OHES Project Reference: 12265

Somerton Water Level Management Plan Review

January 2019

by OHES on behalf of:

Caroline Laburn
Broads IDB

11th January 2019

This page has been left blank intentionally

Somerton Water Level Management Plan Review.

January 2019

Caroline Laburn
Environmental Manager
Water Management Alliance
Kettlewell House,
Austin Fields Industrial Estate,
Kings Lynn,
Norfolk,
PE30 1PH

Activity	Name	Position
Author	Kirsty Spencer	Principal Consultant
Approved by	Andy Went	Divisional Manager – Ecology and Environmental Monitoring

Head Office:
1 The Courtyard
Denmark Street
Wokingham
Berkshire
RG40 2AZ

Bury St Edmunds:
Unit A2, Risby
Business Park,
Newmarket Road
Risby
Bury St. Edmunds
Suffolk
IP28 6RD

Tewkesbury:
Unit 7
Gannaway Lane
Northway Industrial
Estate
Tewkesbury
GL20 8FD

Leicester:
Block 61B, Room 5,
The Whittle Estate,
Cambridge Road,
Whestone,
Leicester,
LE8 6LH

Exeter:
Unit 3
Woodbury Business
Park
Woodbury
Nr Exeter
EX5 1AY

www.ohes.co.uk

This page has been left blank intentionally

CONTENTS

1 PURPOSE OF THE PLAN 7
1.1 Purpose of the WLMP 7
1.2 Agricultural Objectives 7
1.3 Nature Conservation Objectives 7
1.4 Objectives of Other Land Uses 8

2 SITE DETAILS 9
2.1 Location 9
2.1.1 Soils 10
2.1.2 Topography 11
2.2 Site Status 13
2.3 Local Planning Authorities 15
2.4 Operating Authority 15
2.5 Owners, Occupiers and Stakeholders 15

3 LAND USES 17
3.1 Conservation Interest 17
3.1.1 SSSI and International Interest 17
3.1.2 Non-statutory Conservation Interest 19
3.1.3 Conservation Aims 21
3.2 Agriculture 21
3.3 Flood Defence 22
3.4 Services 23
3.5 Other Land Uses 23

4 HYDROLOGY 24
4.1 Current Hydrological Function 24
4.2 Water Levels 26
4.3 Impacts on Ecology 33
4.4 Climate 34
4.5 Maintenance Responsibilities 35

5 WATER QUALITY REVIEW 36
5.1 Ochre 36
5.2 Salinity 38
5.3 Acidity 40
5.4 Suspended Solids 40
5.5 Phosphorus 41

6 WATER LEVEL AND WATER QUALITY MANAGEMENT OBJECTIVES 42
6.1 Water Level Management Objectives and Recommendations 42

6.2 Summary of Recommendations 43

7 CONSTRAINTS AND IMPACTS ON ADJACENT GROUND 45
7.1 Constraints 45
7.2 Impacts on Adjacent Ground 45
8 ALTERATIONS TO INFRASTRUCTURE AND PROCEDURES 46

9 OTHER PROPOSED ACTION 47
9.1 Monitoring 47
9.2 Further Investigations 47

10 BIBLIOGRAPHY 48

1. PURPOSE OF THE PLAN

1.1 Purpose of the WLMP

Water Level Management Plans (WLMP) were an initiative developed by the then Ministry of Agriculture, Fisheries and Food in 1994. The Plans provide a means of balancing and integrating the requirements of a range of activities in a particular area, including agriculture, flood defence and conservation. Previous WLMP's were prepared for the Somerton catchment by Mike Harding in 2001 and by OHES in 2013. However following the 2013 report, a meeting of all stakeholders resulted in an adjustment to the proposed pump water levels at Somerton.

In 2018, OHES were commissioned by the Broads Internal Drainage Board (IDB) to conduct a Habitat Regulations Assessment (HRA) of the existing water level regime on the nearby Sites of Special Scientific Interest (SSSI). The information gained from the HRA can now be used to inform this Somerton WLMP Review and confirm the agreed levels which will operate at the North and South Pumps. This hydrological management regime has been chosen to satisfy both the nature conservation objectives and agricultural objectives within the catchment of Somerton.

1.2 Agricultural Objectives

The District is an important agricultural area. Broad draft objectives identified during consultations, which are continued from the 2001 and 2013 water level management plans are:

- In the arable marshes, to maintain a sufficiently low water table to allow cultivation operations and good growth of crops, particularly in the perimeter dykes surrounding proposed new arable fields.
- To provide sufficient water level and quality for livestock within the grassland areas of the catchment.

Each holding, or part of a holding, may have different objectives and different water level requirements.

1.3 Nature Conservation Objectives

Water from Somerton South Pumps discharge, via a short section of dyke, into Martham Broad NNR, which is connected to the River Thurne. Water levels within the Somerton District will also potentially affect Winterton Dunes NNR at the east of the district. Maintenance of these features, as well as the four County Wildlife Sites present in the district, through management of the pumping regime is an objective of the plan and a requirement of the Habitat Regulations. This objective was defined and agreed in the 2001 Water Level Management Plan (Harding 2001) as:

- To maintain the water dependent features of the dune slacks and connected features of Martham Broad, through management of the pumping regime (which is an IDB objective but also a requirement of the Habitats Regulations).

1.4 Objective of Other Land Uses

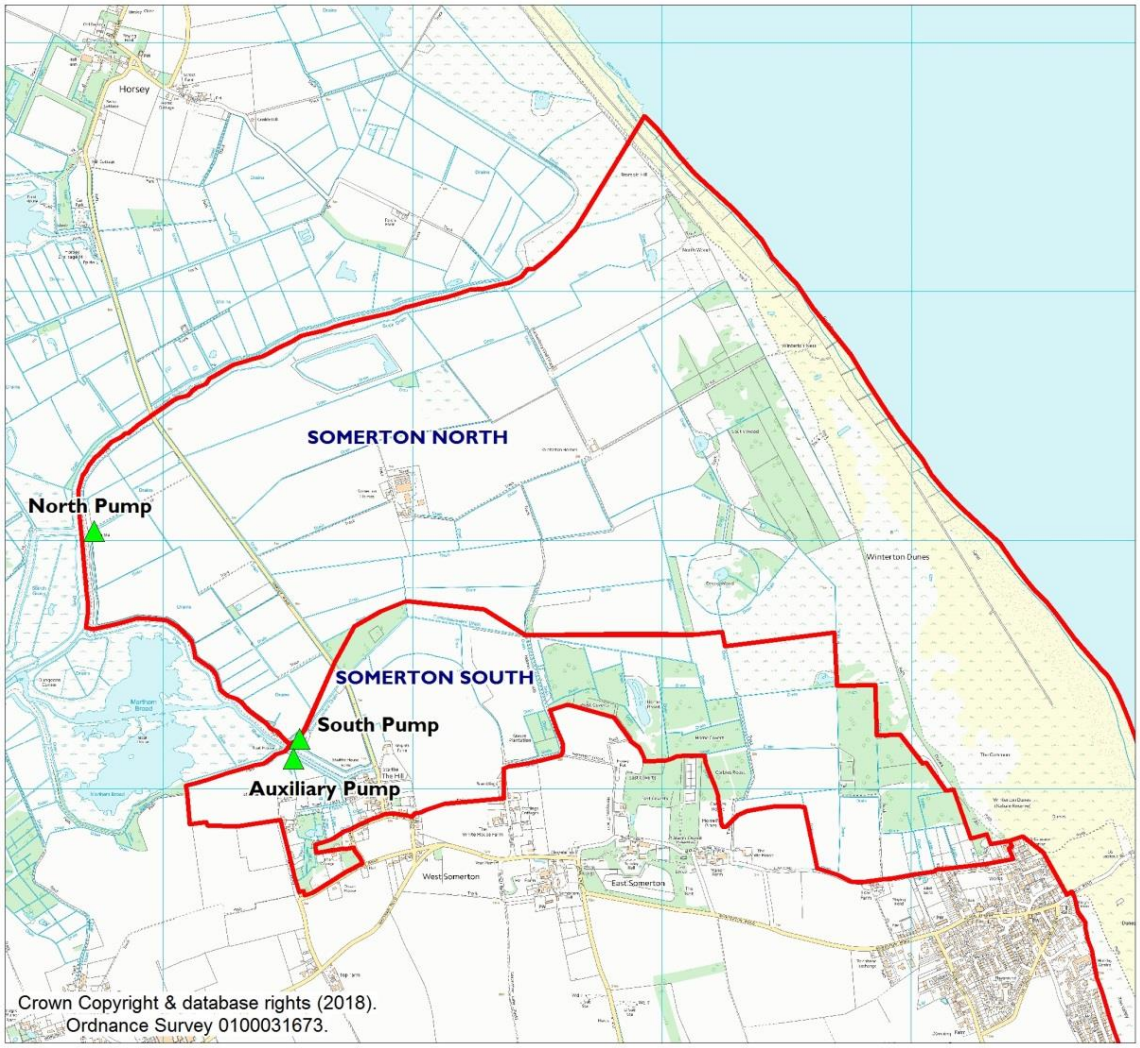
Flood water from Winterton-on-Sea is directed into the ditch system at Somerton in the south east of the site, which is then pumped out through Somerton South Pump. It is an objective of the IDB to continue to provide the existing service without increasing the flood risk to Winterton residents (H. Cator and S. Daniels pers. comms.).

2. SITE DETAILS

2.1 Location

This plan covers the Somerton North and South IDB districts, located to the south of Horsey and east of the Martham WLMP areas, with the sea forming the eastern margin. The area principally consists of low lying agricultural ground, with the coastal dune system of Winterton – Horsey Dunes SSSI & SAC contained along the eastern edge of Somerton North District. The Somerton North District is 625ha while the Somerton South District is 180ha, as shown in figure 2.1.

Figure 2.1: Location of Somerton North and South IDB Districts



2.1.1 Soils

Recent investigations on the soils of the districts (OHES, 2018) show that there are four main zones distinguishable from the data (see Figure 2.1.1);

- ***Zone 1. Upland soils.***
  Here, the soil texture was quite uniform throughout, being a sandy silty loam. It corresponds to Norwich Brickearth, with the addition of a silt component.

- ***Zone 2 Mineral alluvial soils surrounding the 'holmes'***
  These are the main soils of Somerton Marshes and are ubiquitous wherever marine alluvium forms the ground surface and Upper Peat is absent. The upper sediments were found to consist of at least 50 cm of silty clay loam over silty clay. In other areas these clay deposits were proved to be more than 150 cm thick. The ground surface was observed to be largely level, but frequent shallow depressions are also evident. These depressions are significant features for cropping as they clearly collect surface water directly from rainfall and from the surrounding soil surface. The development of these depressions is most likely the result of differential shrinkage following land drainage.

  A rise in water table was observed in many cores during the 2018 survey. Although the amount of rise is very much related to the time of year and amounts of previous rainfall, these figures give an indication of the potential rise in watertable where the overburden is removed.

- ***Zone 3. Soils with surface peat***
  This zone of floodplain soils is concentrated to the south of the 'holmes', but a similar soil was also recorded from the eastern end of the northern transect. These soils have two common features: the presence of Upper Peat on the soil surface, and a consistently recorded layer of Middle Peat at depth. The Upper Peat is largely within the plough layer, and two issues are associated with this: i) loss of bulk due to disturbance of the peat (which lies above the water table), and ii) a tendency of rainwater to "pool" at the surface due to the loss of ability in de-watered peat to absorb water (coupled with compression caused by vehicle movements).

  The rises in watertables during coring were very similar rise to the average recorded for most of the cores in Zone 2. However with zone showed the lowest readings of acidic groundwater (pH 3.95 to pH 4.5) and evidence of pyrite within the peat.

- ***Zone 4. Coastal sand barrier soils***
  The porous sands found here are largely composed of inert silica coated in iron-rich alumino-ferrous compounds, in an environment where oxygen-rich soil air can readily diffuse. This makes them very sensitive to certain aspects of the hydrochemical character of the local groundwater conditions, particularly along the margin with Zone 3. Here, sulphidic groundwater has stripped sand grains of their iron-coatings, which has been re-deposited as iron ochre in the drainage network along the boundary between the two zones.

  The presence of sulphidic groundwater was detected in many cores from soils across the survey area and, although ochre production is likely to be most prolific along the junction

between Zones 3 and 4, it may also occur in situations where drain sides expose the groundwater in organic matter-bearing silts, clays and peats to an oxygen-bearing atmosphere.

Detailed transects were taken combining soil and topographic data across west to east transects and are contained within the HRA (OHES, 2018).

