HOLME-NEXT-THE-SEA

NEIGHBOURHOOD PLAN 2016-2036

WATER QUALITY REPORT

Evidence Base: Research Report

20 March 2017 (**Updated** 20/12/2017; 14/2/2018; 03/06/2018; 31/01/2019; **16/04/2019**)

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1 WATER QUALITY IN THE RIVER HUN CATCHMENT

1.1 Background

1.1.1 Holme-next-the-Sea lies entirely within the North Norfolk Coast AONB and more than 40 per-cent of the Parish is covered by Protected Sites. At the heart of these sites lies the River Hun, one of a small number of rare chalk streams which should provide a unique habitat for wildlife. The entire Parish lies within the catchment of the River alongside parts of Old Hunstanton and Hunstanton.

1.1.2 The river rises in springs to the south-east of Hunstanton and flows north and then eastwards through Holme Dunes National Nature Reserve to reach the sea via a sluice at Thornham Sea Bank. The lower reaches pass through an area of international importance for nature conservation with Ramsar, SAC, SPA and SSSI designations.

1.1.3 By virtue of the habitat which they provide these sites represent a vital hub in the Natura 2000 international network for conservation of migrating birds. In addition they have become an AONB hot spot for visitors looking to experience the unspoiled landscapes and wildlife they support.

1.1.4 The ecosystem services these sites provide are the main pillar of the local economy and both local people and visitors place enormous value on these parish assets. They are however coming under increasing pressure from growth in visitor numbers, associated car traffic and increases in county-wide development. Their future is threatened by Climate Change and the East Coast Shoreline Management Plan envisages that they will suffer significant damage as a result of Sea Level Rise. This could happen within the lifetime of the Neighbourhood Development Plan (NDP)

1.1.5 In response to a questionnaire survey carried out in 2016 in conjunction with work on the NDP, more than 80% of respondents expressed concern over damage to the local environment from inappropriate development. 85% of respondents supported positive environmental management to improve habitats and the Parish environment.

1.1.6 Effective conservation of the Protected Sites is clearly dependent on development that takes place within the catchment of the River Hun.

1.1.7 In response to the consultation survey and to reports of pollution and declining observations of wildlife in The Hun, the NDP team decided it was necessary to follow up these concerns to provide a sound basis for the policies being created for the NDP.

1.1.8 This decision coincided with an approach to the Parish Council by the Norfolk Coast Partnership (NCP) who, working with the Norfolk Rivers Trust (NRT), have been successful in establishing improvement programmes for other chalk streams in Norfolk and wanted to explore likely levels of support for a programme of improvements to the Hun.

1.1.9 The Parish Council (PC) indicated informally that they would support improvements to The Hun, subject to establishing that changes to the river would not impact negatively on the Protected Sites or any risk of flooding. This further underlined the need for investigation.

1.1.10 In spring 2017 sightings of a persistent algal bloom on Broadwater Lagoon (Figure 1) gave rise to further concerns about pollution of water bodies in the Parish. Some preliminary monitoring of water quality in both the River and the lagoon was undertaken using test kits

supplied by The Freshwater Habitats Trust. The initial results were reviewed with the NRT and in view of the findings it was agreed that it would be important to carry out more detailed investigations via a more extensive project to examine water quality and its likely impact on wildlife/environmental health.

1.1.11 In order to establish priorities for the project and to begin addressing the pollution issues, the NCP, NRT and the Parish Council (via the NDP Team) agreed to work together on a programme of water quality monitoring spanning the period from May through to December. NRT agreed to fund a demonstration / training exercise followed by a further 6 months of structured water sampling based on four sites in the Hun Catchment and one on Broadwater Lagoon.

Figure 1: Broadwater Lagoon – exhibiting a strong algal bloom first seen in May 2017. The bloom has persisted and at times is associated with a strong, unpleasant odour.

2 INTRODUCTION

2.1.1 After the first three months of water quality monitoring sufficient data had been collected to identify the main issues likely to emerge from the study. An interim report was written setting out the main findings and their implications for the environment. This report is included as Appendix 1 to this document.

2.1.2 After completion of the full, 7 month programme of sampling the main conclusions remain largely unchanged – but obviously they are supported by a stronger, underpinning set of data.

2.1.3 Appendix 1 also explains how the data has been collected and used in detail, how critical thresholds have been identified and used to evaluate quality and what the main implications are in terms of wildlife and biodiversity.

2.1.4 Rather than simply repeat this material this report will present a non-technical description of the main findings and their implications for the catchment moving forward based on the consolidated data that has now been collected.

3 COLLECTION AND PROCESSING OF DATA

3.1.1 Water samples were collected by members of the NDP team taking precautions to ensure that all equipment used was free of contamination from external sources or cross contamination between collection sites. Samples were carefully labelled and sent by courier to the Environment Agency for accredited laboratory processing on the same day as they were collected to ensure no deterioration.

3.1.2 Four sample sites were located on the River Hun itself with the aim of getting a representative picture of its entire length while at the same time picking up pollution from potential entry points. A fifth was located at the end of a small pier in Broadwater Lagoon (see Figure 2).

3.1.3 For each set of samples River Stage was checked using a depth stick located at the Beach Road sampling station. Although one set of samples was collected during heavy rainfall there were no extremes of flow observed suggesting that measurements were representative of typical conditions in the river. It should be noted however, that flows at Hunstanton Park were extremely variable and on one occasion the river was virtually dry.

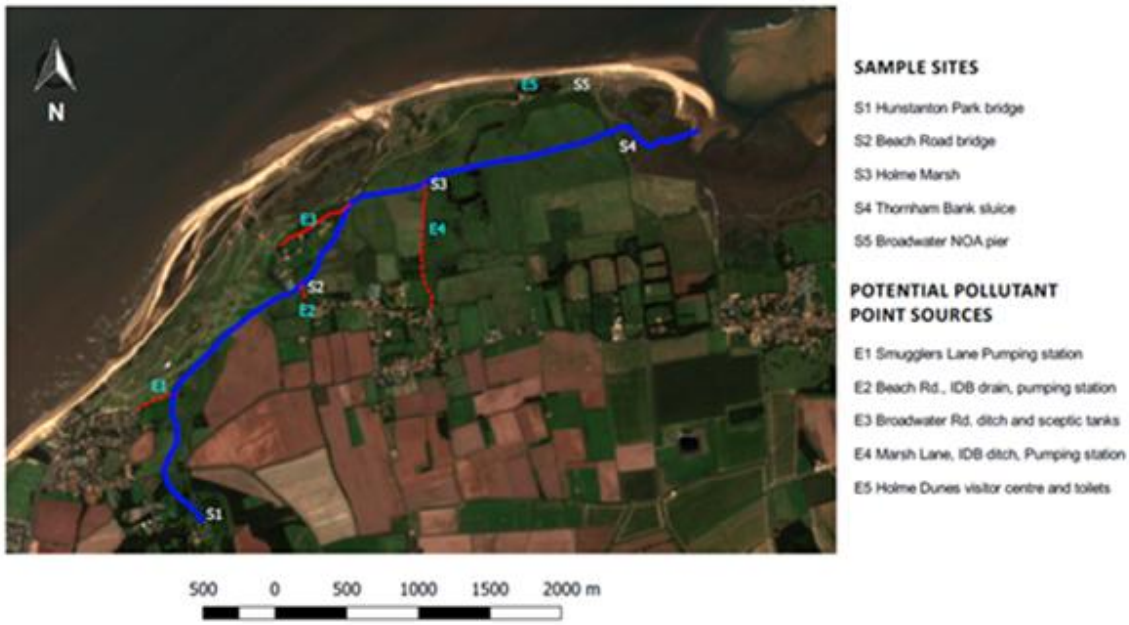

Figure 2: Location of catchment and sampling sites. These are labelled S1-S5 in white. Their locations have been selected to reveal as much information about the catchment as possible in relation to possible point source locations for pollutants which are shown in blue and labelled E1-E5.

