoring set up under WFD will allow any changes to

concentrations in the river and Broads to be identified and an assessment made of the causes and implications of this.

C1.8 Natural England recommendations

As part of their comments on the draft version 1 of this SAP, Natural England have put forward two recommendations for further work in the Upper Thurne area. These do not form part of this Review of consents process but are detailed here for completeness. These recommendations are:

- That the Environment Agency, as part of good practice, undertake a survey of small un-consented discharges within West Somerton, Hickling and Horsey and use regulatory powers to resolve any problems.
- That the Broads IDB in developing a solution to ochre, salinity and acidity problems of the catchment should also look to maximise nutrient reduction within their proposals.

C2 WATER RESOURCES

C.2.1 Options Available

Across the majority of the assessment cells at the Upper Thurne Broads and Marshes, the scale and number of threshold breaches are relatively small and occur only in the year that the threshold is set. At these locations it is considered that the hydrological functioning of the site is not significantly impacted by real fully licensed abstraction. The exception to this is at Mrs Myhill's Marsh where the drought summer primary threshold breach occurs multiple times and reaches a maximum magnitude of 13.4cm.

For the Upper Thurne Broads and Marshes it is therefore concluded that there is a low risk that the environmental outcomes for the site will not be achieved under Real Fully Licensed abstraction conditions except for Mrs Myhill's Marsh where Options Appraisal will be required.

With reference to the information provided above, this section identifies options by which the desired environmental outcome for the site may be achieved. Options are assessed by reference to the guidance paper HDPP05(04) Preferred Options Paper: Options Selection At Stage 4 of the Review Of Consents.

It has been ascertained that there are no site management actions which could be taken which would enable the environmental outcomes for the site to be achieved under Real Fully Licensed conditions. It is therefore necessary to identify appropriate abstraction licence modification.

At Stage 3 no licences were identified as having an effect "alone" on the Upper Thurne Broads & Marshes SSSI. Licences having an adverse effect acting in combination will therefore be appraised.

As explained above, the methodology for assessing the impacts of abstractions has changed since Stage 3. In the options appraisal the regional groundwater model is used iteratively to establish which changes in quantity or spatial pattern of groundwater abstraction will reduce the risk that the environmental objectives will not be achieved to **low.** The use of the regional groundwater model in options appraisal involves removing licences identified in each option from the model, while running the model with all other abstractions included at the Real Fully Licensed rates. One of the model scenarios, run at an early stage, confirmed that the majority of the impact was due to 3 permanent and 2 time-limited licensed abstractions in the vicinity of the site.

Options considered are:

Option 1: Do nothing, hence affirm all licences assessed at stage 3

Option 2: Do something, modify or revoke licences

C.2.2 Description of options to be appraised

Option 1: Do Nothing / Affirm
The 'do nothing' option has been appraised with respect to groundwater abstraction, to confirm, or otherwise, the result of the stage 3 assessment. The action to implement this option would be to affirm, under Regulation 50 (1), all licences listed above, except the ones which have been already assessed through Regulation 48.

The appraisal used model runs in which licensed abstraction operates at a worst case, that is producing the greatest impact at the site, within the constraints of the licences.

Option 2: Do Something- Modify or Revoke Existing Permissions
In Stage 4, this option is usually limited to permissions that are listed as "cannot show no adverse effect" that have not been assessed under Regulation 48. The actions to implement this option would be to quantify the necessary reductions in permissions through the Options Appraisal process. The licensed abstraction for the relevant permissions would then be reduced under Regulation 50 (1) in a manner proportionate to their contribution to potential impact at the site. Options involving modification of licences having an adverse effect acting alone should be appraised as a first step. However, due to the changed methodology at Stage 4, all licences included in the groundwater model may be included in the options appraisal.

A total of 7 abstraction scenarios were modelled and the results of these showed that two abstractions were clearly having the greatest effect on the site, AWS Ludham (7/34/09/*G/0091) and HA Overton (7/34/10/*G/0111). The options appraisal has therefore focussed on these two abstractions.

Both these licences have a base licence which is being considered within the review and a variation that is time limited and has been considered under Regulation 48.
The impacts of the two variations to the licences (which have been assessed under Regulation 48) are very small and revocation of these would not reduce the risk of failing to achieve the environmental outcomes to Low. In both cases the options will focus on the base licences which are being considered under the review

This option can be split into three sub options which have been considered separately.