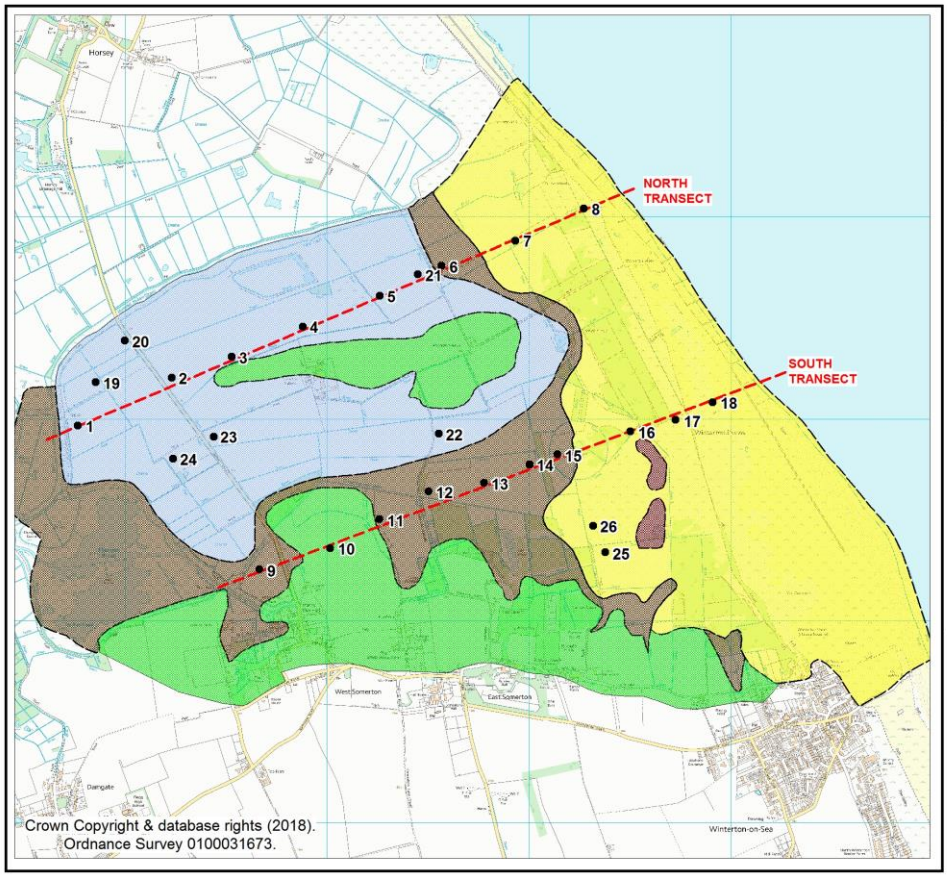


Figure 2.1.1 Location of soil cores transect lines and soil zones

Key:

- Soil core
- Zone 1: Upland soils
- Zone 2: Mineral alluvial soils
- Zone 3: Soils with surface peat
- Zone 4: Coastal sand barrier soils

OHES ENVIRONMENTAL

Drawn by: KLS Dated:22/07/18
OHES reference: 12265

2.1.2 Topography

Figure 2.1.2 shows the approximate topography of the Somerton area, which ranges from up to 11mAOD (above Ordnance Datum) within the Dune system, down to -1.4mBOD (below Ordnance Datum) within the drained marshland and fields. The 2015 LiDAR data, which was ground-truthed as part of the HRA, still appears to be relatively accurate (to within approximately 6cm), and most ground truthed spot heights were still within the ranges shown in figure 2.1.2 However, there are clear signs of land subsidence in those fields where peat is present, with standing water present in the majority of cases during March 2018.

The lowest fields in the northern half of the district occur around the North Pump and within the northern-most fields (close to the Soke Drain). In the southern half of the district, the lowest fields were recorded within the peat zone and around the edge of the holmes.

Figure 2.1.2 Topography and land heights at Somerton

Key: all levels in mOD

- Water control structure
- Main IDB drain
- Blocked culvert
- -0.566 Spot height
- 0.5 to 0.7m Lidar elevation range
- Cut and fill operations

OHES ENVIRONMENTAL

Drawn by: KLS Dated:22/07/18
OHES reference: 12265

The Somerton fields adjacent in the west of the district are currently between 1m to 1.8m below marsh level at Martham Broad and 0.85 to 1.85m below marsh height at Starch Grass. Cut and fill operations have taken place recently in four fields (see figure 2.1.2) in order to raise some of the lowest hollows and install footdrains (J. Chapman pers.comm).

2.2 Site Status

Figure 2.2.1 outlines all conservation features and designation boundaries. Much of the area is within the Broads Authority Executive Area and the Broads Environmentally Sensitive Area.

The eastern margin of the site (approximately 400 to 800m wide) is part of the Winterton-Horsey Dunes SSSI/SAC and the Winterton Dunes NNR. The shingle beach is part of the Great Yarmouth North Denes SPA due to the breeding bird colonies. The water levels within the Winterton-Horsey Dunes SSSI and SAC have the potential to be impacted by the draining of the marshes. This is because of the presence of dune slacks (low-lying areas that are seasonally flooded) and their associated species (such as Natterjack toads). This is one of the reasons why an HRA was commissioned by the IDB in 2018 (under advisement from Natural England).

The Somerton Catchment is also adjacent to, and upstream of, Martham Broad NNR, which is part of the Upper Thurne Broads and Marshes SSSI. Martham Broad is a component of the Broads SAC, Broadland SPA and Ramsar site. This area was also carefully considered within the HRA as water discharges into Martham Broad via the South Pump. Water from the North Pump can also potentially enter the Broad when water backs up into the River Thurne.

There are four County Wildlife Sites (CWS 1436, 1437, 1438 and 1440), containing wetland features such as pools, wet woodland, fen and reedbed. Many of these features overlie former broads as shown in Fadens Map of 1794.

In the period covered by the 2001 water level management plan, the areas identified in figure 3 (land use section) were under a 10-year ESA agreement. These agreements have now reached term on all holdings. New HLS agreements have now been awarded and are shown in figure 3 of this report.

Gauge boards have been sited at key locations for water levels to be monitored and recorded for management purposes. However, recent checks undertaken by the IDB's Operations Engineer showed that these gaugeboards had become inaccurate and consequently new gaugeboards were installed and calibrated to the correct level (both to Ordnance Datum and Local Marsh Datum). In December 2017 all operating levels were shifted across to the new gaugeboards, but the old gaugeboards currently also remain in situ.

Water quality monitoring of the pumped discharges is mainly undertaken by the Environment Agency, but is supplemented by additional monitoring of the drainage dykes under studies such as the HRA.

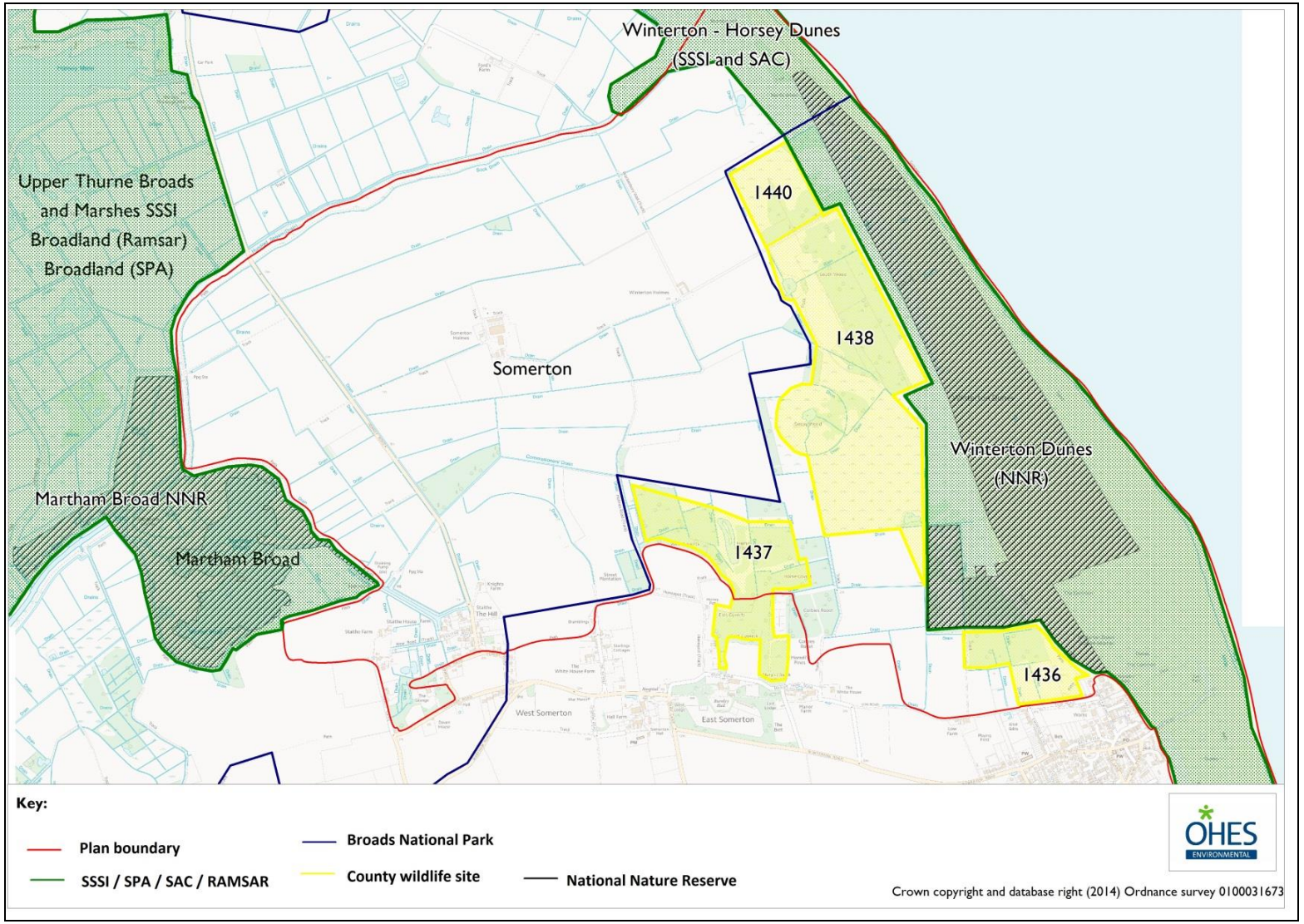


Figure 2.2.1: Conservation features and designation boundaries at Somerton

2.3 Local Planning Authorities

- Norfolk County Council
- The Broads Authority
- Great Yarmouth Borough Council

2.4 Operating Authority

Broads Internal Drainage Board, Water Management Alliance, Kettlewell House, Austin Fields Industrial Estate, King's Lynn, Norfolk, PE30 1PH.

2.5 Owners, Occupiers and Stakeholders

Under the 2013 WLMP Review, OHES contacted and met with all land owners, occupiers and stakeholders in order to obtain their views and thoughts on the issues relating to water management and how they would like to see the catchment managed in the future in relation to water levels. Their comments have been incorporated into the report where appropriate and were assumed by the author to be accurate.

As part of the HRA process, stakeholders were also consulted on the draft HRA report and invited to a consultation meeting on the 29th August 2018 (chaired by H. Cator). The purpose of the meeting was to review the information which had been gathered on the environmental issues pertinent to the districts and to gain a consensus on whether the pumps could stay at their current operating levels or whether some adjustment was needed. Table 2.5 presents those who attended the meeting in August 2018.

Table 2.5: *Owners, occupiers and stakeholders within the Somerton catchment who attended the August 2018 consultation meeting (provided by Caroline Laburn, Environmental Manager, Broads IDB)*

Name	Role
Natural England	
Karen Kramer-Wilson	Broads and Wensum Area Senior Team Leader
Alex Prendergast	Lead Advisor & Field Unit Ecologist - Norfolk and Suffolk Team
Hannah Thacker	Manager, Norfolk and Suffolk Team
Broads Authority	
Andrea Kelly	Senior Ecologist
Environment Agency	
Chris Strachan	Biodiversity Officer
Somerton Parish Council	
Richard Starling	Council Chairman
Norfolk Wildlife Trust	
Kevin Hart	Head of Nature Reserves
Broads IDB Board	
Henry Cator	Chairman
Giles Bloomfield	Catchment Engineer
Caroline Laburn	Environmental Manager
A. Goose	Operations Manager
Henry Alston	Member
James Chapman	Member
Simon Daniels	Vice-chairman
M. Harris	Member
Keith Girling	Burnley Estate
S. D. Wright	Member

J. G. Tallowin	Member
RSPB	
Ian Robinson	Broads Area Manager (RSPB)
Other	
Kirsty Spencer	Consultant (OHES Environmental)

3. LAND USES

The current land uses and HLS agreements within the plan boundary are shown in figure 3 (sourced from the 2013 WLMP). Comments from stakeholders and landowners are included in the following sections of the report.

3.1 Conservation Interest

3.1.1 SSSI and International Interest

Martham Broad lies within the Upper Thurne Broads and Marshes SSSI. This SSSI is a component of the Broads SAC / SPA / Ramsar site and is also a NNR. The SSSI and site description and the broad international citations of the Upper Thurne Broads and Marshes (last updated in 2008 by Natural England) has identified the features present, which are shown in Table 3.

Martham Broad is officially considered to be in Favourable Condition and continues to support water plants such as Holly-leaved naiad (Nationally Rare) and stoneworts (charophytes). However, NE report that following evidence of declines/losses of macrophytes in recent years (combined with water quality declines) it is being considered whether it should be re-classified as Unfavourable Declining. Martham Broad is listed as an Important Stonewort Area (ISA) for the UK (Stewart, 2004) and contains several species of stonewort which are listed as Red Data Book species.

Martham Broad has long been held to be one of the least nutrient-enriched Broadland waterbodies and therefore has some of the most species-rich aquatic plant assemblages. The presence and abundance of stoneworts depends on multiple factors such as clarity, nutrient levels, salinity, acidity, water depth and grazing pressure, but the interactions of these factors can be complex. Their requirements are the subject of continued investigation by organisations such as the Broads Authority and Natural England, and the HRA provides a literary review of what has been published in this respect to date.

Table 3: International features of the Upper Thurne Broads and Marshes which are water dependant (taken from the HRA, 2018)

Code	Upper Thurne
cSAC features	
H3140	Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.; Calcium-rich nutrient-poor lakes, lochs and pools
H3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation; Naturally nutrient-rich lakes or lochs which are often dominated by pondweed
H6410	*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*); Purple moor-grass meadows

H7140	Transition mires and quaking bogs; Very wet mires often identified by an unstable `quaking` surface
H7210	Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*; Calcium-rich fen dominated by great fen sedge (saw sedge)*
H7230	Alkaline fens; Calcium-rich springwater-fed fens
H91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*); Alder woodland on floodplains*
S1016	*Vertigo moulinsiana*; Desmoulin`s whorl snail
S1355	*Lutra lutra*; otter
S1903	*Liparis loeselii*; fen orchid
S4056	*Anisus vorticulus*; little whorlpool ram's-horn snail
SPA features	
A021	*Botaurus stellaris*; great bittern (Breeding)
A037	*Cygnus columbianus bewickii*; Bewick"s swan (Non-breeding)
A038	*Cygnus cygnus*; whooper swan (Non-breeding)
A050	*Anas penelope*; Eurasian wigeon (Non-breeding)
A051	*Anas strepera*; gadwall (Non-breeding)
A056	*Anas clypeata*; northern shoveler (Non-breeding)
A081	*Circus aeruginosus*; Eurasian marsh harrier (Breeding)
A082	*Circus cyaneus*; hen harrier (Non-breeding)
A151	*Philomachus pugnax*; ruff (Non-breeding)
A021	*Botaurus stellaris*; great bittern (Non-breeding)
A040	*Anser brachyrhynchus*; pink-footed goose (Non-breeding) Waterbird assemblage

* denotes a priority natural habitat or species

Winterton Dunes NNR lies within the Winterton-Horsey Dunes SSSI/SAC. Annex I habitats that are a primary reason for selection of this site and which are sensitive to water level/water quality permissions are the Humid dune slacks. These are of particular interest because they are situated within an extremely base-poor dune system on the dry coast of East Anglia. As a result of the acidic soils and water levels, the dunes contain swamp, mire and slack communities. The slacks

support a breeding population of natterjack toads (Epidalea calamita) that receive full protection under the Wildlife and Countryside Act 1981 (as amended) and The Conservation of Habitats and Species Regulations 2017 (Halcrow, 2013).

