From: [redacted]
To: Norfolk Boreas
Cc: [redacted]
Subject: Norfolk Boreas Consultation - Judicial Review of Norfolk Vanguard & Judgement
Date: 19 October 2021 12:06:52
Attachments: CO028362020-0008[57].pdf
Judgement Feb 2021.pdf

Your References:
A. EN010087 dated 22 September 2021.
B. EN010079 dated 29 April 2021

Link to Judgement:
[redacted]

Dear Planning Inspectorate,

In the Secretary of State's letter at Reference A, Interested Parties (IPs) were invited to make further comments on the Norfolk Boreas planning application with a deadline of 23:59 on 21st October 2021. As the deadline approaches, we have been reviewing the Applicants submissions and relevant Documents and note that the Judgement handed down by Justice Holgate on 18th February 2021 has not been published on the National Infrastructure Planning page for the Norfolk Boreas application.

We contest that it cannot be assumed that the IPs for the Norfolk Boreas application will be exactly those for the Norfolk Vanguard application, otherwise the applicant's insistence that the two projects are separate would be further flawed! Therefore, the tenuous link in the Secretary of State's letter at Reference B is inadequate to inform the public of the details from the Judgement, as at the Link and Attachment for completeness. Also, when considering the importance of that Judgement on the Norfolk Boreas application, and, with regards to the so called "joint consultation" for both Norfolk Vanguard and Norfolk Boreas applications, it would be appropriate that the details are published on the Norfolk Boreas application page for all to see.

With reference to the Judgement, there are points for consideration by the ExA with specific regards to the Norfolk Boreas project. Further, as Justice Holgate made clear, the Secretary of State's failure to assess cumulative landscape and visual impacts of the two wind farm developments went to the heart of the Secretary of State's assessment of the acceptability of the Norfolk Vanguard wind farm, making the Judgement wholly relevant to the Norfolk Boreas examination, and therefore, the ExA and ExAR . In particular, it includes an appraisal of the following matters:

a. The strategy of co-location of Norfolk Vanguard and Norfolk Boreas (see the Judgment at [132], [134]); it needed to be determined before granting consent for Norfolk Vanguard (the first project) whether the cumulative impacts both of a grid connection at Necton (and the related cable corridor) were acceptable or should be reconsidered [133].
b. The acceptability of the choice of Necton as the grid connection point in that context [132].
c. Whether the acquisition of land for Norfolk Boreas by the Norfolk Vanguard proposal

satisfies a “compelling public interest” test for compulsory acquisition [132].

d. A full and complete assessment of the cumulative impacts of the two projects, **not limited to design**. As the Judge held, the approach taken by both the Secretary of State and the ExAR’s recommendation was fundamentally flawed both as a matter of Environmental Impact Assessment (EIA) and rationality. It omitted from consideration an entire category of impacts. EIA requires that **all** the information be taken into consideration in making a decision. That cannot be done in a piecemeal way. Therefore, the ExA must revisit the overall planning balance, which Justice Holgate noted concluded in favour of the proposed development “on balance” only [159].

Furthermore, it is incumbent on the ExA in making any recommendation to the Secretary of State to address (at least) the following matters, which flow from the Judge’s conclusions at [132]-[136]:

a. First, given the greater magnitude of and thus weight to be afforded to adverse landscape impacts which arise from the cumulation of the two projects, the consultation and ExA must consider the weight that is to be afforded to alternatives that avoid or mitigate those adverse impacts. These alternatives exist at both the strategic and the local level, as we have consistently maintained throughout the examination for both Vanguard and Boreas. In particular:
    i. Greater weight may fall to be given to local alternatives, such as Top Farm.
    ii. Greater weight may fall to be given to strategic alternatives, such as the Offshore Transmission Network (OTN). The case for the OTN has strengthened recently and we will address this alternative by separate submission. We note that at [59] Justice Holgate commented adversely on the consideration that had been given by the ExA to this alternative.
b. Second, even if the Norfolk Boreas ExA concluded that siting at Necton was acceptable in the light of a proper consideration of cumulative impacts between Norfolk Vanguard and Norfolk Boreas, such a conclusion will not avoid the necessary consideration of mitigation measures in order properly to account for those cumulative impacts. Some potential mitigation solutions, such as the lowering of the substations or part concealment by bunding, can only be considered as part of the Norfolk Vanguard process. These are not simply matters of design as has been offered by the Applicant in their submissions to Norfolk Boreas.

We note that at paragraph 4 of the Secretary of State’s letter at Reference B, the reasoning that Norfolk Vanguard was quashed as relating, in particular, to the design of the Norfolk Boreas substation. However, that seems to us “an impermissible attempt to rewrite the ExAR and the quashed decision letter” (to borrow the expression from the Judgment at [139]) and not to be a justified reading at all. The assertion that “the Secretary of State considered that without some further detail of the design [of the Norfolk Boreas substation], it was not possible to fully assess the potential cumulative effects of it and the Norfolk Vanguard substation.” This substantially mischaracterises the findings of the High Court, that there was an inexplicable absence of any reasoning to inform the EIA process in particular, or the decision in general, which importantly, also applies to the Norfolk Boreas application. The submission by the Applicant of the Substation Masterplan is woefully inadequate and does not provide any information regarding the extra mitigation or measures required to evaluate and negate the cumulative impacts arising from both the Vanguard and Boreas projects as discussed in the Judgement.