- **Option 2a:** Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 40 tcma in drought years

- **Option 2b:** Reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 400 tcma

- **Option 2c:** Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 55 tcma in drought years and reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 512 tcma

C.2.3 Discussion of Options

Option 1: Do Nothing / Affirm
The "do nothing" option is the Real Fully Licensed model scenario, the results of which are summarised in the risk matrix. In drought summers, for the representative cell, the water level threshold is breached in five years (1973, 1974, 1976,1991 and 1997) by a maximum of 13cm in 1974 (see Table 8.4 Entec Options Appraisal October 2009). In non-drought summers the soil moisture threshold is not breached. Upward flow and streamflow are not maintained in all years, even under naturalised conditions, and the situation is worsened under real fully licensed abstraction.

Option 1 (Do Nothing / Affirm) is ranked as low against cost, sustainability impact, social consequences and economic effects. It is ranked as medium / high risk against failing to achieve the Environmental Outcomes (see table C2.2). This option would not achieve the environmental outcomes, and is not considered further.

Option 2a: Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 40 tcma in drought years
The reduction from 72.7 tcma to 40 tcma was proposed because the actual abstraction under this licence has only exceeded 40 tcma once since it was granted in 1984, that being in 1990. The next highest actual abstraction was 33.9 tcma in 1996.

In drought summers the water level threshold is breached in three years (1973, 1974 and 1976), by a maximum of 11cm in 1974. This does not meet the environmental outcomes and it is likely that the abstraction would have to be reduced to 30-35 tcma in order to do so. Additional model runs have not been carried out to explore this further as a reduction on this scale would not be accommodated within licence headroom and this option would not be the most cost effective.

Option 2a (Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 40 tcma in drought years) is ranked as medium / low risk against sustainability and low risk against cost, social consequences and economic effects. It is ranked as medium risk against failing to achieve the Environmental Outcomes (see Table C2.2. below).

This option would not achieve the environmental outcomes, and is not considered further.

Option 2b: Reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 400 tcma
This option has been included as this is the largest abstraction in the area and it was considered likely that the magnitude of the required licence reduction to reduce the risk of failing to meet the environmental outcomes to low would be around this figure.

In drought summers the water level threshold is breached in three years (1973, 1974 and 1976), by a maximum of 10cm in 1974.

Option 2b (Reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 400 tcma) is ranked as high risk against cost, medium / high risk against sustainability, medium risk against economic effects and low risk against social consequences. It is ranked as low risk against failing to achieve the Environmental Outcomes (see Table C2.2. below).

Option 2c: Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 55 tcma in drought years and reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 512 tcma
This option is a combination of Options 2a and 2b. The maximum actual abstraction under licence 7/34/10/*G/0111 was 46.6 tcma in 1990 so the proposed reduction is within the existing headroom. The proposed reduction in licence 7/34/09/*G/0091 will mean reducing actual abstraction but the magnitude of the reduction has been identified as a sustainability reduction in the AWS AMP5 submission.

In drought summers the water level threshold is breached in three years (1973, 1974 and 1976), by a maximum of 10cm in 1974.

Option 2c (Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 55 tcma in drought years and reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 512 tcma) is ranked as medium risk against cost, low / medium risk against sustainability and economic effects and low risk against social consequences. It is ranked as low risk against failing to achieve the Environmental Outcomes (see Table C2.2 below).

C.2.4 Use of Standard Appraisal Criteria

Options have been appraised against a standard set of criteria drawn from the Environment Agency's work instruction on "Stage 4 of the review of existing Water Resources permissions under the Habitats Regulations" and a review of other relevant Stage 4 work (e.g. at Rutland). The low – medium – high scoring mechanism used is described in Table C.2.1.