3.1.4 Data collected covered just the basic chemistry of the river with regard to phosphorus and Nitrogen. Ideally there would have been more sample sites and a wider range of variables monitored but this was beyond the resources available. This meant that no data was collected for sediments, dissolved oxygen, bacteria or invertebrates. However, it has been

clear for many years that the River is devoid of fish, choked with sediment and probably very limited in aquatic life.

3.1.5 After two months of data had been examined it became clear that the site in Hunstanton Park and the site on the lagoon had high levels of ammonium so steps were taken to incorporate temperature and pH into the monitoring scheme. This in turn opened up the possibility of recording turbidity and electrical conductivity for the same budget.

3.1.6 This meant that for the samples where these observations were available it was possible to calculate ammonia concentrations. All variables were measured for the last three months of sampling.

3.1.7 Laboratory results were consolidated into Excel spreadsheets for checking, harmonisation of units and subsequent analysis. The draft report in Appendix 1 contains examples showing the first three months data.

3.1.8 Table 1 below shows mean values for all of the pollutants measured. Generally these are based on seven months of observations with two exceptions. Firstly, ammonia was available for four months at Broadwater Lagoon and three months in Hunstanton Park. Secondly, pH, conductivity and turbidity were measured for the last five months of the sequence.

3.1.9 This variability in recording was taken into account when calculating mean values. The mean value was selected to summarise the observations on the grounds that generally values were similar month on month. With a maximum of seven observations spanning only part of a year, no suggestion is made that the value has any statistical significance.

3.1.10 Chlorophyll was measured for just the first and last month in the series at Broadwater Lagoon to try and learn more about the algal bloom. The figure in Table 1 is thus the average of just two, excessively high values.

4 SUMMARY OF MAIN FINDINGS

4.1.1 The observations fall into three distinct categories, each with a very different chemistry. These are (1) Hunstanton Park, (2) the remainder of the River Hun and (3) Broadwater Lagoon.

(i) Hunstanton Park

4.1.2 Hunstanton Park is the only site that shows very high variability in the measurements over the seven months of recording so care is needed in interpretation of mean values. However, Phosphorus (Total as P) is consistently high for the entire period and exceeds recognised limits. Total nitrogen levels tend to be low and well within accepted limits but Nitrite concentrations are more variable and on occasions exceed accepted limits.

4.1.3 As nitrite is a relatively transient stage in the conversion of Ammonia to Nitrate this suggests there is a fairly constant supply of Ammonia at the site.

4.1.4 The very high mean for Ammonia is heavily skewed by one extreme observation of 127 ug/l for November 2018. This coincided with the river virtually drying up at this sample point despite significant rainfall in previous weeks.

4.1.5 The river bed and banks at this point have large amounts of sediment/sludge which probably contains decaying organic material. The site is also adjacent to a patch of deciduous woodland so decaying leaves may in part explain levels of ammonia and nitrite.

RIVER HUN CATCHMENT: WATER QUALITY ANALYSIS (JUNE 2017 TO JANUARY 2018)

TABLE 1: *SUMMARY OF OBSERVATIONS*

	Phosphorus : Total as P	Orthophosphate, reactive as P	Ammoniacal Nitrogen as N	Ammonia	Nitrogen : Total Oxidised as N	Nitrite as N	Nitrate as N	Chlorophyll, Acetone Extract	ph	Turbidity	Conductivity	Temp
	mg/l	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l	ug/l	pH units	FTU	uS/cm	deg C
Hunstanton Park	0.59	0.50	1.60	48.92	1.60	0.03	1.57		7.73	3.90	548.00	12.50
Beach Road Bridge	0.03	0.02	0.01	0.00	15.23	0.02	15.23		7.70	2.58	825.40	10.50
Broadwater Lagoon	0.40	0.00	0.40	17.58	0.00	0.00	0.00	195.80	8.19	19.08	19686.00	13.19
Thornham Bank Sluice	0.03	0.01	0.03	0.00	13.84	0.02	13.84		7.84	2.72	978.60	11.25
Holme Marsh	0.03	0.02	0.02	0.00	15.03	0.02	15.03		7.81	3.10	839.20	11.33
Limit (Fresh Water)	0.09		0.30	15.00		0.01	11.30	50.00				
Limit (Salt water)	0.035			21.00								

Notes:

1. The table shows mean values for the variables measured

2. The mean for Chlorophyll is based on just 2 observations (80.6, 311) taken at the start and end of the observation period

3. The means for Phosphorus, Orthophosphate, Ammoniacal nitrogen, Nitrate and Nitrite are based on 7 observations covering the entire observation period.

4. Measurement of ph, Turbidity and Conductivity were only made for the last 5 months of the period and the means have been adjusted accordingly.

5. Reliable temperature measurements were possible for the last four months at Broadwater Lagoon and 3 months for all other sites - the means have been adjusted accordingly. The measurements for Ammonia are based on these adjusted mean values.

The low levels of nitrate are more difficult to explain but maybe related to very low levels of dissolved oxygen in the water which is barely moving.

4.1.6 This site is very close to the source of the Hun which originally would have been supplied by freshwater springs. However, the headwaters are heavily modified and inputs come from at least one substantial surface water drain originating in Hunstanton and wastewater from local houses in the park. The river channel also appears to form part of the moat around Old Hunstanton Hall.

4.1.7 A further explanation for variability of observations here and the very high level of ammonium could well be a decline in water from natural springs causing relatively increased concentrations of waste water and accumulation of organic material in sludge. Breakdown of this material would quite likely result in bad odours and it is interesting to note that a large volume of sludge has been excavated from the channel just upstream of the site in mid winter 2018/19.

ii) The main river channel –Beach Road Bridge to Thornham Sluice

4.1.8 All three of the stations along this stretch of the river show a very stable pattern of observations. Levels of Phosphorus are very low and ammonia is virtually undetectable but levels of nitrate are high. Nitrite is also detectable at levels which exceed recognised limits.

4.1.9 All of these stations are below two known pollutant sources – the overflow outfall from Smugglers Lane pumping station and the ditch to the north of the houses along Broadwater Road (E3 in Figure 2). The status of the IDB ditches, also shown in Figure 2 is unknown but there is local concern about pollution in both.