We realise that, post consultation, the Secretary of State and the Department for Business Energy & Industrial Strategy (BEIS) have driven the uptake of information regarding the Norfolk Boreas application. However, we respectfully ask that the ExA for Boreas, if there is any further influence on the DCO to be had, considers very carefully the legal implications of the Judgement, including what Justice Holgate makes reference to with regards to the cumulative impacts between Norfolk Vanguard and Norfolk Boreas, and makes its recommendation accordingly.

Yours faithfully,

Ray & Diane Pearce

IN THE HIGH COURT OF JUSTICE **CO/2836/2020**
QUEEN'S BENCH DIVISION
PLANNING COURT
BEFORE THE HONOURABLE MR JUSTICE HOLGATE

BETWEEN:

MR RAYMOND STEPHEN PEARCE

Claimant

-and-

THE SECRETARY OF STATE OF BUSINESS ENERGY AND INDUSTRIAL STRATEGY

Defendant

-and-

NORFOLK VANGUARD LIMITED

Interested Party

ORDER

UPON hearing Mr Westaway and Mr Brett for the Claimant, Mr Moules for the Defendant and Mr Phillpot QC for the Interested Party

IT IS ORDERED THAT:

1. The Defendant's decision letter dated 1 July 2020 and SI 2020 No. 706 are quashed.

2. The Defendant shall pay £35,000 towards the Claimant's costs of and incidental to the claim.

3. The Interested Party shall pay £2,500 towards the Claimant's costs of and incidental to responding to the witness statement of Victoria Redman dated 5 November 2020 and paragraph 27 of the Interested Party's Detailed Grounds of Resistance.

Dated 18 February 2021

BY THE COURT

Neutral Citation Number: [2021] EWHC 326 (Admin)

Case No: CO/2836/2020

IN THE HIGH COURT OF JUSTICE
QUEEN'S BENCH DIVISION
PLANNING COURT

Royal Courts of Justice
Strand, London, WC2A 2LL

Date: 18/02/2021

Before :

THE HON. MR JUSTICE HOLGATE

- -

Between :

RAYMOND STEPHEN PEARCE	**Claimant**
-and-	
SECRETARY OF STATE FOR BUSINESS ENERGY AND INDUSTRIAL STRATEGY	**Defendant**
-and-	
NORFOLK VANGUARD LIMITED	**Interested Party**

- -
- -

Ned Westaway and Michael Brett (instructed by **Thrings LLP**) for the **Claimant**
Richard Moules (instructed by **Government Legal Department**) for the **Defendant**
Hereward Phillpot QC (instructed by **Womble Bond Dickinson (UK) LLP)** for the **Interested Party**

Hearing dates: 19 and 20 January 2021

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Approved Judgment

Mr Justice Holgate

Introduction

1. The Claimant, Mr Raymond Pearce, makes this application for judicial review under s.118 of the Planning Act 2008 ("PA 2008") to challenge the decision of the Defendant, the Secretary of State for Business, Energy and Industrial Strategy, on 1 July 2020 to make the North Vanguard Offshore Wind Farm Order (SI 2020 No. 706) ("the Order"). The Order grants development consent to the Interested Party, Norfolk Vanguard Limited ("NVL") for what is said to be one of the largest offshore wind projects in the world. This development ("Vanguard") is closely related to a second wind farm project Norfolk Boreas ("Boreas"), lying immediately to the north-east of the offshore Vanguard array. Together they would have an export capacity of 3.6 GW.

2. On 8 June 2018 NVL submitted its application for a development consent order ("DCO") under s.37 of PA 2008 in respect of Vanguard. The examination of that application began on 10 December 2018 and ended on 10 June 2019. The Examining Authority submitted its report to the Defendant ("ExAR") on 19 September 2019. The application for development consent in respect of Boreas was made on 11 June 2019. The examination of that second application began on 12 November 2019 and closed on 12 October 2020. The court was informed that a decision by the Defendant on the Boreas application is anticipated to be made in April 2021.

3. NVL proposed that the onshore infrastructure of the two projects be co-located. This involved a cable route carrying high voltage direct current for 60 km from the landfall at Happisburgh to a substation site near the village of Necton. There the power would be converted to alternating current and fed into the National Grid.

4. The Environmental Statement ("ES") prepared by NVL for Vanguard assessed cumulative impacts arising from both projects, including landscape and visual impacts from the infrastructure proposed at Necton.

5. The development proposed at Necton for both the Vanguard and Boreas projects has attracted substantial objections, including objections from the Claimant who lives near the planned cable route. They concern both the impacts of the Necton infrastructure for Vanguard in isolation and also the cumulative impacts which would occur if infrastructure for Boreas were to be added at Necton.

6. In their assessment of landscape and visual impacts for the Vanguard application, both the Examining Authority and the Defendant decided that consideration of cumulative impacts from Vanguard and Boreas should be deferred to any subsequent examination of the Boreas proposal.

7. This challenge raises three issues: -

    (1) Whether the Defendant was obliged to take the cumulative impacts at Necton into account when determining the Vanguard application and acted unlawfully by deferring consideration of that subject to any examination of an application for a DCO in respect of the Boreas project;

(2) Whether the reasons given by the Defendant for not taking those cumulative impacts into account when determining the Vanguard application were legally inadequate;

(3) In the event of the court deciding that the Defendant erred in law in either of those two respects, whether it should refuse to grant relief in the exercise of its discretion.