Table C.2.1: Description of Standard Appraisal Criteria

	Risk	Cost	Sustainability	Social Consequences	Economic Effects
Low Impact	Desired environmental outcome certain. Methodology simple and easily defined. Independent of other agreements / licences / initiatives.	£0-10,000	No changes to existing permissions. No reliance on other permissions or agreements to guarantee Favourable Condition for the foreseeable future. No additional	No negative effect on peoples' lives, or effects minor and limited to a localised geographic area or time.	No negative economic impact to licence holders, Environment Agency, or wider economic environment.

			demand on natural resources.		
Medium Impact	Desired environmental outcome achievable, but methodology complex or uncertain. Depends in part on other agreements / licences / initiatives.	£10,001 - £100,000	Some changes to existing arrangements. Some reliance on other permissions or agreements to guarantee Favourable Condition for the foreseeable future. Additional demands on natural resources minor or short term only	Negative effect on peoples' lives significant, effects limited to a localised geographic area or time (<10 years).	Economic impact to licence holder and or Environment Agency, but no impacts on wider economic environment.
High Impact	Desired environmental outcome heavily dependent on other agreements / licences / initiatives.	>£100,001	Only ongoing reliance on other permissions or agreements guarantees favourable condition for the foreseeable future. Major additional demands on natural resources.	Negative effect on peoples' lives significant, effects perceptible at regional or national level or over a long time period (>10years).	Negative economic impact to licence holder and or Environment Agency. Impact on wider economic environment.

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Table C.2.2: Overview of appraisal results against Options Appraisal criteria

Option	**Option 1: Do Nothing / Affirm (RFL)**	**2a – Modify 7/34/10/*G/0111 (abstraction reduced to 55% of licensed quantity in drought years)**	**2b – Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 60% of licensed quantity)**	**2c – Modify 7/34/10/*G/0111 (abstraction reduced to 75% of licensed quantity in drought years). Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 75% of licensed quantity)**
Risk	**Medium / High**: Will not meet Environmental Outcomes	**Medium**: Will not meet Environmental Outcomes (groundwater level breaches >10cm)	**Low**: Meets Environmental Outcomes (groundwater level breaches ≤10cm)	**Low**: Meets Environmental Outcomes (groundwater level breaches ≤10cm)
Cost	**Low**: There will be a minimum cost to the Agency	**Low cost**: Licence holders have not used full quantity during	**High cost**: Assumes modification of single licence but significant reduction of PWS	**Medium cost**: Licence holders have not used full quantity during

	associated with affirming the current licence agreements	historical drought years. Additional cost to Agency in terms of time required to modify licences plus compensation payments.	source, above that planned for sustainability reduction (see 2c), will require more investigation and planning to replace source by Water Company and Agency. Additional cost to Agency in terms of time required to modify licences plus compensation payments.	drought years. Reduction at PWS source has been planned for (sustainability reduction) but cost attached to replace source. Additional cost to Agency in terms of time required to modify licences plus compensation payments
Sustainability	**Low**: No change to the existing situation	**Medium** / **Low**: Little change to existing arrangements needed.	**High** / **Medium**: Some changes to existing arrangements needed. Possible additional pumping and treatment costs may be associated with replacement PWS.	**Medium** / **Low**: Some changes to existing arrangements needed. Some additional water needs to be brought in for PWS.
Social Consequences	**Low**: Maintaining status quo would not alter current social environment	**Low**	**Low**: If replacement PWS water supply developed.	**Low**

Table C.2.2 (continued): Summary of Appraisal against Standard Criteria

Option	Option 1: Do Nothing / Affirm (RFL)	2a – Modify 7/34/10/*G/0111 (abstraction reduced to 55% of licensed quantity in drought years). Modify 7/34/09/*G/0091 to revoke abstraction point 2 (East Ruston).	2b – Modify 7/34/09/*G/0091 (AWS Ludham source abstraction reduced to 60% of licensed quantity and revoke abstraction point 2 (East Ruston)).	2c – Modify 7/34/10/*G/0111 (abstraction reduced to 75% of licensed quantity in drought years). Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 75% of licensed quantity and revoke abstraction point 2 (East Ruston)
Economic Effects	**Low**: Maintaining status quo would not change the economic impact of the licences	**Low**: Reduction within headroom – no economic impact on business	**Medium**: Additional pumping costs associated with replacement PWS	**Low / Medium**: Additional pumping costs associated with replacement PWS

Assumptions:
Cost: Assume licence reduction made good by mains supply or storage reservoir and costs are those associated with construction / installation costs and running costs (mainly additional pumping). **Sustainability**: Mains supply – greater pumping distance – medium impact.

Social consequences: Have assumed solutions are implemented to replace licence reductions. **Economic effects**: If mains supplies implemented economic impacts low (could be beneficial in terms of reliability of water supply).