The dune slacks were assessed in 2009 as being in *favourable* condition with "*a good mix of open to terrestrialised slacks, but these may need further active management in the next 5 years to prevent them becoming unfavourable. There is a good % of bare ground through trampling and wind blow*." (Halcrow, 2013).

The Natterjack toad population within the pools (with peak counts recorded in the 1980's of circa 400 adults) has suffered a significant decline since 2000, with the adult population estimated in 2013 to be only circa 50 adults. The ponds are known to be at least partially acidic as a result of the site's geology, and liming is undertaken in some years to mitigate this (Halcrow, 2013). Iron levels which are thought to be toxic to Natterjack toads have also been observed within the pools. It therefore appears that this feature of the SSSI unit is in unfavourable condition.

3.1.2 Non-statutory Conservation Interest

Ecological surveys of the ditches within the catchment during different land use periods were undertaken over the last 40 years by Rob Driscoll (Drake et al., 2010). The surveys found that there was a loss of aquatic habitat within the ditch system, with species becoming less frequent and less abundant in ditches associated with arable production. Some of the more tolerant species (see Driscoll, 1986 and Drake et al., 2010) thrived under these conditions but then became a nuisance and had to be removed or controlled. Generally dykes that drained grazing marshes supported the richest flora and fauna whereas dykes draining arable land were impoverished (Driscoll, 1986). There was also an increase in brackish species, with a continued loss of species-rich freshwater communities (Drake et al., 2010).

An additional feature of interest is an area of land, approximately 6 ha, which is owned by the Poor's Trust. This land is currently managed as wet grassland, which is now in an Entry Level Stewardship agreement with Natural England. The dykes within this area have been identified as being suitable habitat for wintering and breeding birds. The Poor's Trust are mainly in control of their own water levels through a series of water control structures, which they manage to allow the area to continue to be wet grassland.

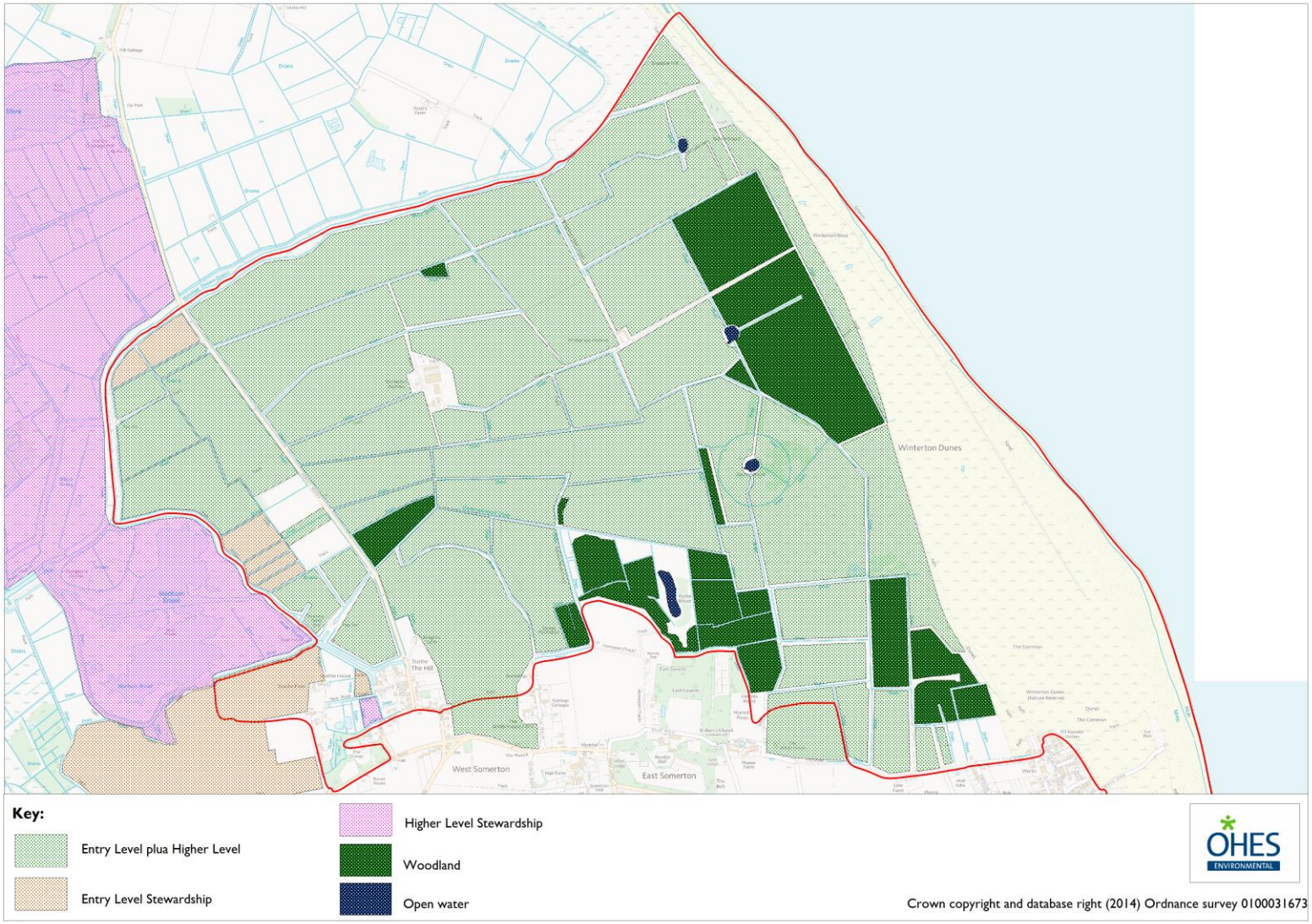


Figure 3: Land use within the Somerton Catchment

3.1.3 Conservation Aims

The conservation of Martham Broad as part of the Upper Thurne SAC / SPA is a European process that cannot be avoided. Natural England, the Broads Authority and Norfolk Wildlife Trust are keen to work with all land owners and managers to prevent damage to Martham Broads and to ensure the protection of the SAC and SSSI features, for which the flow of fresh water is critical.

Natural England's conservation objectives for Martham Broad are to maintain the habitats and geological features (outlined below) in favourable condition status, with particular reference to any dependent component special interest features (habitats, vegetation types, species, species assemblages etc.) for which the land is designated (SSSI, SAC, SPA and Ramsar).

Habitat types represented (BAP categories)

Standing Open Water and Canals
Fen, Marsh and Swamp

The following objectives have also been outlined by Natural England [Conservation Objectives and Definitions of Favourable Condition for Upper Thurne Broads and Marshes, March 2008]:

- Ensure sediment loads through changes in land use (particularly over-drainage (ochre)) are kept at a level that will not influence biological communities.
- Stable conductivity levels appropriate to lake type (Hickling Broad and Horsey Mere have targets of 2400µS/cm and <4000µS/cm respectively). It is assumed that Martham Broad will have a similar target.

In regard of the ditch system within the Somerton catchment Natural England have identified the following key aspects:

- Maintain both shallow and deep water to allow diverse plant and invertebrate assemblages to develop.
- The levels characteristic of the site, in relation to both freeboard and water depth, should be maintained. High water levels are particularly important in spring and early summer for semi-aquatic riparian invertebrates.

3.2 Agriculture

The Somerton district has had a mixed agricultural history, with alternating pasture and arable land use. Historically much of the lower land was coastal grazing marsh, with arable on the raised sandy holmes, and fringes of woodland, reedbed and fen adjacent to the dune system. In the 1980's and 90's some of the marsh was put into arable production, with associated lowering of the water table and installation of deep field drains. This operation appears to have been of limited success, with aerials from 1999 showing crop failure on multiple fields, presumably where surface water flooding, either due to the presence of hollows or low permeability soils, had occurred.

In 2003, 143ha of land was put into Tier 4A (Arable Reversion) of the Broads Environmental Sensitive Area (ESA) agri-environmental scheme by the Burnley Estate. These fields were intensively grazed by cattle and sheep or cut for silage (Halcrow, 2013). Under this scheme (and

to ensure compliance) water levels must be no lower than 45cm below ground level throughout the year with some flexibility under derogations to allow ditch management. In addition, a) water levels should be maintained where possible so that from 1st May to 30th August levels are no lower than 1m from the surface of the centre of the marsh, and b) between 1st September and 30th April to ensure that there is at least 60cm of water in the bottom of the dykes (Halcrow, 2013).

However in April 2013 this agreement expired and consequently some of the fields were put back into arable production. Since this time, the Estate have maintained that water levels within the ditches are not sufficiently low to allow viable cultivation, and that the levels need to be dropped ideally by 0.5m, though there is some flexibility as to the exact amount which would be acceptable (J. Chapman pers. comm.).

In contrast, low ground within the southern third of the district, i.e. south of the Commissioners Drain, has remained largely under low-intensity land use (such as woodland and pasture).

It has been suggested that changes in land use from grazing marsh to arable and the improvements in land drainage associated with such changes could and have in the past adversely affected the quality of water in the dykes that drain the area and enter the Broad system via the pumps (Driscoll, 1999). Holman and Hiscock (1998) have also shown that saline intrusion is a major issue and any reduction in levels will cause greater intrusion.

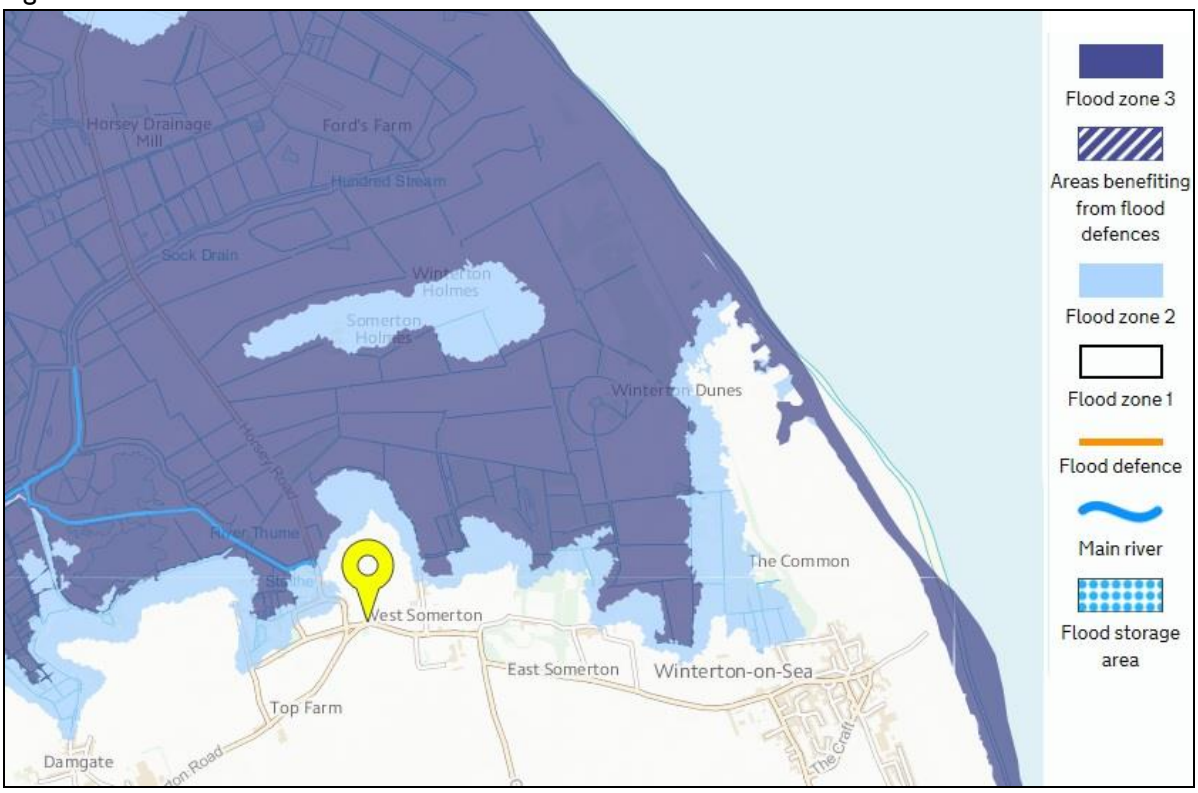
3.3 Flood Defence

The majority of the Somerton District is within the Environment Agency's Flood Zone 3 (land having a 1 in 100 or greater annual probability of river flooding; or land having a 1 in 200 or greater annual probability of sea flooding). An example of such an event occurred in 1938, when seawater breached the area (after sea defences gave way) and resulted in much of the area being underwater for a prolonged period. Events such as these are more likely in the light of land subsidence across some fields.

Among the IDB's major responsibilities are their rate payers, for whom the flooding of built up areas is a key issue. There has historically been a problem with getting flood water from Winterton-on-Sea to the pumps through the ditch system. Keeping ditch levels high will reduce flood storage within the catchment, which may impact Winterton-on-Sea, however, as dyke levels have been higher in the past this may not be so much of an issue.

There have been very few issues with flooding over the last decade or so, with the main problems being due to flooding from the sea or the road drainage system (M. Blake pers. comm.). Previous flooding issues due to ponds located close to the church have now been resolved and no further problems have occurred since (M. Blake pers. comm.). Winterton-on-Sea Parish Council however, are not aware of any current actions at Somerton that may impact flooding and feel that they have very little involvement with IDB decisions (M. Blake pers. comm.).