8. The remainder of this judgment is set out under the following headings:

The Statutory Framework

Planning Act 2008

9. The framework laid down by the PA 2008 has been summarised in a number of cases, for example, *R (Friends of the Earth Limited) v Heathrow Airport Limited* [2020] UKSC 52 at [19] to [38]; *R (ClientEarth) v Secretary of State for Business, Energy and Industrial Strategy* [2021] EWCA Civ 43 at [6] to [8] and [104] to [105] and *R (Spurrier) v Secretary of State for Transport* [2020] PTSR 240 at [21] to [39] and [98] to [109]. There is no need for that analysis to be repeated here.

10. In so far as is material, s.104 of the PA 2008 provides:

> "(1) This section applies in relation to an application for an order granting development consent if a national policy statement has effect in relation to development of the description to which the application relates.
> (2) In deciding the application, the Secretary of State must have regard to –
>
> (a) any national policy statement which has effect in relation to development of description to which the application relates (a "relevant national policy statement"),
>
> (aa) ….. ,
>
> (b) any local impact report (within the meaning given by section 60(3)) submitted to the Secretary of State before the deadline specified in a notice under section 60(2),
>
> (c) any matters prescribed in relation to development of the description to which the application relates, and
>
> (d) any other matters which the Secretary of State thinks are both important and relevant to the Secretary of State's decision.
>
> (3) The Secretary of State must decide the application in accordance with any relevant national policy statement, except to the extent that one or more of subsections (4) to (8) applies.

> (4) This subsection applies if the Secretary of State is satisfied that deciding the application in accordance with any relevant national policy statement would lead to the United Kingdom being in breach of any of its international obligations.
>
> (5) This subsection applies if the Secretary of State is satisfied that deciding the application in accordance with any relevant national policy statement would lead to the Secretary of State being in breach of any duty imposed on the Secretary of State by or under any enactment.
>
> (6) This subsection applies if the Secretary of State is satisfied that deciding the application in accordance with any relevant national policy statement would be unlawful by virtue of any enactment.
>
> (7) This subsection applies if the Secretary of State is satisfied that the adverse impact of the proposed development would outweigh its benefits.
>
> (8) This subsection applies if the Secretary of State is satisfied that any condition prescribed for deciding an application otherwise than in accordance with a national policy statement is met.
>
> (9) For the avoidance of doubt, the fact that any relevant national policy statement identifies a location as suitable (or potentially suitable) for a particular description of development does not prevent one or more of subsections (4) to (8) from applying."

11. Section 104(2)(d), allows the Secretary of State to exercise a judgment on whether he should take into account any matters which are relevant, but not mandatory, material considerations. This reflects the well-established line of authority which includes *CREEDNZ v Governor General* [1981] NZLR 172, 183; *In Re Findlay* [1985] AC 318, 333-334; *Oxton Farm v Harrogate Borough Council* [2020] EWCA Civ 805 at [8]; and *Friends of the Earth* [2020] UKSC 52 at [116] to [120].

12. When determining an application for development consent, section 114 requires the Secretary of State either to make a DCO or to refuse such consent. Section 116 requires the Secretary of State to prepare and publish a statement of the reasons for his decision.

13. Section 115 enables a DCO to be granted not only for development of the defined categories of nationally significant infrastructure projects ("NSIPs") requiring development consent (Part 3 and s.31 of PA 2008), but also for "associated development" as defined in s.115(2) to (4).

14. A decision to grant a DCO is liable to be challenged by way of judicial review under s.118(1) of PA 2008. The general principles upon which a legal challenge may be

brought were summarised by the High Court in *ClientEarth* at [2020] PTSR [98] to [100].

Environmental Impact Assessment

15. The relevant legislation on environmental impact assessment ("EIA") for the determination of the Vanguard application was Directive 2011/92/EU, which, in relation to DCO procedures, was transposed by the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 (SI 2009 No. 2263) as amended ("the 2009 Regulations"). The 2011 Directive was amended by Directive 2014/52/EU, but the latter does not apply to a project for which a screening opinion was sought before 16 May 2017 (article 3(2) of the 2014 Directive). The 2014 Directive was transposed by the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (SI 2017 No. 572) ("the 2017 Regulations"), regulation 37(2) of which gave effect to the transitional provisions of the 2014 Directive. In the present case NVL sought a scoping opinion on 3 October 2016 and so it is common ground that the 2009 Regulations governed the EIA process in this case.

16. Paragraph 1.5.4 of the ExAR records that NVL decided voluntarily to prepare the ES in accordance with the 2017 Regulations and the statement submitted was examined in accordance with those regulations. The Defendant's decision letter appears to have proceeded on that basis (see e.g. DL 14.1). Nevertheless, no authority has been cited to show that the subsequent regulations can be treated as applying on a consensual basis for the purposes of determining a judicial review under s. 118. This judgment therefore refers to the 2009 Regulations. Fortunately, it is common ground that there are no relevant differences between the 2009 and 2017 Regulations affecting the merits of the grounds of challenge.

17. Regulation 3(2) provides: -

> "Where this regulation applies, the Secretary of State or relevant authority (as the case maybe) must not (in the case of the Secretary of State) make an order granting development consent or (in the case of the relevant authority) grant subsequent consent unless it has first taken the environmental information into consideration, and it must state in its decision that it has done so."