C.2.5 Use of the Principles Checklist

Options are assessed against the Principles Checklist from Stage 4 Guidance, set out in Table C.2.3.

Table C.2.3: Principles Checklist

Habitats Regulations Principles	Option 1: Do Nothing / Affirm (RFL)	2a – Modify 7/34/10/*G/0111 (abstraction reduced to 55% of licensed quantity in drought years). Modify 7/34/09/*G/0091 to revoke abstraction point 2 (East Ruston)	2b – Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 60% of licensed quantity and revoke abstraction point 2 (East Ruston))	2c – Modify 7/34/10/*G/0111 (abstraction reduced to 75% of licensed quantity in drought years). Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 75% of licensed quantity and revoke abstraction point 2 (East Ruston)).
Does it enable a conclusion of no adverse effect on integrity to be reached (subject to consideration of imperative reasons of over-riding public interest and compensation in accordance with Regulations 49 and 53)?	**No.** 'Worst case' RFL abstraction is deemed to be unacceptable to the SSSI during dry conditions.	**No.** Abstraction is deemed to be unacceptable to the SSSI during dry conditions. It is likely that reduction would need to be >50% to meet the Environmental Outcomes for the site.	**Yes**. The remaining risk of adverse effect is considered to be acceptably low, therefore no adverse effect on site integrity.	**Yes**. The remaining risk of adverse effect is considered to be acceptably low, therefore no adverse effect on site integrity.
Does it stand up to the fair and reasonable test?	**Yes.** This option is fair and reasonable because it invokes no changes to the status quo.	**No**. This option places a cessation on a Spray Irrigation licence in drought years which (based on current usage) could be expected to be accommodated by the licence holder. However, this licence is one of two licences which have been identified as the largest contributors to impact on the site and it is not fair or reasonable to favour modification of this abstraction.	**No**. This option requires a significant (40%) reduction in PWS abstraction from the Ludham source. A reduction of this magnitude may require investigation into alternative sources by the Water Company. This licence is one of two licences which have been identified as the largest contributors to impact on the site and it is not fair or reasonable to modify only this abstraction.	**Yes.** This option is fair and reasonable because it requires modifications to both of the licences that are the largest contributors to impact on the site. This option places a cessation condition on a spray irrigation licence (of a lesser magnitude than option 2a) and reduces annual abstraction from the Ludham Source (25% reduction compared to 40% reduction in Option 2b). Both of these changes are expected to be accommodated by the licence holders.
Has the contribution from other sources been addressed adequately?	**No**. This option just considers the current status quo, without looking at any licences in particular.	**No. T**his option only considers one of two licences which have been identified as the largest, and equal, contributors to potential drawdown at the site.	**No. T**his option only considers one of two licences which have been identified as the largest, and equal, contributors to potential drawdown at the site.	**Yes.** Other licences make a small contribution to potential drawdown at the site. Alteration of other licences would provide little benefit in terms of reducing impacts at the site.

Habitats Regulations Principles	Option 1: Do Nothing / Affirm (RFL)	2a – Modify 7/34/10/*G/0111 (abstraction reduced to 55% of licensed quantity in drought years). Modify 7/34/09/*G/0091 to revoke abstraction point 2 (East Ruston)	2b – Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 60% of licensed quantity and revoke abstraction point 2 (East Ruston)).	2c – Modify 7/34/10/*G/0111 (abstraction reduced to 75% of licensed quantity in drought years). Modify 7/34/09/*G/0091 (Ludham source abstraction reduced to 75% of licensed quantity and revoke abstraction point 2 (East Ruston)).
Is it consistent with the requirements of Regulation 48, the Sustainability Paper and with decisions taken under the Habitats Regulations for similar consents across other parts of the Environment Agency?	**No**. Unacceptable risk of adverse impact remains.	**No**. Unacceptable risk of adverse impact remains.	**Yes**	**Yes**
Is it legally defensible and consistent with the requirements of the Habitats Regulations? (This should also cover those options that rely on other competent authorities to deliver improvements to the site as per Regulation 51(3)).	**No**. Unacceptable risk of adverse impact remains.	**No.** Unacceptable risk of adverse impact remains.	**Yes**	**Yes**
Have the implications for permissions that are also relevant to other sites been considered appropriately?	Not Applicable for the Do Nothing Option.	**Yes.** This option would not have an adverse effect on the integrity of other sites.	**Yes.** This option would not have an adverse effect on the integrity of other sites.	**Yes.** This option would not have an adverse effect on the integrity of other sites. It would also be beneficial to the Ant Broads & Marshes SSSI.
Has the requirement for legal QA before confirming decisions been considered?	QA will be carried out by the Environment Agency.	QA will be carried out by the Environment Agency.	QA will be carried out by the Environment Agency.	QA will be carried out by the Environment Agency.