Figure 3.3 Flood Zone classification within Somerton IDB.



An embankment has been constructed along the eastern bank of the river as part of the flood defence improvements for Compartment 6A (West Somerton) undertaken as part of the BFAP. The embankment levels were set back to the 1990s levels which are designed to last until 2027. The embankment was widened and slackened with a reed buffer to try and prevent erosion of the embankment toe. The embankment is monitored for settlement and leakage in the winter, with regular cutting of the vegetation during annual condition surveys. It is important that the water levels within the dykes that run parallel with the defence are kept as high as possible to prevent slippage of the embankment.

3.4 Services

There was no available information regarding services. No issues were raised during the 2001 WLMP or during consultation with the Board and other interested parties.

3.5 Other Land Uses

It has been reported in previous reviews that graziers who operate within the catchment require stable water levels and can have issues with getting stock in and out if water levels are low within the dykes. Salinity is an issue within the catchment which is exacerbated during the summer when rainfall is lower, or when the water levels near the pumps are dropped. Ideally water levels would be kept high during the summer.

4. HYDROLOGY

4.1 Current Hydrological Function

There are two main water management systems in the District; Somerton North Pump and Somerton South Pump. There is also a third system, controlled by the Auxiliary pump. Figure 4.1 outlines the location of the pumping stations, their flow patterns and provides water levels taken during the HRA investigations in March 2018 (OHES).

4.1.1 North Pump System

Somerton North Pump drains the northern and central part of the district and was originally installed in the 1980's to draw poorer water away from the South Pump. It collects water arising along the dune margins in the east via three IDB main drains that trend east-west. These include:

- The Soke Dyke: running along the foot of the Hundred Stream embankment (which was built as part of the flood alleviation project)
- A second IDB drain approximately 200m south of the Soke Dyke (which appears to be partially spring-fed)
- A dyke running eastwards from Decoy Wood.

All three of the IDB main dykes are connected by an IDB drain that runs north-south, on the west side of the Horsey Road. The pump discharges into the Hundred Stream, which then passes through a series of linear settlement lagoons before feeding into the River Thurne (downstream of Martham Broad). It is therefore expected that the majority of water passing through the North Pump would bypass Martham Broad. However, it is also likely that under certain circumstances such as through tidal influx (EA, 2007) water will be able to back-up into North Martham Broad. There is no physical barrier preventing water entering Martham Broad should a major incoming tide cause water to flow upstream (Halcrow, 2013).

In recent years, The Burnley Estate have installed 3 new water control structures approximately 500m inland of the dune system in order to raise water levels in the east and improve water quality. Four fields have also undergone improvement works (via installation of footdrains at approximately 3ft below ground level) in late 2017 to facilitate arable production.

4.1.2 South Pump System

The South Pumps are supplied by a combination of spring water (to the far east), road run-off (from Winterton-on-Sea) and then surface water drainage from fields in the south of the District. The original pump has been supplemented by a second variable-speed pump, which allows water to be pumped at lower volumes. Water is delivered to the South Pumps by the IDB's Commissioner's Drain, which arises to the north of Winteron-on-Sea. Water is pumped from Somerton South Pump into Somerton Boat Dyke, which then passes through Martham Broad. In exceptional circumstances, such as during ditch maintenance work, water from the Commissioners Drain can be re-routed into the North Pump system via the Somerton North Sluice (WCS029P0301-01), in order to maintain good water quality to Martham Broad.

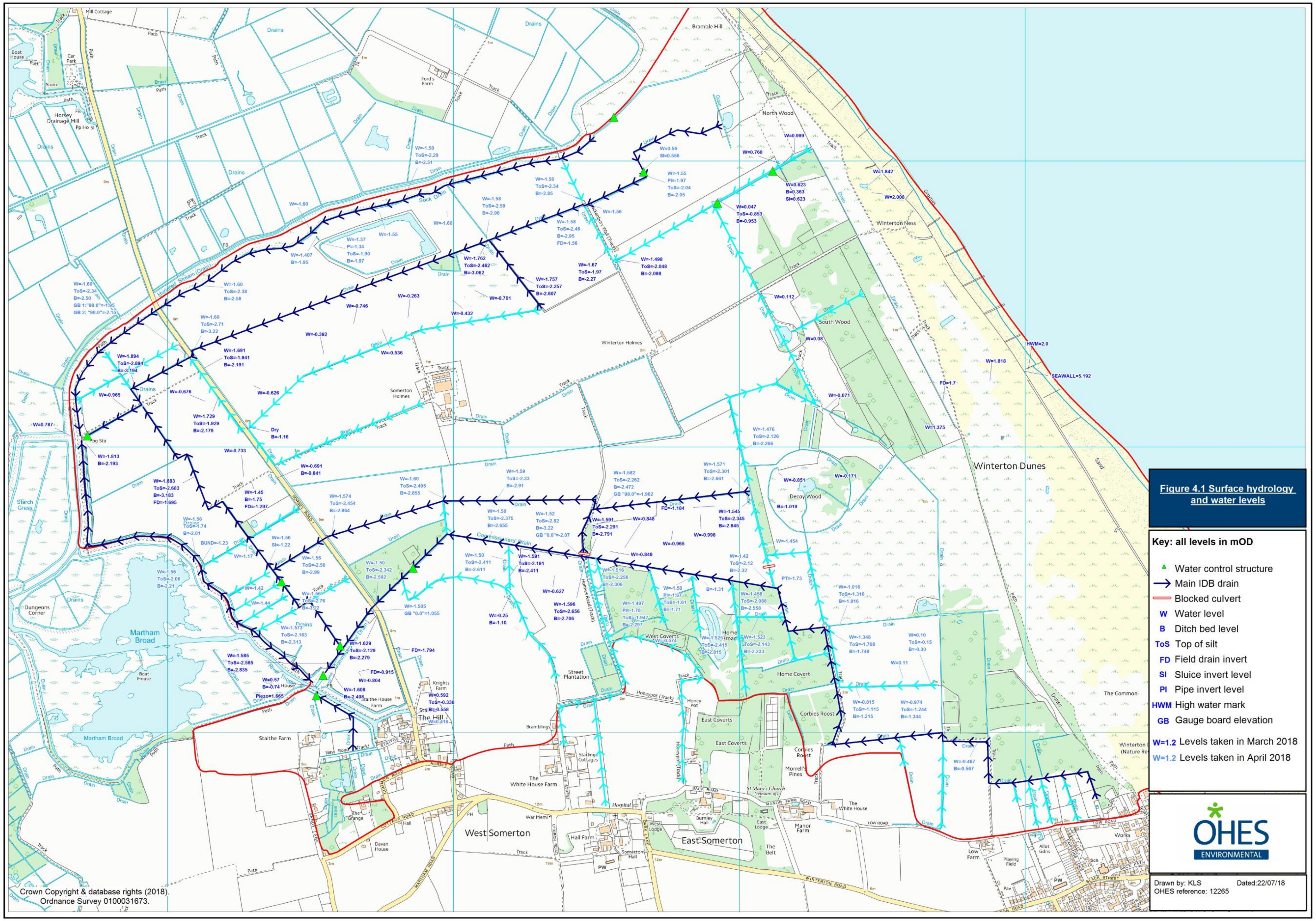


Figure 4.1 Surface hydrology and water levels

The Poor's Trust land has three water control structures which help to control water levels within their dykes. The main source of water into this part of the system is leakage from the river and precipitation (M. Lees pers. comm.). There are two bunds along the Soke Dyke on the western boundary, one to the north (put in by the BFAP initially to help mitigate short-term iron ochre release following the excavation of the new soke dyke) and one to the south (put in by the Poor's Trust in September 2013), which hold back water within the Poor's Trust dyke system and prevent water being drawn to the North and South Pumps. There is also an overflow pipe which is controlled by the Trust and can deliver water to the IDB drain to the north, which feeds into the North Pump.

There are three IDB water control structures to manage water within the southern system (figure 4.1). The Somerton North sluice can direct water from the southern system towards the North Pump and prevents poorer quality water from entering into the South Pump and therefore into Martham Broad. The Somerton tilting gate along the Commissioner's Drain was installed around 2006 to hold up water for the benefit of the upstream designated sites (Paul George pers. comm.) but is rarely used to hold up water now (other than in drought conditions). The third structure is along the main dyke at South Pump and is known as the Somerton South Sluice. It is a dam board structure which allows control of water between the North and South drainage systems and was refurbished in the summer of 2018.

4.1.3 Somerton Auxiliary Pump

The small area of land south of the River Thurne and adjacent to West Somerton Village is drained by an IDB drain which runs along the Martham Broad and River Thurne walls and pumped into Martham Broad by the Auxiliary Pump. This pump has a small capacity and is generally considered to be insignificant in influencing Martham Broad.

4.2 Water Levels

Water levels within the North Pump system are typically held at a slightly lower level than the South Pump, in order to encourage movement of poorer quality water away from the South Pump. Several gaugeboards have been installed across the districts (by the IDB and landowners) which are set to local marsh datum (to coincide with the North and South pumps). It is believed that until recently the water table has remained relatively unchanged within the Somerton District from around 2005 to 2013 at the levels shown in Table 4.2. However, it is noted that a recent levels survey of the gauge boards (and therefore the pumps also) has shown a discrepancy in the local marsh datum being recorded (WMA, 2018). New gauge boards have now been installed and accurately levelled in, but the pumps are still operating under the old levels system and therefore have been calibrated to the main gaugeboards using Ordnance Datum data.

The 2013 WLMP Review states that, despite the very wet conditions from March 2012 to February 2013, the Parish council felt that both pumping stations worked satisfactorily although problems with heavy sediment discharge took place when the larger 'flood pumps' were in operation (R. Starling pers. comm.).

Table 4.2 Water level ranges at the Somerton North and South Pumps since 2005 (using road bridge gauge boards).

	Winter range			***Summer range***		
2005 to early 2013 (R. Starling pers. comm.)	Old LMD	Corrected LMD	Corrected mBOD	Old LMD	Corrected LMD	Corrected mBOD
North Pump	98.60 to 98.40					
South Pump	98.60 to 98.40					
2013 report (April onwards)	Old LMD	Corrected LMD	Corrected mBOD	Old LMD	Corrected LMD	Corrected mBOD
North Pump	98.45 to 98.25	98.30 to 98.10	-1.70 to -1.9			
South Pump	98.60 to 98.40	98.55 to 98.35	-1.45 to -1.65	98.60 to 98.40	98.55 to 98.35	-1.45 to -1.65
2014 (October)	Old LMD	Corrected LMD	Corrected mBOD	Old LMD	Corrected LMD	Corrected mBOD
North Pump	98.45 to 98.25	98.30 to 98.10	-1.70 to -1.9	98.50* to 98.30	98.35 to 98.15	-1.65* to -1.85
South Pump	98.50 to 98.30	98.45 to 98.25	-1.55 to -1.75	98.60 to 98.40	98.55 to 98.35	-1.45 to -1.65

South pump corrected in connection with local gauge board being on average 50mm too low.
North pump corrected with local gauge board being 150mm too high.
(based on June 2018 recheck of levels survey by WMA engineers.)
* = this level went up to 98.70 on telemetry and also -1.60 in OHES levels survey (i.e. 0.4m range)

Daily water levels are taken from Martham Broad by R. Starling (data for which goes back more than 30 years). This data shows a daily rise and fall of the water level at Somerton, which is influenced by the tide (R. Starling pers.comm). Rainfall is also reported to have a significant impact on water levels within the River Thurne, with Potter Heigham bridge acting as a significant restriction to downstream flow when all drainage pumps are discharging and when the tide is flooding (R. Starling pers. comm).

Daily discharge volumes from the North Pump are shown in Figure 4.2.1, which shows that peaks in discharge tend to occur in winter but can also occur in spring. Figure 4.2.2 shows water levels at the North Pump during 2017 to 2018. It should be noted that these levels do not precisely correspond to those of the North Pump Road Bridge gaugeboard (i.e. those shown in Table 4.2), due to the gradient between the two points and discrepancies in calibration similar to those found at the old gaugeboards.

Concerns have been raised by one landowner that the North Pump does not drawdown ditch water levels to the full agreed range, sufficient for the field drains to operate. However figure 4.2.2 confirms that there is typically a 20 to 25cm drawdown (at least daily) between the upper and lower ranges of pump operation. The issue of ditch water levels not dropping the full 20cm in parts of the district is therefore likely to be a result of delayed effect versus the quantity of new water entering the system upstream.