18. "Environmental information" is defined in regulation 2(1) as follows: -

> *"environmental information"* means the environmental statement (or in the case of a subsequent application, the updated environmental statement), including any further information and any other information, any representations made by any body required by these Regulations to be invited to make representations, and any representations duly made by any other person about the environmental effects of the development and of any associated development,"

"Environmental information" therefore covers all information which is obtained through the overall EIA process, which includes the ES and representations in response to the statutory publicity and consultation procedures.

19. "Environmental statement" is defined in regulation 2(1) as follows: -

> *"environmental statement"* means a statement—
>
> (a) that includes such of the information referred to in Part 1 of Schedule 4 as is reasonably required to assess the environmental effects of the development and of any associated development and which the applicant can, having regard in particular to current knowledge and methods of assessment, reasonably be required to compile; but
>
> (b) that includes at least the information referred to in Part 2 of Schedule 4."

20. Schedule 4 defines information for inclusion in the ES. Part 1 includes the following: -

> "17. Description of the development, including in particular—
>
> (a) a description of the physical characteristics of the whole development and the land-use requirements during the construction and operational phases;
>
> (b) a description of the main characteristics of the production processes, for instance, nature and quantity of the materials used;
>
> (c) an estimate, by type and quantity, of expected residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc) resulting from the operation of the proposed development.
>
> 18. An outline of the main alternatives studied by the applicant and an indication of the main reasons for the applicant's choice, taking into account the environmental effects.
>
> 19. A description of the aspects of the environment likely to be significantly affected by the development, including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, landscape and the inter-relationship between the above factors.
>
> 20. A description of the likely significant effects of the development on the environment, which should cover the direct effects in any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the development, resulting from:

> (a) The existence of the development;
>
> (b) The use of natural resources;
>
> (c) The emission of pollutants, the creation of nuisances and the elimination of waste,
>
> and the description by the application of the forecasting methods used to assess the effects on the environment.
>
> 21. A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment."

21. Part 2 of schedule 4 lists the following information which must be provided: -

> "24. A description of the development comprising information on the site, design and size of the development.
>
> 25. A description of the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects.
>
> 26. The data required to identify and assess the main effects which the development is likely to have on the environment.
>
> 27. An outline of the main alternatives studied by the applicant and an indication of the main reasons for the applicant's choice, taking into account the environmental effects.
>
> 28. A non-technical summary of the information provided under paragraphs 1 to 4 of this Part."

22. Under regulation 17(2), where the Examining Authority or the Secretary of State consider that the ES ought to contain further information they must, under regulation 17(1), issue a statement giving clearly and precisely the full reasons for that conclusion and suspend consideration of the application for a DCO until the applicant has provided the further information and the requirements in regulation 17(3) are satisfied. Those requirements include further consultation with the designated consultation bodies and other parties and publicity to enable representations to be made.

23. Alternatively, where the Examining Authority does not consider that additional information ought to be included in the ES, it may request an "interested party" to supply that material under rule 17 of the Infrastructure Planning (Examination Procedure) Rules 2010 (SI 2010 No. 103) ("the 2010 Rules"). By rule 2(1) an "interested party" refers to a person who is an "interested party" for the purposes of Chapter 4 of Part 6 of the PA 2008. By s. 102(1) of that Act an "interested party" includes the applicant for the DCO. Rule 17(2) requires the examining authority to consider whether an opportunity should be given to all interested parties to comment in writing on the further information received.

24. Regulation 23 of the 2009 Regulations sets out a number of requirements for the notification of the decision on the application for a DCO. Regulation 23(2)(d), requires

a statement to be made publicly available which sets out (inter alia) the main reasons and considerations on which the decision has been based and a description of the main measures to avoid, reduce and offset, the "major adverse effects" of the development.

National Policy Statements

25. Three National Policy Statements were relevant to the application: NPS EN-1 (Overarching National Policy Statement for Energy), NPS EN-3 (Renewable Electricity Generation) and NPS EN-5 (Electricity Networks Infrastructure). NPS EN-1 applies in combination with the relevant technology-specific NPSs.

26. Part 3 of NPS 1 establishes the need for new energy NSIPs. Applications for energy infrastructure falling within its scope are to be assessed on the basis that "the Government has demonstrated that there is a need for these types of infrastructure and that the scale and urgency of that need is as described for each of them in this part" (Paragraph 3.1.3). Substantial weight should be given to the contribution which a project would make towards satisfying that need (paragraph 3.1.4).

27. There is an established urgent need for new, and particularly low carbon, energy NSIPs to be brought forward as soon as possible (paragraph 3.3.15 of EN-1). Section 3.4 of EN-1 sets out the importance of the large-scale deployment of renewable sources of energy for tackling climate change. Offshore wind projects are expected to make the single largest contribution towards renewable energy generation targets (paragraph 3.4.3). The need for such projects is "urgent" (paragraph 3.4.5).

28. Part 4 of EN-1 sets out certain "Assessment Principles" for DCO applications. Paragraph 4.1.2 refers to a presumption in favour of granting consent "unless any more specific and relevant policies set out in the relevant NPSs clearly indicate that consent should be refused" and subject also to s.104 of the PA 2008 (paragraph 4.1.2).