4.1.10 The observed levels of nitrate in themselves would be sufficiently high over long periods to account for lack of fish characteristic of chalk streams – especially trout. In combination with nitrates and high levels of sediment/sludge they would account for the lack of visible aquatic organisms in the river. The ditch linking the outfall from Smugglers Lane to the river is heavily choked with vegetation reflecting the very high levels of nutrients available.

4.1.11 It is suspected that the nitrites are the result of decaying, organic material from sediments and sludge carried by the river.

4.1.12 There are many obvious potential sources for the levels of nitrate in the river. These include fertilisers used on surrounding arable land, Smugglers Land, sceptic tanks, wild and domestic animal waste and road traffic.

4.1.13 The observed levels are over Water Framework Directive targets and are not consistent with those required to maintain good environmental status in the Ramsar/SAC/SPA/SSSI Protected Sites.

iii) Broadwater Lagoon

4.1.14 Broadwater Lagoon is a qualifying feature within the Special Area of Conservation and it was concerns over its persistent algal bloom that prompted this study.

4.1.15 Just two tests of Chlorophyll were made at the start and end of the 7 month study period to try and asses its intensity. The level increased from 80.6 ug/l at the start of the period to 311 ug/l at the end. Both are very much higher than accepted limits for a lake of this type.

4.1.16 With the exception of one reading in August conductivity readings were on average around 20,000 MicroSiemens. This reflects very high concentrations of nutrients in the water supporting the algal bloom. Filamentous algae in the water samples also contribute to high turbidity readings (20 FTU on average).

4.1.17 The main chemical nutrient found was phosphorus which had an average concentration of 0.4 mg/l – substantially above recognised limits for a water body of this type. Ammonia concentrations were also found to be high and at the pH levels recorded would have been present in damaging quantities of un-ionised NH_3 as opposed to less harmful ionised ammonium NH_{4+}. Nitrites and Nitrates were virtually absent.

4.1.18 The effect of such high levels of algae in the lagoon would be to screen out light from the lower levels of the water column and smother aquatic plants. This would have a serious knock on effect for dependent invertebrates, fish depriving them of shelter and food. This in turn would limit the lagoon as a food source for foraging birds.

4.1.19 Long term exposure to the levels of ammonia would reinforce this effect by damaging sensitive aquatic populations. The absence of Nitrites and Nitrates would appear to suggest that reactions normally expected to break down ammonia into these products via organisms such as Nitrosomonas and Nitrobacter are absent. This possibly implies very low levels of dissolved oxygen preventing these reactions which are aerobic. It was not possible to monitor dissolved oxygen but low levels would also be damaging to fish and aquatic life.

4.1.20 The sources of the phosphorous driving eutrophication of the lake are not clear and they are very likely to be diffuse. Obvious possibilities include public conveniences/waste water at the Firs visitor centre, ground water leaching from the sea and water contaminated with phosphorus from the river used to maintain water levels in the lagoon – or some combination of all three. Other factors that could be considered include wild/domestic animal feces/urine (cattle, dogs and birds). Whilst these may well play a role the algal bloom is a relatively recent feature and they have been present for many years though the numbers of visitors and dogs has increased significantly over the last few years.

The source of the ammonia is very likely to be decay of dead algae and the combination of pollutants in the lagoon is likely to be very toxic to aquatic life.

5 WATER QUALITY, EUTROPHICATION AND MANAGEMENT

5.1.1 Water is the lifeblood of terrestrial ecosystems. When water supply becomes restricted or polluted problems inevitably follow. In the Hun catchment there is clear evidence that water resources are being polluted with excessive levels of nutrients from a range of different sources.

5.1.2 This kind of surface water quality issue is not uncommon in UK catchments, many of which fail to reach Water Framework Directive Standards. However, because of the extensive landscape designations enjoyed by the lower reaches of the River Hun and the sensitivity of the environments involved it is a serious issue. The levels of pollutants present are clearly having a negative impact on the Protected Features of the sites.

5.1.3 Clear evidence of these impacts is seen in the persistent algal bloom on the Broadwater Lagoon and the lack of aquatic life – especially fish – in the River Hun.

5.1.4 Despite their complexity, the effects of eutrophication and nutrient enrichment on species biodiversity and ecosystem function are now well understood. For example, Isbell et al (2013) conducted long term experiments which demonstrated the links between nitrogen enrichment, changes in dominant species, biodiversity loss and changes in ecosystem function in grasslands.

5.1.5 MacDonald et al (2006) reviewed impacts of nutrient enrichment on biodiversity in general and birds in particular for the RSPB. They identified water pollution as contributing to over 20,000 has of UK SSSIs (7%) being in unfavourable condition. In case studies of farmland, aquatic and moorland environments, they linked nutrient enrichment to the decline of many species of British birds including Bittern, CornCrake, Cirl Bunting and the extinction of Red Shrike.

5.1.6 In grasslands, nutrient enrichment usually results in small numbers of plants that thrive in nutrient rich environments growing rapidly and becoming dominant. The favoured species then dominate the habitat causing the loss of larger numbers of more specialist plants that need a low nutrient environment to survive. This change then impacts on soil organisms, invertebrates, beetles and moths by depriving many species of their food source/habitat. It then ripples through the food chain to affect higher order species - mammals and birds.

5.1.7 Looking at the bigger picture it is very unlikely that the impact of excessive, water-borne nutrients (especially phosphorus and nitrates) is likely to be restricted to just the River Hun itself and the water in one lagoon. Inevitably, the same nutrients spread via overland flow and the water table to adjacent plant communities which experience elevated levels of growth.

5.1.8 Given the poor water quality found in the Hun catchment generally it is important to know what the overall impacts it might be having on the surrounding landscape. One way to get a broad indication is to use so called false colour, infrared aerial photography to search for places in the landscape where vegetation photosynthesis and growth may be elevated above normal expectations.

5.1.9 Figure 3 shows the Holme Dunes area on just such a photograph. Areas of high photosynthesis and vegetation (biomass) amount appear bright red while low areas appear in darker tones. Clearly it is only possible to compare tones within the same land cover class (i.e. grassland with grassland, salt marsh with salt marsh etc). It should also be noted that biomass and hence tone can be controlled by factors other than nutrient availability. Soil moisture might be particularly important but as the image was collected in December it is unlikely that this would be a major issue.

5.1.10 Several areas which might be affected by nutrient enrichment can be seen in the photograph including isolated patches on the beach, an area in the salt marsh on the extreme east of the image, areas within the sand dunes (some of which are being colonised by Sea Buckthorn) and patches of salt marsh in the west.

5.1.11 One of the most striking areas is in the fields to the north of the Hun around Broadwater Lagoon as compared to those south of the river. All are currently grassland with ostensibly similar structure and management (cattle grazing) although those to the south were converted from arable c. 15 years ago and so might be expected to have higher nutrient levels caused by residual nutrients in the soil from fertilizers.