Notes:

1. The summary comments above focus on options relating to the remaining Regulation 50 licences carried forward to Stage 4
2. Note: The comparisons with the "Principles Checklist" are preliminary and are subject to review and revision by the Environment Agency

C.2.5.1 Options Appraisal Conclusion

Option 1 (Do Nothing / Affirm) and Option 2a (Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 40 tcma in drought years) have a medium / high risk of failing to achieve the Environmental Outcomes and are not acceptable. Options 2b (Reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham) from 680 tcma to 400 tcma) and 2c (Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 55 tcma in drought years and reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham)) both have a low risk of failing to achieve the environmental outcomes.

When looking at the Habitats Regulation Principles summarised in table C.2.3, it can be seen that Options 2b and 2c will potentially enable a conclusion of no adverse effect on integrity to be reached. Option 2c is considered to be fair and reasonable as it reduces abstraction under the two licences which have the greatest impact on the site in a proportionate manner. Option 2b would reduce abstraction from only one of these abstractions, therefore it does not address the contribution to impact from other sources and is not considered to be fair or reasonable. The proposed licence reduction and condition are the least onerous modifications which would achieve the environmental outcomes for the site.

In summary, Option 2c is considered to be fair and reasonable and is the most cost effective and least onerous option.

C.2.5.2 Preferred Option

The preferred option is Option 2c (Place a condition on licence 7/34/10/*G/0111 (HA Overton) to reduce abstraction from 72.7 tcma to 55 tcma in drought years and reduce abstraction under licence 7/34/09/*G/0091 (AWS Ludham)) as it is considered, based on technical appraisal, that reduced abstraction at these sources would reduce drawdown at the SSSI to a level which would reduce the risk of failing to achieve the environmental outcomes to low.

This option has a medium cost, low / medium risk against sustainability and economic impact and low risk against social consequences.

C.2.6 Stage 4 Action

Therefore abstraction licences 7/34/09/*G/0091 and 7/34/10/*G/0111 will be **modified** as detailed above and all other water resource permissions subject to the Habitats Directive Regulation 50 assessment will be **affirmed.**

The mechanism for operating the cessation condition for licence 7/34/10/*G/0111 is to be determined but will be based on a suitable water level threshold in an observation borehole, possibly in conjunction with groundwater modelling.

D1 Consultation process

(Reference the Habitats Directive Area Communication Strategy)

Table D1.1: Communications Log

Permission Reference	Permission holders name or contact	Document reference	Contact format	Date	NE / CCW consulted	EAW departments consulted										AHDC* contacted	RHDC ** contacted.	Reply Requested (and when)?
						WQ	WR	PIR	Waste	EM	FRB	EAT	Hydrology	Hydrometry	Legal			
Water Company discharges	Anglian Water Services	WQComAWS a1&a2	Meeting / Presentation	19-02-07		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS b	Meeting	11.10.07		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS c	Meeting	14.11.07		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS d	Meeting	14-12-07		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS e	Meeting	15-01-07		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS f1 & f2	Meeting	08-02-08		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS g1, g2 & g3	Meeting	18.3.08		*4*										*4*		
Water Company discharges	Anglian Water Services	WQComAWS h	Meeting	25.4.08		*4*										*4*		
Water Company discharges	Natural England	WQComNE a	Meeting	29.11.07		*4*										*4*		
Water	Natural	NE email re	E-mail	23.5.08		*4*										*4*		

Company discharges	England	WQSAP 28.4.08																
Water Company discharges	Natural England	NE comments re WQSAP 28.4.08	E-mail attachment	23.5.08		*4*										*4*		
Water Company discharges	Natural England	2nd NE email re WQSAP 28.4.08	E-mail	29.5.08		*4*										*4*		

* Area Habitats Directive Co-ordinator

** Regional Habitats Directive Co-ordinator