29. Section 4.2 of EN-1 deals with the 2009 Regulations. Paragraphs 4.2.5 to 4.2.8 deal with cumulative effects and cases where details of certain aspects of a project have yet to be finalised: -

> "4.2.5 When considering cumulative effects, the ES should provide information on how the effects of the applicant's proposal would combine and interact with the effects of other development (including projects for which consent has been sought or granted, as well as those already in existence). The IPC may also have other evidence before it, for example from appraisals of sustainability of any relevant NPSs or development plans, on such effects and potential interactions. Any such information may assist the IPC in reaching decisions on proposals and on mitigation measures that may be required.
>
> 4.2.6 The IPC should consider how the accumulation of, and interrelationship between, effects might affect the environment, economy and or community as a whole, even though they may be acceptable when considered on an individual basis with mitigation measures in place.

> 4.2.7 In some instances it may not be possible at the time of the application for development consent for all aspects of the proposal to have been settled in precise detail. Where this is the case, the applicant should explain in its application which elements of the proposal have yet to be finalised, and the reasons why this is the case.
>
> 4.2.8 Where some details are still be to be finalised, the ES should set out, to the best of the applicant's knowledge, what the maximum extent of the proposed development may be in terms of site and plant specifications, and assess on that basis, the effects which the project could have to ensure that the impacts of the project as it may be constructed have been properly assessed."

Following the changes made by the Localism Act 2011, references to the Infrastructure Planning Commission ("IPC") now relate to the Secretary of State.

30. Paragraph 4.2.8 of EN-1 accords with well-known principles set out in *R v Rochdale Metropolitan Borough Council ex parte Milne* [2001] Env. L.R. 406. In the present case NVL's application proposals for the Vanguard infrastructure at Necton were presented as a "Rochdale envelope". That is, because certain design details remained to be determined subsequently, the DCO application defined the parameters within which the buildings would be constructed, and the ES assessed the environmental effects of the proposals by reference to those parameters and any flexibility they involved. The DCO granted by the Defendant authorised the "Works" within those parameters (see [41] below).

31. Section 4.4 of EN-1 deals with alternatives to an applicant's proposal. Paragraph 4.4.3 states that alternatives which are vague or inchoate may be discounted.

32. Part 5 of EN-1 addresses impacts which are common to all types of energy infrastructure, that is "generic impacts", including landscape and visual impacts (section 5.9). Paragraph 5.9.14 states: -

> "Outside nationally designated areas, there are local landscapes that may be highly valued locally and protected by local designation. Where a local development document in England or a local development plan in Wales has policies based on landscape character assessment, these should be paid particular attention. However, local landscape designations should not be used in themselves to refuse consent, as this may unduly restrict acceptable development."

33. On the subject of infrastructure for connections to the National Grid, paragraph 2.6.36 of EN-3 states: -

> "When considering grid connection issues, the IPC should be mindful of the constraints of the regulatory regime for offshore transmission networks. At the time of the application, the applicant may or may not have secured a connection with the

> network operator into the onshore transmission network and is unlikely to know who will own and manage the offshore transmission assets required for the wind farm."

The Proposals

34. The Vanguard wind array would be located in two areas approximately 47 km from the shore. The export capacity of the generating station would be 1.8 GW providing for up to 1.3m UK households or the equivalent of 2% of the UK's annual energy demand. The initial proposal was for a maximum of 200 turbines, with a maximum hub height of 200m and a maximum blade tip height of 350m. During the course of the examination the number of turbines was reduced to 158.

35. The buried onshore cable would run between the landfall at Happisburgh to Necton, some 60 km away. The Vanguard substation would be located to the east of an existing National Grid Substation (ExAR paragraph 2.1.4).

36. Paragraph 2.1.8 of the ExAR noted that NVL's parent company, Vattenfall Wind Power Limited, was also developing Boreas, which would share with Vanguard a grid connection location as well as much of the offshore and onshore cable corridors. The Vanguard DCO would also include some enabling works for Boreas, including installation of ducts along the entirety of the onshore cable route from Happisburgh to the Necton National Grid connection and overhead line modifications.

37. Chapter 4 of the ES addressed NVL's site selection process. This was summarised in paragraphs 4.4.5 to 4.4.8 of the ExAR. The offshore location was limited to areas within the East Anglia Zone which formed part of the Crown Estate's Round 3 Offshore Wind Farm development process. The developer adopted a strategic approach to Vanguard and Boreas, which included site selection based on the co-location of both projects. An iterative process resulted in the identification of the most suitable locations, having regard to technical constraints and environmental impacts. Following the identification of the offshore areas for Vanguard and Boreas, site selection addressed offshore cable corridor routes and a landfall with the aim of avoiding "high level designations". Three potential landfall sites were identified, from which the one at Happisburgh was selected. Then, National Grid Electricity Transmission plc and NVL worked on the identification of a National Grid connection point. This led to a grid connection offer being made by National Grid plc which NVL accepted in November 2016. Following that exercise, the offshore cable corridor was further refined, and the landfall site was finally selected.

38. The design work on Vanguard and Boreas sought to achieve synergies between the two projects. So, ducts for both projects would be installed along the onshore cable route as part of the Vanguard works, reducing construction times and avoiding the need to reopen land at a later date to install ducts for Boreas.