Figure 4.2.1 Somerton North Daily Discharge Volume (m³)

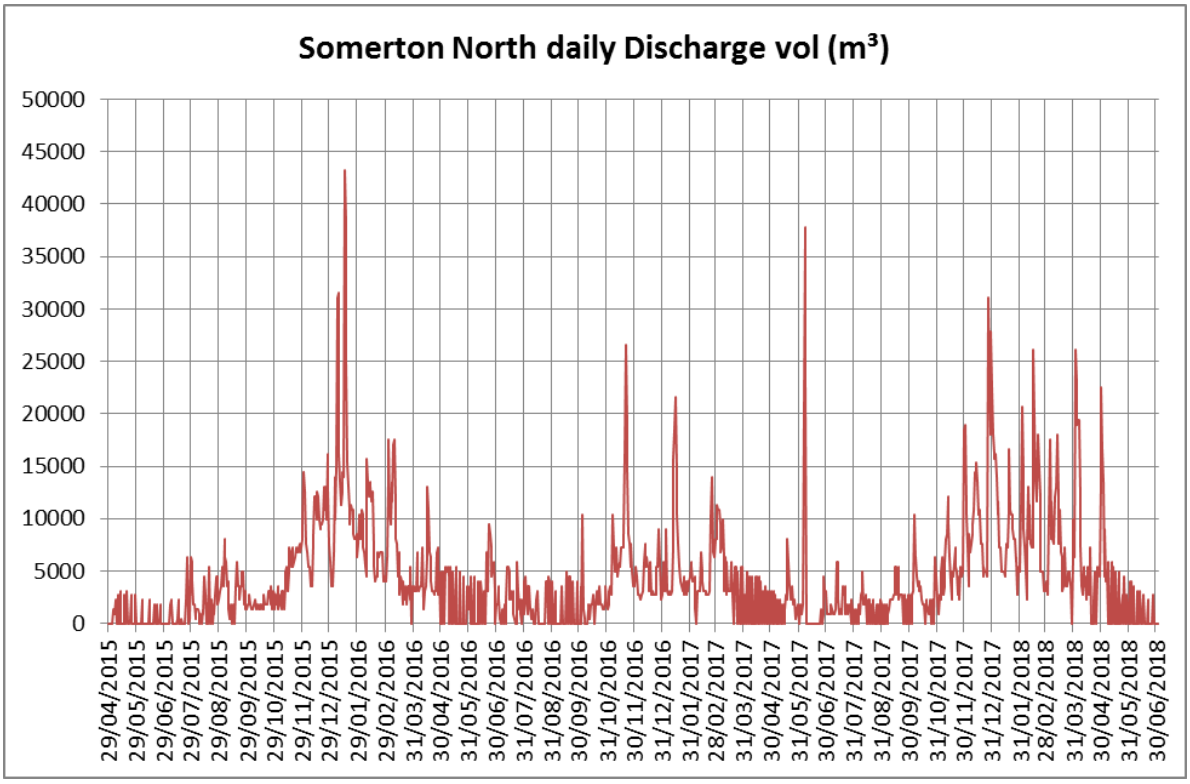
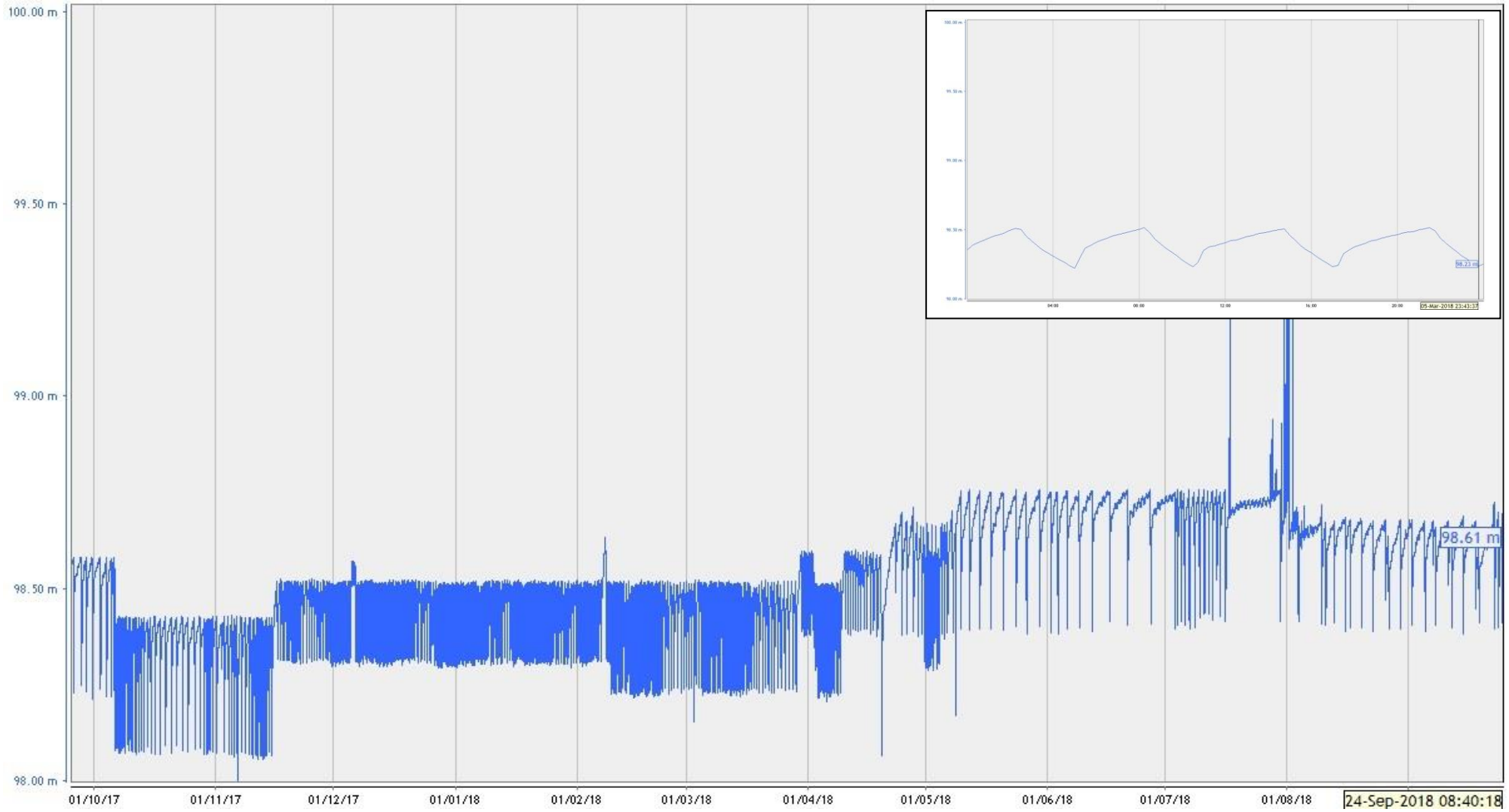


Figure 4.2.2 Water levels at North Pump from Oct 2017 to Oct 2018, with insert of fluctuation in water level during a single day (Broads IDB)



Daily discharge volumes from the South Pump are shown in Figure 4.2.3, which shows similar discharge volumes to the North Pump system. Figure 4.2.4 shows water levels at the South Pump during 2017 to 2018. Once again it is noted that these levels do not precisely correspond to those of the South Pump Road Bridge gaugeboard (i.e. those shown in Table 4.2), due to the gradient between the two points and discrepancies in calibration similar to those found at the old gaugeboards. Figure 4.2.4 also confirms that there is typically a 20 to 25cm drawdown between the upper and lower ranges of South pump operation.

Figure 4.2.3a Somerton South Daily Discharge Volumes from pump 1 (m^3)

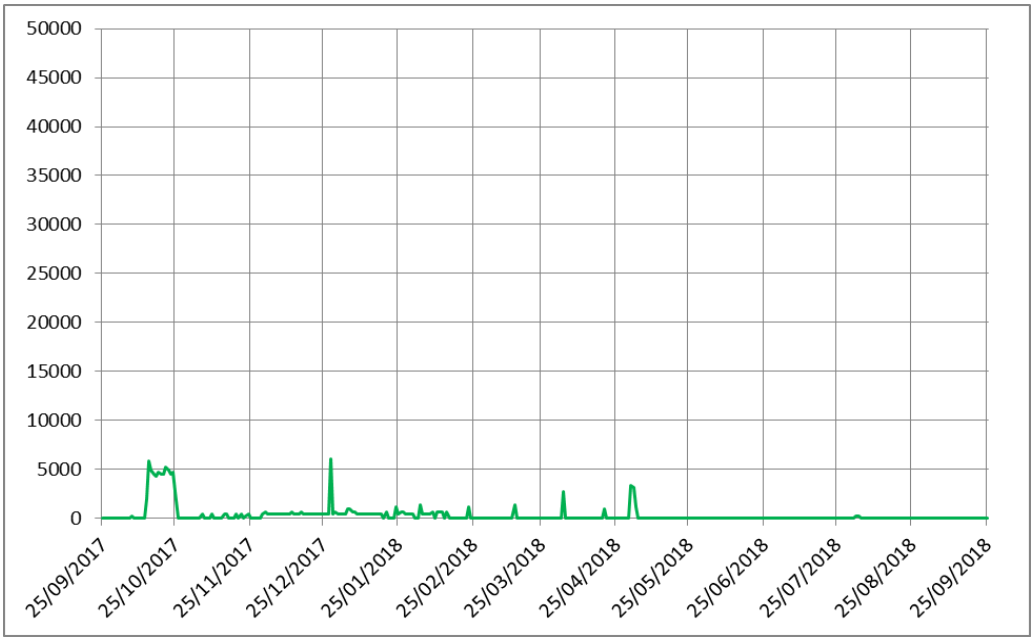


Figure 4.2.3b Somerton South Daily Discharge Volumes from pump 2 (m^3)

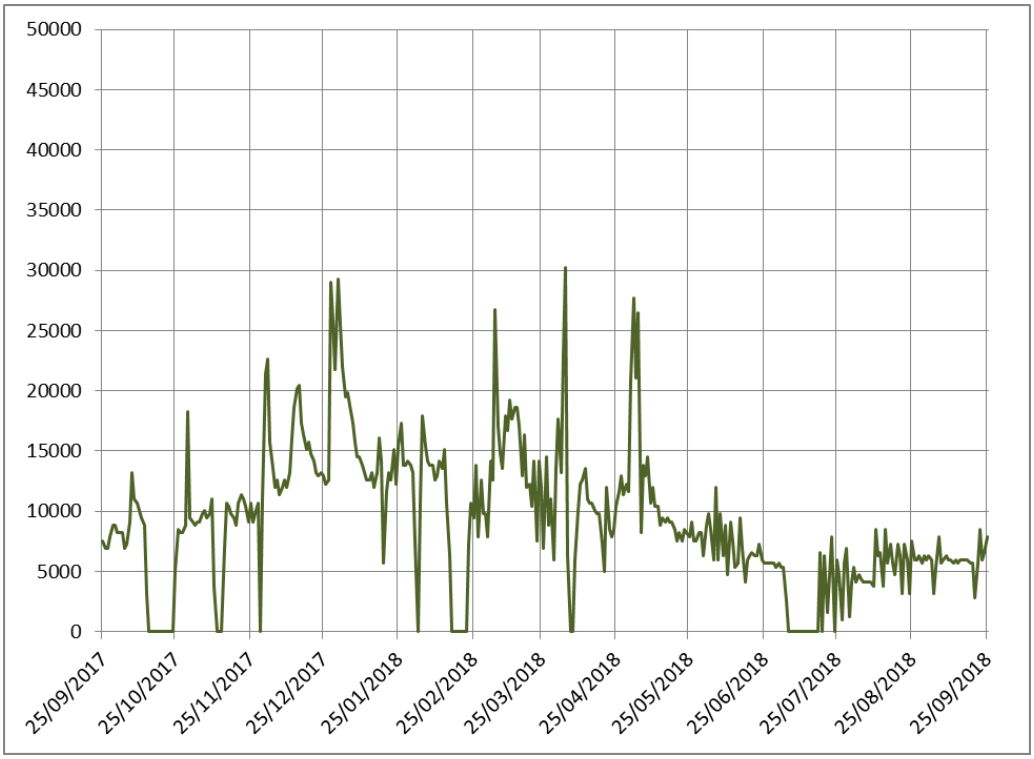
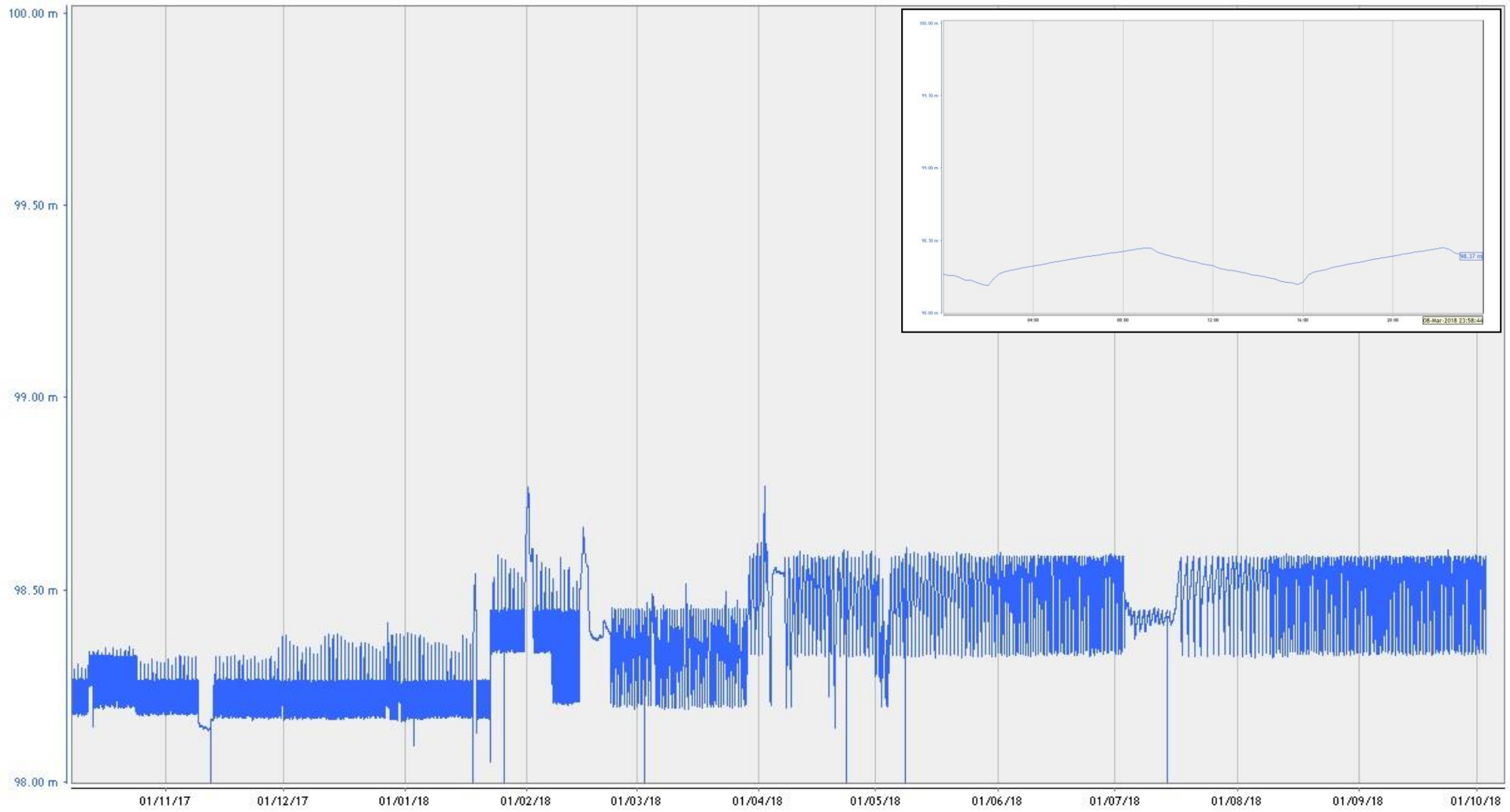


Figure 4.2.4 Water levels at South Pump from Oct 2017 to Oct 2018, with insert of fluctuation in water level during a single day (Broads IDB)



At a meeting, held at Somerton Village Hall on the 13th March 2013, all parties present including the Broads Drainage Board and the land agent representing the Burnley Hall Estate agreed that the current drainage operations at North and South pumps had worked satisfactorily over the past 12 months (R. Starling pers. comm.). At that time the water levels at Somerton South Pump main drain were set at a maximum of 98.6[1]m Old LMD and a minimum of 98.4m Old LMD on the gauge board giving a range of 0.2m. It was agreed that operating the South Pump within this range of levels keeps sediment discharge into the River Thurne at a minimum.