5.1.12 However, the opposite is true with those to the north exhibiting particularly high levels of productivity. This suggests that the eutrophic nature of the lagoon is to some extent being mirrored in the surrounding fields and may in part be due to water from the Hun which is high in nitrates being used to irrigate them via a wind pump and the relict creek systems evident in the photo.

5.1.13 Other areas where there may be less extreme issues include the north and south extremeties of Redwell Marsh and significant parts of Holme Marsh. Both of these sites use sluices to raise water levels and both have potential to be affected by nutrient rich runoff.

Figure 3: False colour infrared aerial photograph of Holme Dunes and the lower reaches of the River Hun from Environment Agency Survey dated 6/12/2014.

6 CONCLUSIONS

6.1.1 In order to (a) better understand community concerns about environmental degradation reported as part of NDP consultation activities and (b) evaluate evidence of eutrophication in local water features (especially Broadwater Lagoon) a study of water quality in the River Hun catchment has been completed.

6.1.2 It has revealed poor water quality in both the river and Broadwater Lagoon which is a qualifying feature of the parish's Protected Sites. Nitrogen-based pollutants contribute to poor water quality in the River Hun and Phosphorus driving a persistant algal bloom is an issue in Broadwater Lagoon.

6.1.3 Both diffuse and point sources of pollutants have been identified including agriculture, tourist related facilities, wild and domestic animals, traffic, sceptic tanks and sewage discharges. It is also known that atmospheric deposition of nitrogen is an issue for the sand dune habitats.

6.1.4 The findings suggest that residents who value their local environment very highly are right to have concerns. No bacteriological analyses of water bodies have been possible to date but it has to be noted that the combination of raw sewage in water courses, tourists/walkers transporting dogs and children in cars to enjoy beaches and picnics is not a good situation. Illness in dogs is not uncommon in the area. More needs to be done to demonstrate public safety by the relevant authorities.

6.1.5 As far as the NDP is concerned it is a legal requirement that it can demonstrate it will not have any 'likley significant effect' on the environment which enjoys EU Protected Status. In order for this to happen it is necessary to have baseline data defining current status so that any likely effects of plan policies can be judged. This report sets out a baseline picture of the environment in relation to water quality, eutrophication and nutrient enrichment. It has demonstrated that all are currently contributing to environmental degradation and poor status.

6.1.6 Self evidently, the NDP must promote policies that will not contribute to this by increasing surface water pollution as this will contribute to damage of the Protected Sites. Where possible it should aim to facilitate improvements.

6.1.7 Water quality is just one of the environmental factors that are significant to impacts on the Protected Sites and it will be discussed alongside other factors in the Environment, Landscape and Biodiversity Report which aims to set out detailed and structured environmental objectives for the NDP.

6.1.8 Finally, it must be noted that the NDP can take all necessary steps to ensure that it does not make water quality worse and it may be able to encourage improvements. However it cannot bring about fundamental change. A broader community project may achieve this.

6.1.9 As climate change progresses and summers suffer more extremes of drought, keeping Holme's marshes wet and preserving its wildlife will become increasingly challenging. Failing to do this will result in environmental damage but equally, irrigating them with polluted, nutrient rich water will be just as bad. Solutions exist – and action is needed now if Holme's very special environment is going to be preserved for future generations to enjoy.

7 REFERENCES

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8 APPENDIX 1:

HUN WATER QUALITY: INTERIM REPORT

Hun water quality: Interim report

1.0 BACKGROUND AND SUMMARY OF FINDINGS

1.0.1 Holme-next-the-Sea lies entirely within the North Norfolk Coast AONB and more than 40 per-cent of the Parish is covered by Protected Sites. At the heart of these sites lies the River Hun, one of a small number of rare chalk streams which should provide a unique habitat for wildlife.

1.0.2 The Hun rises in springs to the south-east of Hunstanton and flows north and then eastwards through Holme Dunes National Nature Reserve to reach the sea via a sluice at Thornham Sea Bank. The lower reaches pass through an area of international importance for nature conservation with Ramsar, SAC, SPA and SSSI designations.

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1.0.4 The ecosystem services these sites provide are the main pillar of the local economy and both local people and visitors place enormous value on these parish assets. They are however coming under increasing pressure from growth in visitor numbers, associated car traffic and increases in county-wide development.

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1.0.6 In response to this questionnaire survey and partly in response to reports of pollution and declining observations of wildlife in The Hun, early in 2017 the Neighbourhood Plan Team decided to follow up these concerns. This decision coincided with an approach to the Parish Council by the Norfolk Coast Partnership (NCP) who, working with the Norfolk Rivers Trust (NRT), have been successful in establishing improvement programmes for other chalk streams in Norfolk and wanted to explore likely levels of support for a programme of improvements to the Hun.

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1.0.9 In order to establish priorities for the project and to begin addressing the pollution issues, the NCP, NRT and the Parish Council (via the NDP Team) agreed to work together on a programme of

water quality monitoring spanning the period from May through to December. NRT agreed to fund a demonstration / training exercise followed by a further 6 months of structured water sampling based on four sites in the Hun Catchment and one on Broadwater Lagoon.

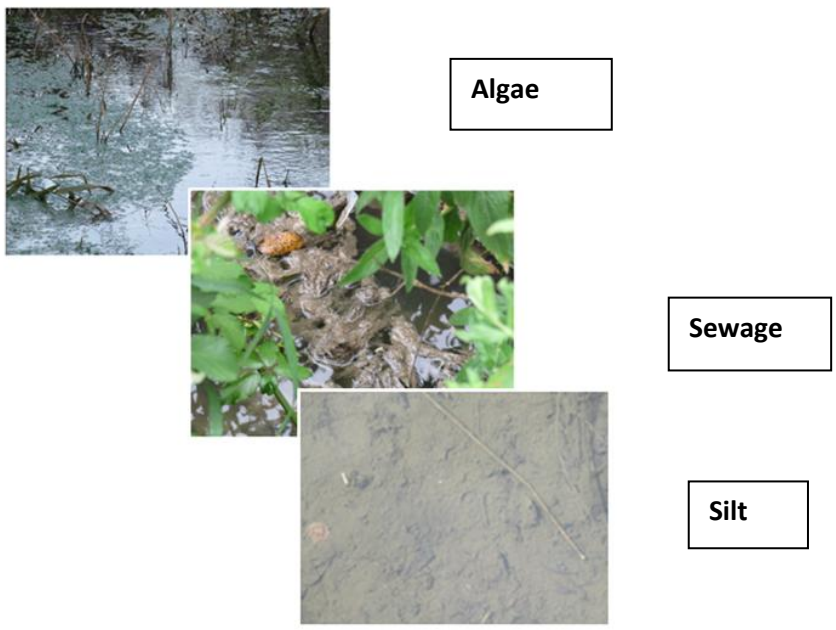
1.0.10 The work has been carried out on a voluntary basis by members of the NDP team with input from the Warden of the Norfolk Wildlife Trust (NWT) and the cooperation of the Norfolk Ornithologists Association (NOA). Analysis of samples has been carried out at the Environment Agency's National Laboratory.