39. All search areas for a National Grid connection point were identified on the basis that they should be capable of accommodating infrastructure for connections by *both* Vanguard and Boreas (Chapter 4 of the ES paragraphs 4 and 47 and table 4.1). The working width of the cable corridor during construction is up to 45m. A width of 20m is required permanently for the majority of that route. Land acquisition under the Vanguard DCO includes land needed for works to connect Boreas cables to the

National Grid (see paragraphs 7.7.6, 7.7.9 and 7.7.37 of NVL's Statement of Reasons for compulsory purchase powers in the DCO).

40. NVL further explained their approach in a document entitled "A strategic approach to selecting a grid connection point for Norfolk Vanguard and Norfolk Boreas" (October 2018). Paragraph 11 stated: -

> "From the outset of development, it was clear to VWPL that it would be more efficient to take a strategic approach to developing the projects. Geographically the projects are close to each other and therefore, the co-location of both projects offers opportunities to explore synergies that might reduce development and operations costs and reduce both regional and local impacts"

Paragraph 18 added that NVL elected to seek common connection points to the National Grid for both Vanguard and Boreas. Paragraph 12 explained that the development programmes for the two projects were only a year apart.

41. Schedule 1 to the DCO defines the works authorised by the Order. They include the two Vanguard substation buildings (Work No. 8A) and the Vanguard extension to the existing National Grid substation at Necton (Work No. 10A). Part 3 of the schedule sets out the "requirements" (which are analogous to conditions imposed on a planning permission) subject to which consent is granted by article 3. Requirement 16 sets out design parameters for onshore works. The area of the fenced compound for Work No. 8A must not exceed 250m by 300m. The total footprint of each of the two buildings in Work 8A must not exceed 110m by 70m and their height must not exceed 19m. The area of the fenced compound for Work No. 10A must not exceed 200m by 150m. The height of the external electrical equipment in Work No 10A may be up to 15m.

42. There was no dispute at the hearing that if Boreas were to be connected to the National Grid at Necton, it would require its own dedicated substation and an extension to the existing National Grid substation, both on a similar scale to the works proposed for Vanguard, along with the associated external electrical equipment. In broad terms the scale of development outside Necton would be doubled. On any view, the development proposed at Necton would be substantial.

Assessment of Cumulative Impacts

43. In November 2016 the Planning Inspectorate issued a Scoping Opinion for the ES that was to be submitted. It stated that, in the assessment of cumulative impacts, other major developments should be identified through consultation with relevant authorities, including projects in the National Infrastructure programme. Boreas was specifically identified in relation to the substation proposals at Necton. Although some cumulative landscape impacts were scoped out of the ES (e.g. offshore infrastructure), those relating to co-located substation development at Necton were not.

44. By the time the ES for the Vanguard project was submitted in June 2018, substantial progress had already been made on Boreas. Grid connection agreements at Necton had been entered into for Vanguard in July 2016 and Boreas in November 2016. The site selection process had already identified preferred substation footprints for both

Vanguard and Boreas. The decision had been taken to use HVDC technology for both developments, determining the nature and scale of onshore infrastructure, including substations at Necton. The Boreas team had a pre-application meeting with the Planning Inspectorate on 24 January 2017, a request for a scoping opinion in respect of Boreas was made in May 2017 and the opinion issued in June 2017.

45. Indeed, paragraph 30 of chapter 33 of the Vanguard ES stated that in view of the request for a scoping opinion for Boreas, the "sister project" to Vanguard, Boreas was included in the cumulative impact assessment, adding: -

> "These projects have been considered for CIA only in those chapters where it is considered that the Scoping Reports contain sufficient detail with which to undertake a meaningful assessment."

Accordingly, where the Vanguard ES assessed cumulative impacts for that project together with Boreas, NVL considered that there was sufficient information available for that assessment to be carried out.

46. Table 33.3, dealing with projects included for cumulative impact assessment of onshore elements, stated that the "status" of the project data for Boreas in relation to landscape and visual impacts was "high". Paragraph 158 of chapter 29 of the ES, dealing with landscape and visual impact, stated:-

> "The development most relevant to the CIA for the Norfolk Vanguard onshore project substation and National Grid substation is the Norfolk Boreas onshore project substation and National Grid substation extension. The cumulative scenario considered in the assessment comprises these developments in the context of the existing Necton National Grid substation and Dudgeon substation."

47. Paragraph 23 of schedule 4 of the 2009 Regulations enables a developer to indicate in the ES any difficulties encountered in compiling the required information. Here there was no suggestion in the ES, or elsewhere, that NVL had found any difficulties in providing information on cumulative visual and landscape impacts from the Vanguard and Boreas developments at Necton. That issue was never raised during the examination. NVL's position did not change on this point during the DCO process.

48. Chapter 29 of the ES followed a conventional approach for EIA. The objective was to identify any "significant effects" of the project on "the landscape and visual resource" (paragraph 22). This approach reflects recital (7) and Article 2(1) of Directive 2011/92/EU and regulations 2(1) and 3(2), together with schedule 4, of the 2009 Regulations. Paragraph 32 in chapter 29 of the ES stated that the guiding principle in preparing the cumulative impact assessment had been to focus on the likely significant impacts and, in particular, those likely to influence the outcome of the DCO process.

49. The ES explained that the significance of effects was assessed as a combination of (i) the sensitivity of the landscape or visual receptor and (ii) the magnitude of the change resulting from the project. To count as a "significant" effect, either the sensitivity or magnitude of change had to be assessed as being at least "high" or "medium/high". If

both factors were assessed as “medium/low”, “low”, or “negligible”, the effect was not treated as “significant”.