The 2013 WLMP states that water levels at Somerton North Pump (in 2012) were set at a maximum of 98.6m Old LMD and a minimum of 98.4m Old LMD. Again, it was agreed that this range kept sediment discharge from the North Pump into the Hundred Stream to a minimum. Ochre and salinity levels within the IDB main drain to the pump was still very high, whilst the Hundred Stream was very ochrous, especially during the summer months.

However, in April, 2013 a request was submitted to the Board to lower the dyke water levels in the north due to abnormally high rainfall in the preceding months, to allow access to farmland, which was granted. The WLMP review in 2013 reports that up until this point when the water levels were dropped the Norfolk Wildlife Trust had no issues at Martham Broads. However following the reduction in water levels they subsequently reported issues with ochre and saline water entering the dykes and the Broad. These events are often generally missed by the monthly water quality sampling data and make detection of cause and effect of water level management at Somerton particularly difficult. However it is noted that water levels across Somerton are now at levels comparable with, and in some cases lower than, those of the nearby Brograve and Hempstead catchments.

The 2013 WLMP Review reported that tenant farmers that harvest haylage had not been affected by the lowering of water levels within the catchment at that time, but that in terms of grazing; the water levels and water quality are not suitable for livestock, particularly during the summer months (J. Childs pers. comm.).

Since 2013, the Burnley Estate have expressed concerns that water levels within the ditches are not permitting sufficient flow of water off the fields. However, the recent water levels transect survey (OHES, 2018) suggests that in winter, the current water level regime provides approximately 3ft of freeboard between average ground elevation and ditch water levels. There are however, multiple exceptions to this, such as;

- On land adjacent to the Soke Drain (where low points can be as little as 25cm above the watertable)
- In the far east of the district where new water control structures have raised water levels as close as 15cm from the marsh surface (within the lowest points)
- In Decoy Wood, where the watertable was above the marsh surface in several places
- In the southern peat zone (where the water table could be as little as 50cm from the marsh surface)

[1] The IDBs use 100m as datum, which is 0.00m OD to avoid the use of negative signs.

- On Poors Trust land (where the watertable could be within 10cm of the surface where hollows occurred).

The in-field water table is typically, higher than ditch water levels in winter, but lower than ditch water levels in summer. This seasonal effect is regularly seen on slowly permeable soils, where summer evapotranspiration rates lower the in-field water table away from the influence of ditch water levels.

In October 2014, another meeting was held which revised the levels slightly at the South Pump to 98.5m maximum and 98.3m minimum Old LMD in winter. As the operation of the North and South pumps have the potential to effect water quality within Martham Broad and Winterton Dunes, an HRA was commissioned by the Broads IDB in 2018. It considered two scenarios;

A. That water levels are maintained at their current level (as decided at the 2014 meeting).

B. That water levels are lowered by approximately 0.5m, in order to assist arable farming in the area at the request of Burnley Hall Estate.

Communication and consultation between the different user groups within the catchment is key to achieving water levels that meets the requirements of all parties and protects Martham Broad and the other conservation sites. Thus as part of the HRA process, a consultation meeting was held on the 29th August 2018 with the stakeholders, which concluded that, in order to balance the demands of nature conservation, farming and residential assets, water levels should be maintained at the existing operating levels (scenario A). It was clarified that the Burnley Estate could continue to pursue applications for water level lowering in the future, but that they would need to support the application with additional evidence of detailed mitigation proposals, to prevent any further deterioration of water quality on the SSSI sites.

4.3 Impacts on Ecology

Over the past 4 decades there has been a large volume of data collected in relation to changing dyke water levels (through changes in land use) and their impacts on the local ecology, within the Somerton catchment, undertaken by Rob Driscoll et al.

In the past, due to the susceptibility of the soils to acidification, successive owners of the Burnley Hall estate have considered it prudent to maintain a high water table and manage most of the marshland as unimproved pasture (George 1994). In 1981 the drainage network in the catchment was improved by replacing most of the subsidiary dykes with plastic under-drainage pipes and the main drains re-profiled and deepened in readiness for arable production (Driscoll 1983). Ditch management in arable land was found to be detrimental to the aquatic plants and invertebrates, resulting in an impoverished community (Drake 2011). The likely damaging factors are low water levels at the bottom of deep ditches (leading to poor water quality, and narrow water width), frequent cleaning, increased deposition of iron oxides from peat soils, and the absence of edge disturbance by grazing animals (Drake 2011).

The lowering of water levels is also likely to cause peat shrinkage, which may in turn create a negative feedback system as water levels may need to be reduced further in order to maintain the required freeboard for arable production (George 1994). This has clearly been the case in some of the fields within the district, where shallow depressions are now evident due to peat shrinkage (OHES, 2018).

At both the South and North pumps, the larger pumps greatly increase the drains flow rates and, in effect, 'drag' bottom sediment from the main drains and connecting dykes to the pumps. This effect has been mitigated within the South Pump system by the installation of a variable speed pump, which allows water to be pumped for long periods at a lower rate. The North Pump does not currently have a variable speed option, though the effects of sediment suspension caused by high flow rates are somewhat mitigated by the presence of the settlement lagoons immediately downstream.

The HRA (OHES, 2018) provides detailed analysis of the impacts on ecology of the pump operation at Somerton and the potential effects of water level lowering. It concludes that Martham Broad, though currently considered in favourable condition, does indicate some areas of concern (particularly in relation to stonewort and other aquatic plant presence). It illustrates that individual stonewort species show considerable range in their tolerances to certain water quality parameters but much more limited ranges for optimal growth. It also demonstrates that, rather than a single variable causing a decline in a species, it can often be the combined effects of "double-stress" environments (such as turbidity and salinity) which can prove the most damaging. The outfalls from the Somerton Pumps have the potential to produce (and may already be creating) such double-stress environments.

4.4 Climate

Various studies investigating the extent of saline waters inland along the Norfolk coast have shown that rainfall and sea levels are critical variables in their intensity. Given the challenges which are likely occur in the future due to climate change, it is important to consider the wider implications of water level management within the Somerton District.

The Broads Climate Adaption Plan (2016) outlines the likely impacts of climate change and sea level rise within the Broads, and assesses potential adaption responses to protect the value of the area. It uses, amongst other sources, information gathered from an in-depth report commissioned by the BA in 2013. Under the high future emissions scenario (modelled for the coming 50 years) the Broads is likely to see:

- Hotter, drier summers with more cloud-free days and future average temperatures closer to current maximum temperatures, and possibly extreme rainfall events.
- Slightly wetter, warmer winters with rainfall in more intense bursts.
- Streams and the sea getting warmer, with associated changes in wildlife and water patterns.
- More extremes in the intensity and frequency of rainfall and storms, and possibly heatwaves and drought.

- Rising sea levels at rates much faster than just through isostatic recovery. This is because sea level is already rising due to land settlement, but as seas warm up it suggests that sea level will be at least 30-40cm higher, possibly over a metre higher by the end of the century. If climate 'tipping points' are reached, perhaps enabling critical amounts of polar ice to melt, sea levels could be much higher.

Detailed assessment was also carried out by Cranfield University (White, 2008) to investigate the likely future hydrological and hydraulic conditions in the Thurne catchment under a range of possible climate, land use and management scenarios. The study found that there is evidence of a higher background level of salinity at Repps when there is low flow and some pumping from upstream. Also that the pumping upstream of Repps can influence short peaks of salinity but high flows from the Ant/Bure system can block tidal ingress to Repps. It indicates that, when tidal incursion occurs, the brackish water from the pumps is less saline than from the incursion from downstream and therefore provides some downstream dilution. However, the pumps can cause higher background salinity in the Thurne during low flow periods, which is when water quality at Somerton is at its poorest (i.e. during summer).

This would suggest that less use of the pumps in summer, would be beneficial to Upper Thurne water quality, but caution should be used in reducing the use of the pumps in winter, when dilution of tidal incursions may be needed. However it is also important to note, as shown by the investigations of Hempstead, that higher water levels within the Somerton ditches are likely to reduce the draw of saline water into the system, which will be particularly important in the light of sea level rise. Lowering water levels within the Somerton ditches does not therefore appear to be a sustainable approach given climate change predictions.

4.5 Maintenance Responsibilities

Water Management Alliance (on behalf of the Broads IDB) is responsible for the North and South Somerton Pumps and the main drains and IDB water control structures. Other water control structures and infrastructure in the side dykes away from the main IDB drains (such as those on the Poor's Trust land) are the responsibility of the land owner. Occupiers are also responsible for management of non-IDB watercourses.

5. WATER QUALITY REVIEW

Ochre (and related acidification) and salinity are both issues within the Somerton Catchment in common with the majority of catchments along the east Norfolk coast. The two issues are independent of one another although the high salinity levels are one of the drivers of ochre production within some of the substrates. Both issues are summarised in the following section but are discussed in detail within the Habitat Regulations Assessment for Somerton (OHES, 2018).

5.1 Ochre

Ochre is formed by solids (precipitates) of iron (Fe), and is the result of a combination of soil, chemical and biological processes, where ferrous ion (Fe^{2+}) in solution is oxidised to form a precipitate of ferric oxides and hydroxides. This produces a reddening similar to rust.

The zone of new ochre formation is at the boundary between aerated and waterlogged soils. Therefore when drainage is significantly improved (to enable arable production) resulting in a reduction in level of the water table and the exposure of a large store of previously unavailable iron from the previously waterlogged soils; ochre is produced, resulting in an orange-brown staining in the water column (Harding and Smith 2002). Pyritic ochre is the typical form in the study area, as in the Brograve Catchment, as it is favoured in soils produced in marine environments, where high concentrations of iron and sulphur are laid down under anaerobic conditions (Harding and Smith 2002). Acidification and reducing conditions are two additional harmful "products" of the drainage process, which have their own environmental consequences (Harding and Smith 2002), which in turn are likely to impact plants, amphibians and invertebrates.

Research summarised by Bartlett (1961) shows that iron oxides deposited on the root surface and within root tissue can cause root cell division and growth to cease in several crops including garlic, leek, sunflower, alfalfa, pea and wheat.

Aquatic plants, attempting to grow in sediments covered in ochre or in waters where there are high concentrations of toxic ferrous iron face similar problems. Aquatic plants also face the problem of ochre solids in the water column. It is often present as a dense, glutinous and opaque sediment. Coatings of ochre on the leaves of aquatic plants reduce the light available for photosynthesis. Suspended ochre in the water can produce very high turbidity, further blocking out the light. As with toxicity, plants vary in their ability to tolerate this, so that progressively higher levels of ochre will result in progressively poorer aquatic plant communities (Harding and Smith 2002) and invertebrates (Driscoll, 1986).

It is suggested that for invertebrates, ochre sedimentation completely alters the nature of the stream bed habitat and also affects feeding and attachment mechanisms and can be directly ingested. Birds are unlikely to suffer direct toxicity or to be adversely affected by ochre precipitates, but will be severely affected indirectly, particularly by changes to aquatic plant communities brought about by turbidity. Water bodies with little or no aquatic vegetation support few waterfowl in winter, when birds depend upon plant material for food.