1.0.11 The results of the first three sets of monthly observations have been enlightening:

- At the sampling stations on the River Hun, Nitrate levels are well in excess of Water Framework Directive standards and Nitrite levels are sufficiently high to give cause for concern.
- Pollution from Orthophosphates and Ammonia is a concern in the headwaters of The Hun (i.e. in Hunstanton Park).
- Water quality in Broadwater Lagoon is very poor with extremely high levels of Chlorophyll A and Phosphorus and levels of Ammonium which also give rise to concern.

1.0.12 The concentration and mix of pollutants in the lagoon can be expected to limit aquatic life and impact negatively on the qualifying features of the protected sites – especially birds. Nitrogen levels in the river will have a similar effect especially if they are mirrored in surrounding pools and ditches.

1.0.13 The work to date indicates that the catchment management plan proposals to make improvements to the channel and flow of the Hun (Phase 1 of the Hun Project), combined with a riparian buffer zone would make a major contribution to improving the current situation if carefully implemented. Supporting proposals for improved public access and pathways would at the same



time improve visitor experience.

1.0.14 However, until nitrate levels in the river are brought down to acceptable levels 'rewetting' of the lagoon(s) and pools in the lower reaches of the Hun could be extremely damaging because it would add nitrogen-based nutrients to the already heavily polluted lagoon which is mainly affected by phosphorus. This would cause further damage to the Protected Sites and their qualifying features. It is clear that funding will need to be found to continue and expand the programme of water quality monitoring beyond six months and to investigate biological status in addition to water chemistry. This further work will help to improve understanding of the issues facing the river catchment and the Protected Sites and assist with the identification of remedial measures.

2.0 INTRODUCTION

2.1.1 The River Hun is a small chalk stream which rises in Hunstanton Park, flows east along the coast through Holme-next-the-Sea before discharging through a tidal sluice into Thornham Harbour. Much of its course has been canalized resulting in a straight channel that is detached from its floodplain. The western part of its course adjoins Old Hunstanton Golf Course to the north and arable farmland to the south. Further to the East in Holme it flows through Holme Dunes NNR and the North Norfolk SSSI, Ramsar, SAC, and SPA Protected Sites.

2.1.2 Its floodplain in Holme consists largely of grazing marshes which support a rich diversity of wildlife – especially birds. Relict oxbow lakes of the river are a feature of the marshes but are now detached from the main channel only being flushed with water from the Hun at times of flood. Broadwater lagoon is one of these lakes and is a qualifying feature of the SAC. It is an important site for several bird species some of which are qualifying SPA features. The lower reaches of the river

Figure 1: The course of the River Hun showing its relict meanders and course through Holme Dunes NNR. (Imagery by courtesy of the European Space Agency; Contains modified Copernicus Sentinel data, 2017).

and the lagoons are brackish (Figure 1).

2.1.3 Chalk streams are relatively rare with only about 200 in the world. The Hun is one of several found in Norfolk. In their natural state they have clean, clear, alkaline water filtered by chalk substrate. They typically would support a rich ecology of plants, invertebrates and salmonid fish species including salmon (*Salmo salar*) and brown trout (*Salmo trutta*). European Otters (*Lutra lutra*) are often found in chalk stream catchments. However, many chalk streams have been seriously damaged by inappropriate management and pollution to the extent that in 2013 some 77% failed to meet the environmental standards required by the EU Water Framwork Directive (WWF, 2014).

2.1.4 Concerns have been expressed about the state of the Hun for some time. Sewage has been reported in both the river and its tributaries, concerns have been expressed about excessive quantities of 'grey sediment' and the lack of fish has been a feature of the river for some years.

2.1.5 The Holme-next-the-Sea Neighbourhood Plan questionnaire survey revealed concerns in the local community about 'inappropriate development' and a strong desire for positive environmental management. One important aspect of this is having policies to ensure that pollution in the Parish does not become intractable.

2.1.6 As part of a broader project aimed at trying to improve Norfolk's chalk streams the Norfolk Coast Partnership in conjunction with the Norfolk Rivers Trust have been seeking Heritage Lottery Funding for the first phase of a project to introduce improvements to the Hun. The broad aims of the project are set out in a catchment plan published by the Norfolk Rivers Trust and the Environment Agency (Blervllet, 2014). Key elements include improvements to channel morphology, riverside planting and reconnection of the river with its floodplain including Broadwater Lagoon. The bid for funding was unsuccessful in the last round due to lack of funds and insufficient evidence of community support.

2.1.7 As part of developing their Neighbourhood Plan Holme-next-the-Sea Parish Council are concerned to ensure an effective management strategy for the Hun and the protected EU sites especially as a significant area within these sites (including much of Home Dunes NNR) is subject to a Shore Line Management Plan policy of Managed Realignment. This policy would ultimately result in the area being open to tidal inundation and reverting to intertidal zone. The policy would, in the words of the Plan's Strategic Environmental Assessment, have a 'major negative' impact on the sites and has permission from the Secretary of State to proceed on the grounds of 'Imperative Reasons of Overriding Public Interest' (IROPI).

2.1.8 The Parish Council is certainly committed to improving the hydrology and ecology of the Hun within the catchment and has agreed to work with interested stakeholders to identify a route forward that best serves the interests of the Parish and at the same time might help with the acquisition of appropriate funding for an agreed programme of work.

2.1.9 In order to progress this aim it was felt important to ensure that reconnecting the Hun with the floodplain and lagoons would not result in any pollutants from the former damaging the latter.

3.0 WATER QUALITY TESTING

3.1.1 Good water quality is a basic requirement for the function and survival of almost all ecosystems and underpins effective management of sites like Holme Dunes. Initial screening of water in the Hun was carried out using simple test kits based on colorimetric methods and a printed colour chart supplied by the Freshwater Habitats Trust. These provided an excellent starting point for general screening of sites and very quickly revealed high levels of nitrates at various points in the river.

3.1.2 Early in 2017 it was noticed that Broadwater Lagoon was exhibiting a strong algal bloom (Figure 2) and this raised further questions about water quality in the catchment.

3.1.3 Whilst lakes of this type are sensitive to nutrient enrichment and growth of algae (JNCC, 2015) and blooms do occur, it is possible that they can become self-perpetuating and lead to eutrophication and damage to the qualifying features of the system. Whilst the lake does appear green in some historical aerial photography, blooms of this strength have not been noticeable in the field during the last ten years.

3.1.4 Against this background, Norfolk Rivers Trust secured funding for some basic water quality

Figure 2: Broadwater lagoon – exhibiting a strong algal bloom first seen in May 2017. The bloom has persisted to September 1st 2017 and at times is associated with a strong, unpleasant odour.

monitoring. It was agreed that samples of nitrates and phosphates would be collected by members of the Holme Neighbourhood Plan team on a monthly basis for a period of 6 months. One

measurement of Chlorophyll A would also be collected from Broadwater at the start of the period and one at the end.