50. The assessments of cumulative impacts were presented in table 29.17 of the ES and summarised in paragraph 174 of chapter 29: -

> “Table 29.17 shows the detail of the assessment for each receptor. In summary, the onshore project substation and National Grid substation extension for Norfolk Vanguard in conjunction with the onshore project substation and National Grid substation extension for Norfolk Boreas would have a significant cumulative effect on landscape character in the localised parts of the Settled Tributary Farmland LCT – River Wissey Tributary Farmland LCU and Plateau Farmland LCT – Beeston Plateau LCU and Pickenham Plateau LCU but would not have significant effects on the remaining parts and all other LCUs. In respect of the representative viewpoints, significant cumulative effects would arise from Lodge Lane to the immediate south of the site and a very localised section of Ivy Todd Road to the south-west. These effects would all occur within 1.2 km of the onshore project substation, making them localised.”

It is to be noted that the term “localised” was simply used to describe effects occurring within 1.2 km of the substation development.

51. Mr Phillpot QC pointed out that language very similar to that in paragraph 174 was also used in another part of the ES to describe the effects of the Vanguard substation development. In my judgment that point is of little, if any, significance for two reasons. First, the term “significant” covers a range of effects involving varying degrees of harm. Thus, the broad categorisation of an effect as “significant” does not mean that solus and cumulative effects so classified are in fact equivalent. Second, the more detailed comments in the ES on cumulative impacts recognised, for example, the effects of the proposed “concentration of these large-scale energy developments” in a rural area. In any event, it should be noted that several objectors made representations during the examination that the cumulative impacts would be more harmful than had been assessed in the ES.

52. It became common ground during the hearing before me that the ES presented the same type and level of detail on the Vanguard and Boreas projects in order to assess the impacts on landscape and visual receptors, whether considering Vanguard in isolation or in combination with Boreas. In both cases the details provided were consistent with a “Rochdale envelope” approach.

53. The ES presented proposals for strategic landscape mitigation, including “embedded mitigation”, for both the Vanguard substation development as a solus project and the Vanguard and Boreas schemes together (see e.g. section 4.5.14 in chapter 4, paragraph 175 and table 29.17 in chapter 29).

The Examination

54. Both the Claimant and other parties in the examination raised objections to the cumulative landscape and visual impacts of the Vanguard and Boreas projects.

55. The local planning authority, Breckland Council, submitted a Local Impact Report under s.60(3) of the PA 2008. When taking his decision, the Defendant was obliged to take this document into account (s.104(2)). Although it appears to have been supportive of the principle of the Vanguard project, the Council did express substantial concerns about the substation development near Necton: -

> "The predicted change in the form of development is of considerable magnitude and size. It is considered that the proposed extension to the existing National Grid substation in Necton would appear as a disproportionate additional development in the countryside. By more than doubling the size of the floor area to cover 51,000 square metres supporting a built height of up to 15 metres would not usually be allowed by the Local Planning Authority except in very special circumstances. Adding to this the 75,000 square metre new substation for the 19 metre tall HVDC convertor station with higher lightning masts, (potentially together with the Boreas development), then land coverage comparable with the core centre of Necton itself, with structures extending much further into the air, would be the outcome.
>
> It is appreciated that the Applicant has gone to considerable lengths in assessing visibility and the photomontages produced are helpful. However, on the ground it would be extremely difficult to screen a development of this huge scale. This is defined as a national infrastructure project for a reason and it will appear disproportionately dominant against the landscape which is remote from Necton. The new structures would be of such a size that the perceived distance from the A47 would appear relatively short. This would be a prominent and obtrusive feature against the skyline.
>
> The cumulative landscape and visual effects of the development would create negative disbenefits in planning terms. The Secretary of State for Energy must therefore balance the advantages of this major renewable energy project with these negative effects."

Plainly these observations were directed at both solus and cumulative effects on what was described as a "sensitive landscape and visual resource."

56. A number of the parties made representations about the dominant and disproportionate effects of the proposed substation development for Vanguard and, even more so, the cumulative effects of both schemes. They included the Necton Substation Action Group, Necton Parish Council and individual objectors. They took issue with the impact assessment in the ES and they asked that the DCO be rejected because of the unacceptable impact of the substation development. For example, the Parish Council referred to the "huge magnitude" of the change to the area and objected to the

development of the "largest substation in Europe" "beside a small village in a rural environment." Some objectors put forward alternatives for a connection to the National Grid away from Necton.

57. In its report the Examining Authority accepted that there is a strong need for the Vanguard project, supported by the NPSs. Vanguard would be one of "the biggest offshore-wind projects in the world" and together with Boreas could prevent more than 4m tCO_2 from entering the atmosphere (paragraphs 4.2.13 to 4.2.15).

58. The Examining Authority reviewed alternative locations for onshore infrastructure, notably the connection point to the National Grid (ExAR paragraphs 4.4.9 to 4.4.33). It found that NVL had made reasonable decisions on alternatives after following an appropriate process. NVL had narrowed down the choice to three locations, Necton, Norwich Main and Eye. It appears that a connection at Eye was unlikely to be achievable "within the required time-frames". Necton was then preferred because of the greater "environmental and other implications" for Norwich Main.