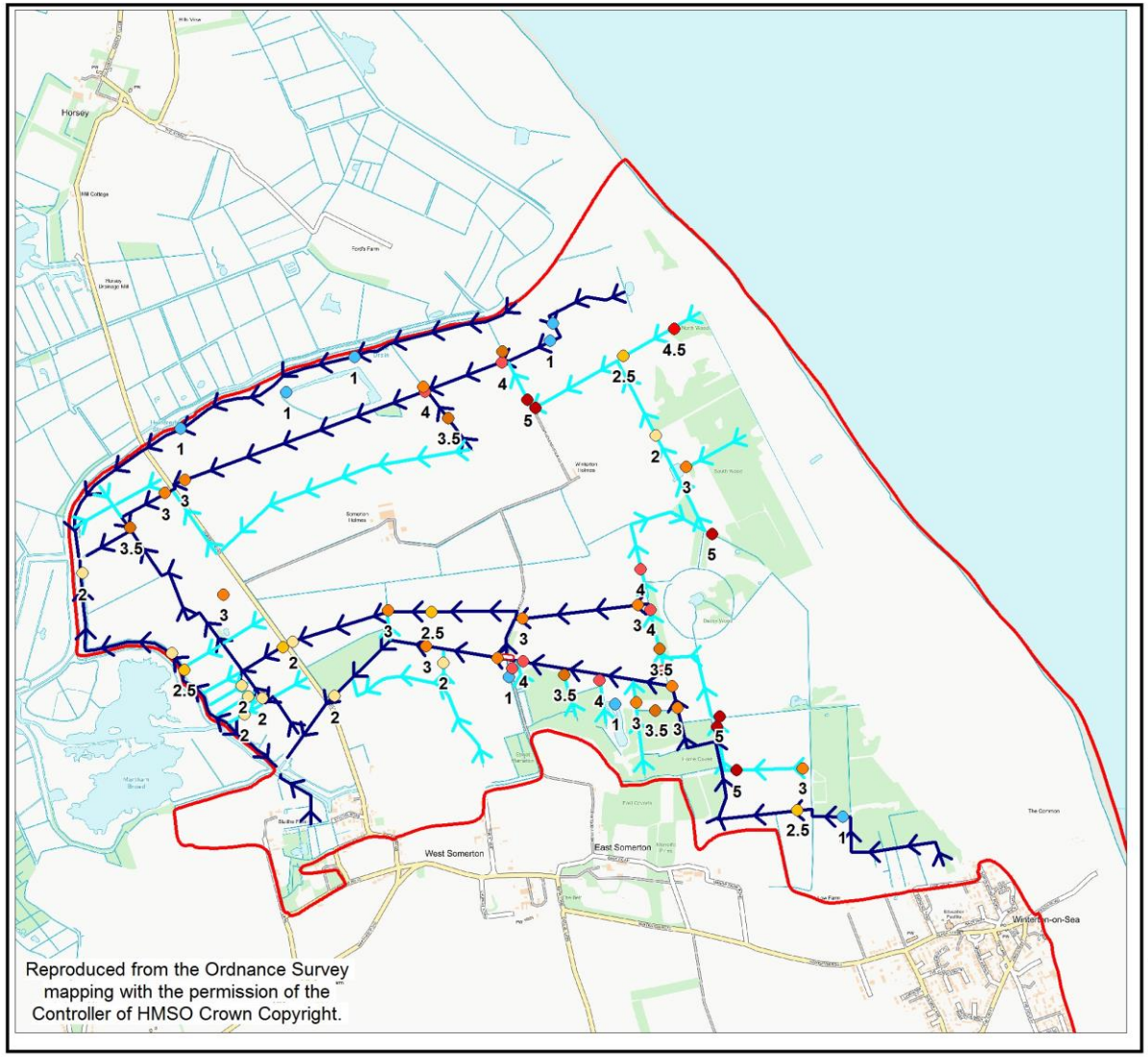


Figure 5.1 Ochre distribution across the site

Key:

1. No observable ochre.
2. Minimal observable ochre
3. Significant ochre
4. Dense suspended orange sediment
5. Bright orange sediment lying in a thick and continuous carpet

Drawn by: KLS Dated:12/07/18
OHES reference: 12265

The Somerton district has several soil types which are rich in iron and could be a source of ochre. Only very limited data on Iron concentrations within the North and South Pumps were available (for the period 1981 to 97). They show that prior to the installation of the second variable-flow pump at South Pump, Iron levels could exceed 7000µg/l at either pump. However the North Pump showed a higher average reading of 4560µg/l compared to 1370µg/l at the South Pump. As a guide, the Water Framework Directive target for Iron is 1000µg/l, which is the freshwater standard proposed to ensure whole lake communities are in good condition.

5.2 Salinity

Freshwater ditches are defined as having a conductivity of < 2,000 µS cm^{-1}. Conductivity readings of > 2,000 µS cm^{-1} indicate either brackish or highly polluted water. Brackish water conductivity readings typically range from c 2,000 to 15,000 µS cm^{-1} (Natural England).

Holman and Hiscock (1993) indicated that in the eastern Broads area, where the water table was below sea level through drainage pumps, dykes could cut into the salt water aquifer and become salinised if the dyke beds were not sealed or the inflow of fresh groundwater is more saline. Salinity levels can be increased further during the summer when evaporation rates are at their highest. This problem is enhanced in dykes with low water levels.

The work undertaken by Rob Driscoll et al. over the 4 decades has also investigated the influence of land use and water levels on the water quality of the dyke system. Prior to the deep drainage of the area in the early 1980's, when the land was pasture and the water levels relatively high, data indicates that the dykes were only slightly brackish (M. Driscoll pers. comm.). However, following changes in dyke water levels during the 1970's and 1980's due to conversion of land to arable, it was found that salinity levels were higher when water levels were lower due to increased seepage (Driscoll, 1986).

Conductivity readings were collected throughout the catchment by OHES in October 2013. They showed considerable variability in readings, with the majority of the low salinity levels (0 – 2000 µS/cm) within the southern marsh drains towards the southern boundary of the drainage district (Halcrow, 2013). However high readings (exceeding 10,000µS) were recorded in multiple ditches within the North Pump catchment, particularly along the western edge of Decoy wood and alongside Brackenbury Wall (exceeding 30,000µS). This coincides with where Zone 3 Peat soils abuts Zone 4 Coastal Barrier Sands and reflects conditions following drier conditions of summer.

Field readings were taken again in March 2018 as part of the HRA (see figure 5.2) demonstrate the considerably lower readings obtained during winter and early spring, following heavy rainfall. Most of the ditches within the South Pump catchment ranged from 550 (at the head of the system) to 2400µS (near the pump). Within the North Pump catchment, ditch conductivity was still found to exceed 6000µS even after heavy rainfall.

Groundwater conductivity readings (as shown in figure 5.2) tended to show a clearer picture, with high readings obtained in two key areas; namely the peat fields (where they lie adjacent to sands), and within the Zone 2 Alluvial deposits in the north-west of the district (ranging from 4000µS to 7000µS). Both areas coincide with evidence in the soil cores of sulphidic deposits (which increase with depth). All of the fields where high conductivities were recorded principally drain into the

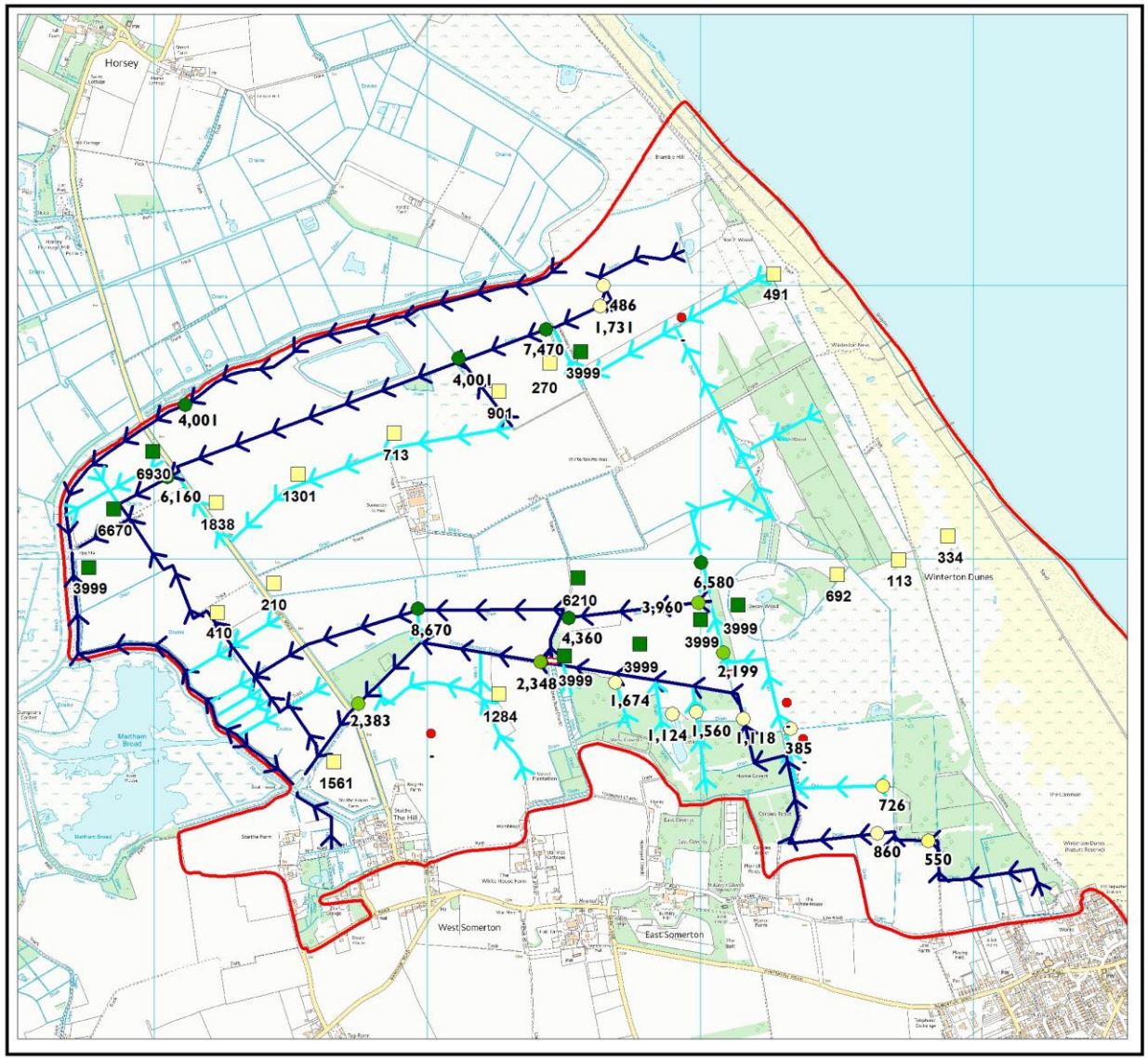


Figure 5.2 Conductiity readings across the site.

Key:

- Direction of flow
- Conductivity: surface water
- Conductivity: core water
- No data available

Drawn by: KLS Dated:06/07/18
OHES reference: 12265

North Pump system and therefore help to explain why Chloride levels with the South Pump are better than those seen in the North Pump.

As stated in the HRA, though many stoneworts can still withstand salinity at these levels, readings above 5,000µS will begin to affect growth rates and disadvantage certain species. Furthermore, other nationally rare freshwater species present at Martham Broad are expected to decline with increasing salinity. Halcrow (2013) also report that increased salinity in some of the Broads has caused algal blooms of *Prymnesium parvum* which produces a toxin that can be fatal to fish and some gill-breathing invertebrates.

Conductivity levels would therefore appear to be on the limit of what is acceptable to maintain the current ecological richness of Martham Broad.

5.3 Acidity

Acidity is an important factor in the ecology of this area as it influences all chemical and biological processes; such as phosphorus binding, availability of carbon for photosynthesis, chemical speciation and the development of toxic effects of pollutants (NERR, 2016). The aquatic communities found within Martham Broad have developed within neutral to calcareous conditions and therefore are likely to be highly disadvantaged by an increase in acidity.

Acidity levels within the ditches and groundwater were taken as part of the HRA. It showed surface water readings within the ditches were typically between pH 6.5 to 7.7, and were therefore of acceptable quality for both farming and ecology. In contrast, groundwater readings show a very different picture, with groundwater along the coastal strip typically between pH 4 to 5.4. Readings were also extremely low within some of Zone 3 Peat soils (readings as low as pH 3.95) and this is believed to be the consequence of oxidation of sulphidic deposits (i.e. resulting in sulphidic acid) along the eastern strip of the district. The absence of such acidic conditions within the neighbouring ditches is explained by several factors including:

- The ineffective drainage of many of the peat fields at present which impedes acidic groundwater from reaching the ditches (due to historic in-field drainage being both below current water levels and also in many cases blocked).
- The low permeability of the clay and peat soils.
- The dilution provided by rainwater and spring water elsewhere in the district.

Environment Agency data illustrates that pH conditions are generally around neutral in both pumps (averaging 7.27 in the North Pump and 7.41 in the South Pump since 2000) and are therefore at acceptable levels.

5.4 Suspended Solids

Suspended solids is a useful as an indicator of water clarity and the availability of light but also can often be linked to the availability of other variables such as Phosphorus (for example, where soil erosion has occurred within arable fields has entered the ditch system). At Somerton, it would also be expected to reflect the degree to which ochre is passing through the system. It is particularly relevant because Stoneworts are less adapted to turbid waters than flowering plants, and many other groups of species can be disadvantaged by receiving deposits of fine sediment.

The only Suspended Solids (SS) data available for the area was EA monthly readings from the pumps and Martham Broad. Both pumps show considerable variation in SS content, with peaks at any time of year, though typically during summer months. Since the installation of the second (variable speed) pump at Somerton South, suspended solids have not exceeded 20mg/l. In contrast, the range recorded at North pump since 2010 is 5 to 90mg/l (averaging 11.6mg/l).

As flow decreases, solids will then be able to drop out of suspension to form new lake sediment or coat aquatic plants. The presence of the linear settlement lagoons within the Hundred Stream immediately downstream of Somerton North Pump, and the installation of the variable speed pump at Somerton South will considerably reduce the extent to which SS can enter Martham Broad from the Somerton District. However, reports of plumes of SS reaching the Broad still occur (R. Starling pers comm.).

5.5 Phosphorus

Phosphorus (P) levels can have a degrading effect on water plant communities and is one of the key parameters used to assess the condition of a water body under the Water Framework Directive. Though Phosphorus does not necessarily have a direct connection with water level management at Somerton, there is an indirect link which is important to consider.

Martham Broad is one of the few broads which is on the limit of achieving its TP (Total Phosphorus[2]) target currently, and work is already planned to resolve nutrient enrichment within the Upper Thurne DWP Plan. Environment Agency data on TP levels clearly show the extent to which water exiting Somerton via the North Pump is enriched and exceeds the TP target for Martham Broad of 0.03mg/l. It is noted that agriculture will not be the sole source of nutrient entering the broads, with other contributions from human waste, soil mobilisation, internal nutrient release and bird guano, and no information was available on the relative proportions of nutrient from each source.

TP levels at the Somerton Pumps are all above the lake target, with average TP value since 2010 at North Pump of 0.064mg/l and at South Pump of 0.042mg/l. However it is noted that both the variable-flow pump at Somerton South Pump, and the settlement lagoons downstream of Somerton North Pump should help to reduce the concentrations of TP reaching Martham Broad.

[2] The sum of all phosphorus compounds (including both orthophosphate and the phosphorus in plant and animal fragments suspended in water)

6. WATER LEVEL AND WATER QUALITY MANAGEMENT OBJECTIVES

6.1 Water Level Management Objectives and Recommendations

This section defines the water level management regime for the Somerton North and South Districts, as agreed at the August 2018 stakeholder meeting (i.e. maintain water levels at their existing elevation). The levels shown below relate to the roadside gaugeboards for the North and South Pumps.