3.1.5 Arrangements were made to send samples by courier immediately after collection to the EA National Laboratories for analysis. After the second samples were taken, additional measurements of pH and turbidity were added. All samples were collected in clean containers supplied by the laboratory. Care has been taken to avoid cross contamination of samples.

3.1.6 Five sample locations were selected at likely entry points of pollutants to the river identified on the basis of local knowledge and discussions with staff from the Environment Agency with

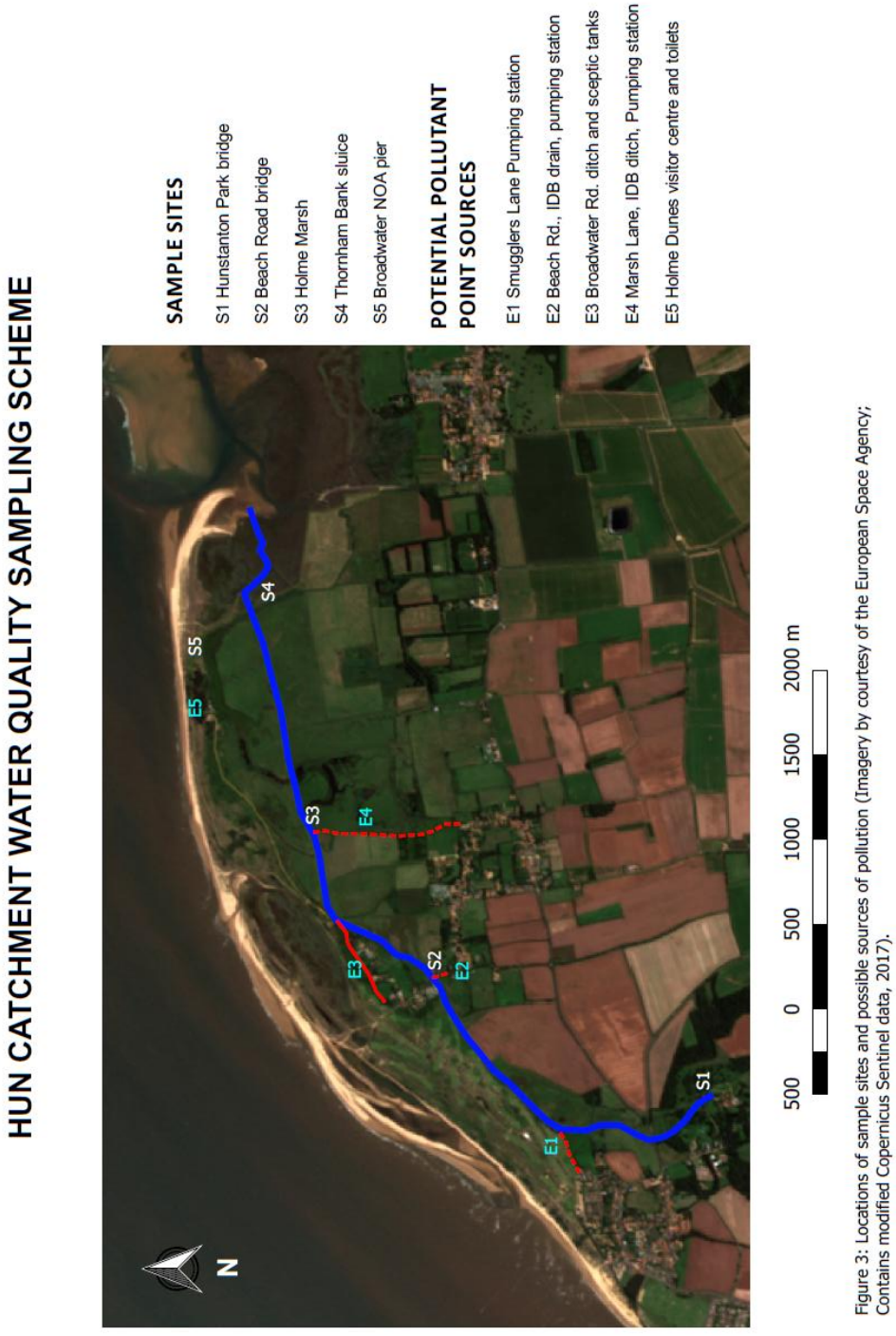


Figure 3: Locations of sample sites and possible sources of pollution (Imagery by courtesy of the European Space Agency; Contains modified Copernicus Sentinel data, 2017).

knowledge of the catchment. These are shown in Figure 3. Since starting the programme a possible, additional pollutant entry point has been located upstream of Sample Site S1 in Hunstanton Park.

3.1.7 Water depths in the river were recorded using a measuring stick located at Sample site S2 under Beach Road bridge (Site S2).

3.1.8 An overview of the results for the first three months sampling is shown in Appendix 1.

9 4.0 WATER QUALITY – SUMMARY OF FIRST QUARTER'S RESULTS

4.0.1 Water quality standards have been developed for many pollutants by a range of organizations. Growing understanding of pollution impact on human and aquatic populations is developing and changing all the time so there are no magic numbers that prove water is unpolluted or otherwise. A particularly complex issue for the developing science of water quality is that pollutants usually act in combination so isolating the effects of one particular pollutant can be extraordinarily difficult.

4.0.2 Furthermore, three months data is too little to draw firm conclusions about general patterns of water quality of a system but it is sufficient to gain some indication of the likely condition and status of the River Hun and Broadwater Lagoon in the context of supporting wildlife.

4.0.3 The first and most striking feature of the results is that the Lagoon and sample site S1 in Hunstanton Park show very different results to the rest of the River (Sites S2-S4). The Lagoon and site S1 are characterized by very high levels of phosphorous and high levels of Ammonium with minimal/low presence of Nitrates and Nitrite. Sites S2-S4 are characterized by very high levels of Nitrates with minimal levels of Phosphorus and Ammonium.

4.0.4 This suggests that during the sampling period to date, there is no connection between the river and the lagoon. This might change when water levels in the river rise in the autumn/winter or it might suggest that they are actually two separate systems. The results for each will thus be described separately.

9.1 Results for the pollutants

Nitrate

4.1.1 Nitrate levels are very low at station S1 in Hunstanton Park (predominantly grassland and woodland surroundings with some settlement). At the remaining stations they are significantly higher than the WFD standard (11.3 mg/l) with a range of 14-16 mg/l and an overall average of 14.97 mg/l. It is possible that the high levels are explained by proximity to arable farmland and the golf course in the section of the Hun between Old Hunstanton and Holme together with IDB drains E2 and E4 which drain arable farmland.

4.1.2 The levels in most of the river are thus worryingly high especially as it flows through a Nitrate Vulnerable Zone over a drinking water aquifer. Camargo *et al.* (2005) present evidence to suggest that even relatively short term exposure to levels this high can be lethal to some invertebrates, damage some amphibians and impact negatively on the fry of sensitive species of fish.