	Winter range (1st Oct. to 21st March)			***Summer range*** (21st March to 1st Oct.)		
	Old LMD	Corrected LMD	Corrected mBOD	Old LMD	Corrected LMD	Corrected mBOD
North Pump Road Gaugeboard	98.45 to 98.25	98.30 to 98.10	-1.70 to -1.9	98.50 to 98.30	98.35 to 98.15	-1.65 to -1.85
South Pump Road Gaugeboard	98.50 to 98.30	98.45 to 98.25	-1.55 to -1.75	98.60 to 98.40	98.55 to 98.35	-1.45 to -1.65

The Habitats Regulations Assessment of this water level regime concluded that under the current water level regime, there are four key areas which would benefit from mitigation in order to ensure the conservation objectives of the designated sites can be met. These could include (see figure 6.1):

- *Replacement of the north pump with a variable flow pump or extending the settlement lagoons* This would reduce the turbidity of water moving into the Hundred Stream, as was found to be the case after the South Pump installation. It would need to be compatible with the requirements of eel migration.

- *Raising of water levels (by approximately 0.65m within the northern Zone 3 Peat soils:* Poor water quality can be mitigated by retaining a higher water level of around -0.90m BOD (below Ordnance Datum) at Points A and B, which would allow more peat to remain saturated while still allowing a small amount of freeboard for use as grazing land. At this level, there should be sufficient drop in water table from the dune slacks that the raised water level will not negatively affect them. However monitoring should be put in place to confirm this.

- *Raising of water levels by 0.3 to 0.4m within the southern Zone 3 Peat soils*: Raising the water level at the eastern side of Honeypot Lane (see Point C and D) to a new level of -1.2mBOD would reduce further impact of poor water quality. However, this will increase the chances of surface flooding so would be incompatible with arable land use. Raising the watertable to this level should have only a slight effect on arable fields around cores 25 and 26 because they currently have a ditch water level in winter of -1.0mBOD (i.e. above the proposed new water retention level). It will however be important to ensure water from these fields continues to flow towards the North Pump and therefore any field drains which feed from these fields into the Commissioners Drain would need to be blocked.

- *Returning summer water levels at the South Pump to 2013 regime*: In 2013, agreed summer water levels were 10cm higher in Somerton South than they are currently (i.e. they were 98.6 to 98.40 using old gaugeboards or 98.55 to 98.35 using new gaugeboards). This previous level ensures less chance of poor water quality entering the Commissioners Drain.

A further option queried by NE is the use of the good water quality within the northern Soke Drain to feed the South Broad. In practical terms, the distance involved in re-routing this water supply to the South Pump may be prohibitive (though there would be some ecological benefit). However, it is conceivable that this water could partially be retained in a new waterbody for the purposes of feeding the dune slacks during summer months (which currently need to be topped up by NNR staff during dry months).

It is recognised that these mitigation measures will not facilitate arable production in the district, and will in some places increase the likelihood of surface flooding. This could to some degree be ameliorated by continuing to install footdrains in the north-west of the site, which would reduce surface water ponding without risking excessive reductions in water quality (especially if water quality is improved within Zone 3 Peat soils by raising water levels).

6.2 Summary of Recommendations

As parts of the district showed some evidence of impacting conservation objectives at Martham Broad and the Upper Thurne (being classed as borderline impact in two areas), under the precautionary principle it is recommended that further measures are taken to improve water quality, including:

- Restore Somerton South to 2013 summer water levels
- Do not install additional footdrains into areas of poor groundwater quality unless additional monitoring can show this is safe to do so.
- Replace the North Pump with a variable-speed pump (or similar) which would allow lower flow rates to reduce suspended sediment and ochre transport.
- To track the effects of peat shrinkage, install a shrinkage pile at Point E on Figure 6.1.
- Consider raising water levels within peat fields to the east of the catchment. However, as there is some uncertainly regarding groundwater movement any such increase should be undertaken gradually and monitored closely.

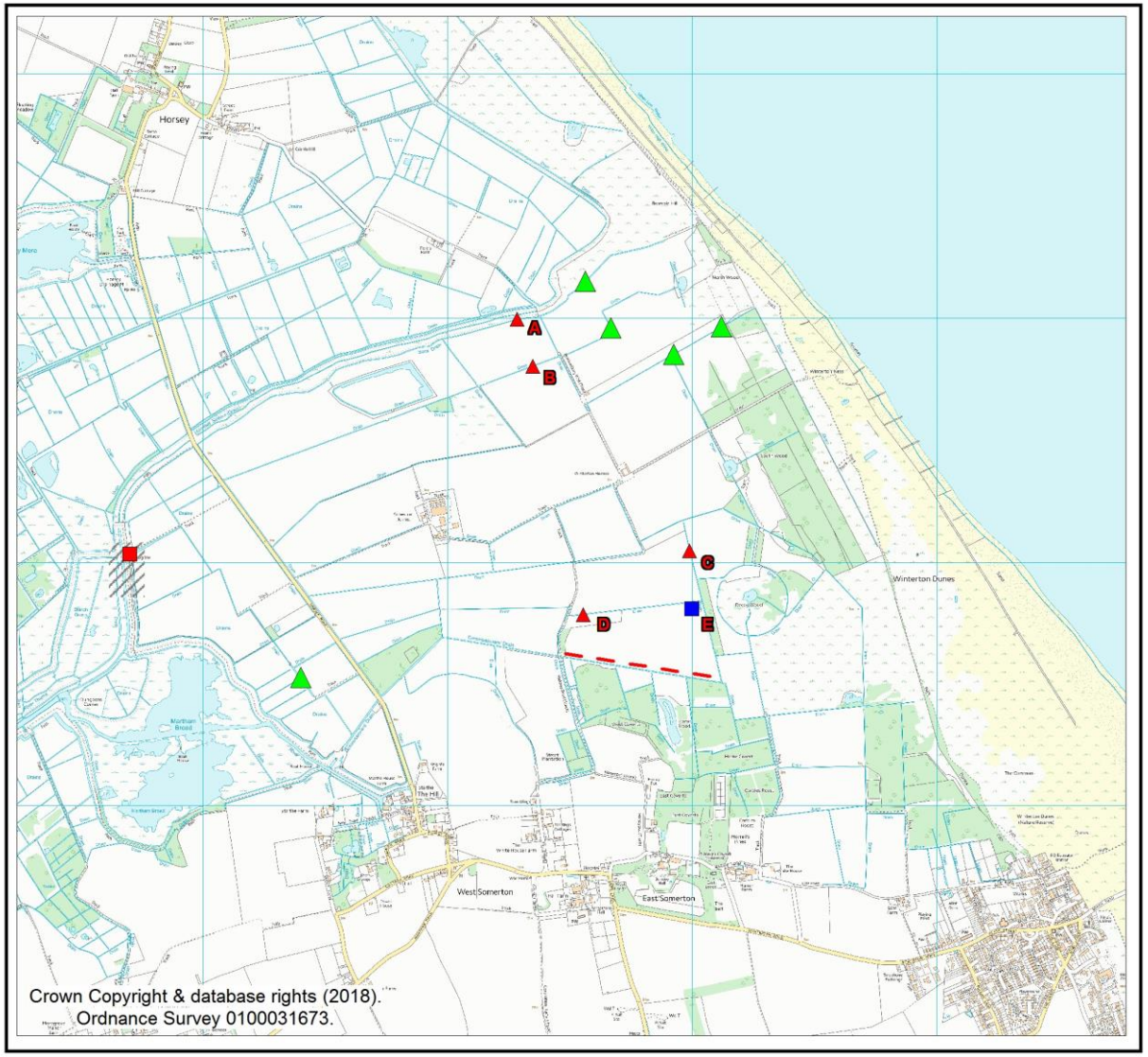


Figure 6.1 Potential mitigation measures for current water levels

Key:

- Possible new sluice
- Existing sluice
- Possible replacement pump
- Potential extention of lagoons
- Blocking of any footdrains
- Shrinkage pile

Drawn by: KLS Dated:22/07/18
OHES reference: 12265

7. CONSTRAINTS AND IMPACTS ON ADJACENT GROUND

7.1 Constraints

The IDB are obliged to ensure that their activities do not have a significant effect on the special features at the site. The Habitat Regulations Assessment (HRA) undertaken in 2018 ensures a suitable level of assessment has been conducted of impacts of maintaining the existing water levels at the North and South Pumps on the SSSI and SAC features. The HRA clearly states that lowering of ditch water levels within Somerton is not advisable using the current data available.

Any raising of water levels, such as those put forward within the HRA mitigation measures, will need to ensure assets such as residential houses, commercial buildings and roads are protected from impact. This has not been fully assessed at the current time.

7.2 Impacts on Adjacent Ground

In the case of Martham Broad, the River Thurne and the Winterton Dunes the Board must fulfil their legal responsibilities under the Habitats Directive and ensure that these sites are protected. Due to the impacts of water levels for one land use on those of another land use within the catchment, compliance with Habitat Regulations may not allow a compromise to be reached.

The balance between agriculture and conservation is key, however, the current water quality situation means that it would not be feasible to lower the water levels in the District to the requested level suitable for improved arable production due to the impacts on the European protected sites.

8. ALTERATIONS TO INFRASTRUCTURE AND PROCEDURES

Operating levels of IDB sluices would remain the same as it is not proposed to lower the water levels of the dykes within the catchment from their current levels. It is also proposed that the operating levels of the water control structures on the Poor's Trust land are kept as they are to allow their conservation objective to be maintained.

Further investigation will need to take place on the feasibility of replacing the North Pump with a variable flow pump, which will also need to consider the requirements of eel migration. Similarly, any installation of new sluices within the Zone 3 peatlands would need to be approached cautiously to avoid unwanted effects on water quality. Therefore any plans to install new (or modify existing) water control structures or install new under-field drainage by landowners within the Somerton District should be checked for approval by the Broads IDB before installation.

It is understood that the IDB have applied to take over the management of the settlement lagoons downstream of the North Pump. Also that the IDB are conducting investigations on the rate of sedimentation within these lagoons. Once this data is available, it should be used to ensure maintenance is undertaken sufficiently regularly to keep the lagoons at optimum effectiveness. This is likely to be through maintaining a mixture of open waterbodies and reed dominated areas for additional filtration.

Following the success of recent ditch dredging techniques in minimising sediment transport, such methods should become standard protocol within the district.

9. OTHER PROPOSED ACTION

9.1 Monitoring

Now that new gaugeboards have been calibrated to Ordnance Datum, it is suggested that moving across to this system rather than Local Marsh Datum would provide easier analysis of levels against not only topographic data but also borehole and surface water data from elsewhere in the Upper Thurne Catchment. Levels from these gaugeboards should be recorded at least monthly, in addition to which half yearly readings of the shrinkage pile should also be undertaken.

Water quality will need to continue to be monitored at both Pumps and within Martham Broad (by the EA) and within the Winterton Dune slacks (by NNR staff). It would also be beneficial to spot test the concentrations of other heavy metals (such as Copper and Manganese) present at the pumps and the broad, to check if they too are over acceptable limits on ecological grounds. Ideally, dataloggers set on the pumps to monitor conductivity and suspended solids would provide valuable information on the levels entering the River Thurne and broads. However, this may be impractical due to the problematic nature of calibrating and maintaining such equipment in ochrous environments.

It is understood that the Burnley Estate have also started regular water quality sampling within the ditches but it this was not available for analysis under the HRA.

9.2 Further Investigations

As discussed within the HRA, the stakeholder meeting held on the 29th August concluded that, under the current circumstances, water levels should be maintained at the existing operating levels. The board proposed that, if the Burnley Estate wished to pursue applications for water level lowering in the future, they would need to support the application with additional evidence of detailed mitigation proposals, to prevent any further deterioration of water quality on the SSSI sites. However it was stated that such additional investigations could not be funded by the board.

10. BIBLIOGRAPHY

Barringer J.C. (1975) Faden's map of Norfolk. Norfolk Record Society. Booklet and 6 maps in slipcase (Vol 42).

Bartlett, R.J. (1961) Iron oxidation proximate to plant roots. *Soil Science*, v.92 pp 372-379.

Broads Climate Partnership (2016). Broads Climate Adaption Plan 2016. Norwich.

Drake, M (2011). Upper Thurne grazing marsh ditches: An analysis of data on aquatic flora and fauna, 1973 to 2009. Buglife, Norfolk Biodiversity Partnership.

Drake, C.M., Stewart, N.F., Palmer, M.A. and Kindemba, V.L (2010). The ecological status of ditch systems. An investigation into the current status of the aquatic invertebrate and plant communities of grazing marsh ditch systems in England and Wales. Technical Report Volume 1. Summary of methods and major findings Buglife.

Driscoll, R.J. (1983). Broadland Dykes: The loss of an important wildlife habitat. Trans. Norfolk Norwich Nat. Soc. **26** (3) 170 – 172.

Driscoll, R.J. (1986). The effect of changes in land management on the dyke fauna at Somerton and Winterton. Trans. Norfolk Norwich Nat. Soc. **27** (3) 215 – 220.

George, M (1994). The land use, ecology and conservation of Broadland.

Halcrow, (2013). Somerton Level Water Management Review: Hydro-ecological Desk Study. Water Management Alliance: Kings Lynn.

Harding, M and Smith, K (2002). Ochre in the Brograve catchment, causes and cures.

Holman, I, P., Hiscock, K, M (1998). Land drainage and saline intrusion in the coastal marshes of northeast Norfolk. Quarterly Journal of Engineering Geology and Hydrogeology, 31, 47-62.

OHES (2013). Somerton Water Level Management Plan Review. Broads IDB, Kings Lynn.

OHES (2018). Somerton Water Level Review and Habitats Regulations Assessment. Broads IDB, Kings Lynn.

Simpson, T., Holman, I.P. and Rushton, K (2011). Drainage ditch–aquifer interaction with special reference to surface water salinity in the Thurne catchment, Norfolk, UK. Water and Environment Journal, 25 (1), 116-128

Stewart, N.F. (2004). Important Stonewort Areas: an assessment of the best areas for stoneworts in the United Kingdom (summary). Plantlife International, Salisbury, UK.

Water Management Alliance (2018). Somerton Catchment Gauge Board Review. Unpublished.
Wells. F and The Burnley Group Partnership (2013). The Somerton Catchment Potential Ochre Settlement Project. Meeting notes.