4.1.3 The very low concentrations in Broadwater Lagoon and Hunstanton Park require further explanation (see below).

Nitrite

4.1.4 Nitrite levels are below the resolution of the laboratory measuring equipment for Broadwater Lagoon but rather higher for the stations on the river. The range for these sites is 0.005 to 0.025 and the mean is 0.0176. Opinions seem to differ on acceptable levels from none to 0.01 mg/l N for 'unpolluted water'.

4.1.5 Nitrite occurs as a result of the oxidation of Ammonia to Nitrate. This is a two step process involving oxidation of ammonia to nitrite by Nitrosomonas bacteria and oxidation of nitrite to nitrate by Nitrobacter bacteria. Nitrite is thus usually short lived and as long as these bacteria are present in appropriate conditions for the oxidization process (including availability of dissolved oxygen) it is usually fairly transient.

4.1.6 Its presence is thus linked to that of Ammonia which can frequently be a sign of pollution by sewage and outfalls from waste water treatment plants although there are other sources. Nitrite can thus be taken as an indicator of pollution.

4.1.7 Although it is rapidly oxidized to nitrate its presence at even low concentrations is very damaging to aquatic organisms.

4.1.8 Average levels of Nitrite in Snettisham Lagoons over a 12 month period were between 0.0054 and 0.011 over a twelve month monitoring period (Natural England, 2011) in a study which demonstrated that despite the presence of algae in the lagoons their function as a habitat for birds was not obviously damaged.

4.1.9 The levels recorded here for stations S1 – S4 are rather higher and if average concentrations started to become much higher than 0.02 mg/l N there would be cause for concern.

Ammoniacal nitrogen

4.1.10 Ammoniacal nitrogen levels were at or near the lower limit of laboratory equipment measurement accuracy (<0.03 mg/l) for stations S2 to S5 on the Hun but were much higher for Broadwater Lagoon (Mean of 0.39 mg/l) and showed through time an increasing trend for Hunstanton Park (0.08 mg/l to 0.719 mg/l).

4.1.11 As a comparison, the highest mean level recorded in the Snettisham Lagoons (Natural England 2011) was 0.03 mg/l and more typical levels around 0.015. This suggests that levels at Hunstanton Park in the Hun and in Broadwater Lagoon are substantially higher – possibly by an order of magnitude. Similarly, the UK Environment Agency (2015) recorded levels of around 0.1 mg/l in the R. Thurne and 0.07 mg/l in Martham and Hickling Broads. In the same report, Horsey Mere was deemed to have fallen below acceptable quality standards for Ammonia with a concentration of 0.3 mg/l. (NB Broads observations are average values for 2012-14).

4.1.12 Ammoniacal nitrogen is a combination of Ammonium nitrogen (NH_4) and Ammonia (NH_3). Ammonium is relatively harmless to aquatic life but Ammonia is very damaging. At any time the proportions of Ammoniacal Nitrogen present as NH_4 and NH_3 depends on the pH and temperature of the water. Recording of pH and temperature only began once the rather high levels of ammonium were seen.

4.1.13 It would appear that the lagoon typically has a pH of around 8 and on the one day measurements were taken temperatures were around 17 degrees C but probably reached 20 degrees C later in the day. This would suggest that levels of NH_3 in the lake would have been around 0.017 mg/l but potentially reaching 0.02 mg/l.

4.1.14 Despite substantial research on toxicity of Ammonia to aquatic organisms, standards have been controversial. The Environment Agency (2007) in proposing revised standards note that "The lowest credible concentration of un-ionised ammonia at which long-term effects were found is 0.022 mg NH3-N l-1 when a cumulative mortality of 71 per cent was observed for eggs, larvae and fry of rainbow trout (Oncorhynchus mykiss) over 73 days exposure". Other Salmonid species, including Brown Trout (Salmo trutta) typical of chalk streams show similar tolerances.

4.1.15 The current WFD, long term exposure standard for salt water is 0.021 mg/l NH_3 and 0.78 mg/l total Ammonium. For fresh water it is 0.015 mg/l. (Environment Agency, 2010). The data collected for Hunstanton Park and Broadwater lagoon suggests that these sites are at best close to these critical levels if not exceeding them.

4.1.16 In the same report the Environment Agency has suggested that rather tighter standards may be appropriate. A significant difficulty in agreeing these standards is that they are dependent on the quality of water in terms of other parameters.

Chlorophyll A

4.1.17 Chlorophyll is vital for photosynthesis and its measurement in water is an indicator of the amount of algae present. It was agreed to take one measurement at the start of the programme from Broadwater Lagoon to learn more about the algal bloom. The sample was taken from a small pier at the edge of the lake. It contained a high level of green solids and returned a concentration of 80.6 ug/l.

4.1.18 By any standards this is a very high concentration. UK Tag (2014) counts the number of times a level of 50 ug/l (dependent on salinity) is exceeded when classifying water quality. On the basis of the colour of the lake and the solids content of subsequent water samples for other pollutants it is not inconceivable that this very high level has been a persistent feature of Broadwater since June 2017 when the sample was collected. On occasions a strong smell comes from the lake.

4.1.19 This level of algal bloom in the lagoon is indicative of high levels of nutrients and is likely to be damaging to aquatic life because it will cause light starvation to organisms in and on the floor of the lake. Certain types of algal bloom (Harmful Algal Blooms or HABS) can pose a threat to public health. These effects are likely to ripple through the food chain and ultimately impact on higher organisms (fish) and birds using the lake. Some of these will be qualifying features for the SPA.

4.1.20 To date no comparators have been found for Chlorophyll A in nearby water features. In the Snettisham lagoons study (*op cit*) Secchi depth was used as a proxy. However, RMB Environmental Laboratories inc. would classify lakes with this level of Chlorophyll A as 'hypereutrophic'.

Phosphorus

4.1.21 For rivers the WFD standard for phosphorus is 0.087 mg/l P. Stations S2-S4 on the Hun are all well within this limit. However, Hunstanton Park (S1) exceeds the limit by a factor of 5 to 7 for the three months in question.

4.1.22 Around 90% of Total P for this location consists of orthophosphate. As there are no arable fields close to the site this suggests that nearby septic tanks may be a source.

4.1.23 Levels for Broadwater lagoon were 0.646 mg/l P, 0.579 mg/l P and 0.374 mg/l P possibly suggesting a decreasing trend. The limit for brackish lakes suggested by the JNCC (2015) is 0.035 mg/l so levels in the lagoon exceeded this by a maximum factor of 18 and a minimum of 10.

4.1.24 The orthophosphate component of these concentrations is below the measurable limit suggesting that the Phosphorus is mainly organic and bound up in the high levels of algae.

4.1.25 These levels in the Lagoon are very high and are almost certainly the cause of the prominent algal bloom seen on the lake. Furthermore, Phosphorus readily attaches itself to sediments and other solids and so can be a very persistent form of pollution.

4.1.26 The very high levels of phosphorus and Chlorophyll A linked to the algal bloom are likely to lead to very low levels of dissolved oxygen in the water. Oxygen is needed for the support of Nitrobactor and Nitrosomonas to break down ammonia into nitrites and nitrates. It was noted above that levels of both nitrite and nitrate are very low in the lake and this is one possible explanation.

4.1.27 No dissolved oxygen levels have yet been measured for the lagoon but this is now seen as a priority.

4.1.28 Chlorophyll A levels were very high suggesting the lagoon could be described as 'hypereutrophic'.

Combined effects of pollutants

4.1.29 As far as the Lagoon is concerned the combined levels of ammonium, phosphate and chlorophyll A (algae) would seem to provide a toxic combination that could not support acceptable levels of aquatic life. Whilst birdlife is not absent from the lake, the relatively small number of birds present seems to be in contrast to other lagoons in the vicinity. Collection of some dissolved oxygen concentrations has to be a priority to get a clearer picture of the lake's status.

4.1.30 As far as the River is concerned the levels of Nitrate and Nitrite would also prove hostile for aquatic species so it is little surprise that fish are rarely seen in the river.

4.1.31 From three months observations it would seem that the river and the lake are separate functional systems given the pattern of pollutants in each. However, with increasing flood levels in the winter and the possibility of flood water from the river entering the lagoon this may change.

4.1.32 The Norfolk Rivers Trust Catchment Plan for the Hun (Blervlett, *op cit*) could make a major contribution to improving water quality in the river based on channel improvements and riparian buffer zones/planting. It is less clear at this point how the problems affecting the lagoon could be addressed. However, re-connecting the river with its floodplain and the lagoons could make matters considerably worse given the rather different patterns of pollutants in each.

4.1.33 Overall, the water quality in both the river and the lagoon needs improvement to be consistent with the conservation objectives of the Protected Sites in terms of their qualifying features. It is also important to maintain ecosystem services and tourist income linked to the sites. Continued monitoring is important in this respect with additional focus on biology. Funding for the first phase of the Catchment Plan could make a major impact and give greater clarity as to if and how the other aspects of the plan might proceed.

5.0 CONCLUSIONS

5.0.1 The first three months of water quality measurements for the Hun catchment have been reviewed. This is not a sufficiently long time series to draw firm conclusions about patterns in the catchment. However, it is sufficiently long to detect high pollutant concentrations that would be damaging to aquatic life.

5.0.2 Of the four recording stations on the Hun: Beach Road Bridge, Holme Marsh and Thornham Sluice (stations S2-S4) had very similar results while Hunstanton Park (S1) was quite different.

5.0.3 The former exhibited levels of Nitrate well over the Water Framework Directive limit. Scientific evidence suggests that these levels would be lethal to some invertebrates, damaging to amphibians and prevent long term survival of sensitive fish populations – including Salmo Trutta (Brown Trout). The catchment is in a Nitrate Vulnerable Zone.

5.04 All of the stations on the river showed rather high nitrite concentrations with some reaching levels that would be damaging in the short term to aquatic life.

5.0.4 Hunstanton Park exhibited very low levels of Nitrate but substantially exceeded the Water Framework Directive limit for Phosphorus in the form of orthophosphate. As the site is some distance from arable fields and Ammonium is also present it is possible that sewage from septic tanks may be the source. Water samples from this location appeared more turbid than those from the rest of the river. At the time of recording pH and temperature levels were low for this site but the levels of ammonium in the third month were worryingly high for the safety of aquatic organisms.

5.0.5 Broadwater Lagoon showed a very different picture to the river. Nitrate and Nitrite concentrations were below the measurable limit. Notable concentrations of ammonium were present and these could easily reach a level where they would be lethal to sensitive fish and other organisms if there was a small increase in lake pH or a larger increase in water temperature.

5.0.6 Phosphorous levels were between 10 and 18 times above the JNCC recommended limits and this obviously is the driving factor for the algal bloom. However, orthophosphate levels were below the measurable limit suggesting that most of this phosphorus was tied up in the algae itself. The persistent algal bloom is damaging to aquatic life.

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7.0 APPENDIX 1: WATER QUALITY MEASUREMENTS FOR JUNE TO AUGUST 2017

Site	Location	Date	Phosphorus: Total as P mg/l	Orthophosphate, reactive as P mg/l	Organic Phosphate (Total P - reactive P)	Ammoniacal Nitrogen as N mg/l	Ammonia est mg/l	Nitrogen : Total Oxidised as N mg/l	Nitrite as N mg/l	Nitrate as N mg/l	Chlorophyll, Acetone Extract ug/l	ph
S1	Hunstanton Park	8-Jun-17	0.428	0.384	0.044	0.080		0.440	0.025	0.415		
S2	Beach Road Bridge	8-Jun-17	0.035	0.013	0.022	<0.0300		16.000	0.016	16.000		
S3	Holme Marsh	8-Jun-17	0.025	0.011	0.014	<0.0300		15.400	0.018	15.400		
S4	Thornham Bank Sluice	8-Jun-17	0.019	<0.0100		<0.0300		14.500	0.020	14.500		
S5	Broadwater Lagoon	8-Jun-17	0.646	<0.0100	~ 0.646	0.310		<0.200	<0.00400	<0.200	80.6	
S1	Hunstanton Park	6-Jul-17	0.550	0.490	0.060	0.337		<0.200	0.019	<0.181		
S2	Beach Road Bridge	6-Jul-17	0.027	0.020	0.007	0.030		15.200	0.015	15.200		
S3	Holme Marsh	6-Jul-17	0.031	0.017	0.014	0.030		15.000	0.018	15.000		
S4	Thornham Bank Sluice	6-Jul-17	0.030	0.017	0.013	0.030		14.000	0.020	14.000		
S5	Broadwater Lagoon	6-Jul-17	0.579	<0.0100	~0.579	0.432		<0.200	<0.00400	<0.200		
S1	Hunstanton Park	3-Aug-17	0.662	0.608	0.054	0.719	0.010	<0.02	0.005	<0.195		7.65
S2	Beach Road Bridge	3-Aug-17	0.019	0.013	0.006	0.030	0.000	15.800	0.017	15.800		7.76
S3	Holme Marsh	3-Aug-17	0.026	0.012	0.014	0.030	0.000	14.800	0.020	14.800		7.88
S4	Thornham Bank Sluice	3-Aug-17	0.046	<0.01	~0.046	0.030	0.000	14.100	0.020	14.100		7.95
S5	Broadwater Lagoon	3-Aug-17	0.374	<0.01	~0.374	0.426	0.019	<0.2	<0.004	<0.2		8.16

Fail — No fill = Pass

Caution

8.0 APPENDIX 2: CONTRIBUTORS

The support of the Norfolk Rivers Trust in funding and supporting this work is gratefully acknowledged. In particular we would like to thank Ursula Juta for her help in making all the necessary arrangements and carrying out the initial set of field tests. The support of Estelle Hook at the Norfolk Coast Partnership and the Freshwater Habitats Trust (Laura Quinlan, People, Ponds and Water Project, funded by the HLF) is also acknowledged. Last but not least, the cooperation of the Norfolk Wildlife Trust and the Norfolk Ornithologists Association is acknowledged.

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