59. The Examining Authority noted the strongly held view of several participants that in view of the number of offshore wind farm projects coming forward in the region, there should be a strategic approach requiring contributions to an offshore ring main to avoid or reduce onshore environmental impacts. The Authority considered that because that would require co-ordination between projects, it was not an alternative which could be considered within the remit of an examination of a single offshore wind farm project. Although it is not apparent how well that reasoning sits with the requirements of the 2009 Regulations, particularly as the Examining Authority did consider elsewhere cumulative impacts resulting from a project being undertaken by an independent developer, no such argument was raised in the grounds of challenge. That is understandable in view of the way in which the Defendant discounted this particular alternative on the merits in his decision letter (see [71] below).

60. The Examining Authority summarised objections to landscape and visual impacts at Necton (paragraph 4.5.18 to 4.5.23 of the ExAR). It accepted that the Vanguard development could not be completely screened and would result in a material change to the landscape character and visual characteristics of the locality (paragraph 4.5.35). It noted that the substation location is not subject to any national or local landscape designations denoting a special sensitivity (paragraph 4.5.46). The Authority set out its assessments of the effects of the Vanguard substation development as a solus project at paragraphs 4.5.46 to 4.5.60 of the ExAR. It accepted that the impacts would be "localised" in that they would only occur within 1.2 km of the Vanguard substations (paragraphs 4.5.54 and 4.5.60). There would be no significant effects on the views of residents in Necton. The Examining Authority addressed the cumulative impacts of the proposed Vanguard buildings and came to the view that although members of the public "would be conscious of two large-scale energy plants in the locality", those "views would be localised and there would not be other views of the totality of the project" (paragraph 4.5.62 of the ExAR). It is common ground that these findings did not address the cumulative impacts of substation development at Necton for both Vanguard and Boreas.

61. Paragraphs 4.5.97 to 4.5.101 of the ExAR assessed cumulative impacts of Vanguard and another offshore wind farm project, Hornsea Project Three, ("Hornsea") located in the vicinity of the two Vattenfall projects. Hornsea was being brought forward

simultaneously with Vanguard but by a different developer. The cable corridor for Hornsea linking to the National Grid at Norwich Main would cross the cable corridor for the Vattenfall projects at Reepham near the Claimant's home. On 1 July 2020 (the day on which the DCO for Vanguard was granted) the Defendant issued a decision letter stating that he was minded to grant a DCO for Hornsea, subject to the resolution of certain matters. The DCO was in in fact granted on 31 December 2020.

62. However, in paragraph 4.5.102 of ExAR the Examining Authority took a different approach to the assessment of the cumulative landscape and visual impacts of Vanguard and Boreas :-

> "Finally, whilst the Norfolk Boreas Offshore wind farm has been included in the Applicant's LVIA cumulative impact assessment, the ExA have not considered it in this part of the assessment due to the limited amount of details available. The ExA considers it would most appropriate for cumulative impacts to be considered in any future examination into Norfolk Boreas." (sic)

63. At paragraph 4.5.114 of the ExAR the Examining Authority said:-

> "The impacts of the development in landscape terms would be generally acceptable save for the localised harm to visual amenity in relation to the substation and associated works. In this respect the proposal would not be in full conformity with Breckland Core Strategy DP11 and DC15. Given the localised nature of the permanent harm the ExA ascribes limited weight to it in the overall planning balance."

This passage related solely to the effects of Vanguard in isolation and not the cumulative effects of Vanguard and Boreas. Nevertheless, it is plain that the solus effects were not regarded as being "acceptable". But purely because of the "localised effect" of the permanent harm that would be caused, the Examining Authority gave limited weight to this factor in the overall planning balance. Plainly, they left unresolved the issue as to how much harm would be caused (including harm within a radius of 1.2km) if both the Vanguard and the Boreas substation developments were to proceed and development on that scale were to take place in the vicinity of Necton.

64. The Examining Authority set out its analysis and conclusions on the Habitats Regulations Assessment under The Conservation of Habitats and Species Regulations 2017 (SI 2017 No. 1012) in chapter 6 of its report. It dealt with cumulative effects with the Boreas project, for example at paragraphs 6.7.167 to 6.7.181 of the ExAR. NVL had agreed with Natural England that these effects had to be considered so as to ensure that mitigation solutions would be compatible for both projects.

65. The Examining Authority set out its overall conclusion on the case for granting development consent in chapter 7 of its report. In relation to landscape and visual impacts the Authority concluded at paragraph 7.3.9: -

> "In terms of landscape effects there would be no significant effects upon landscape character or visual amenity other than

> for limited localised effects on visual amenity in the vicinity of the substation. Significant localised landscape character effects, as a result of the new substation and substation extension, would reduce to moderate after 10 years. Along the onshore cable route and at landfall any effects would be temporary and localised. Subject to the mitigation measures to be secured through the Requirements, the ExA concludes that proposal would accord with the policy requirements of NPS EN-1 and EN-3 and would not cause material harm to key characteristics protected by relevant development plan policies."

66. The Examining Authority struck the overall balance in paragraph 7.3.26:-

> "Many of the principal issues have been resolved to the satisfaction of the ExA or are capable of resolution subject to the recommended changes to the DCO. Excepting the offshore ecology matters, the ExA concludes that, in relation to all other matters, the Proposed Development would be in accordance with NPSs and national policy objectives. When these matters are taken into account the ExA concludes that, in a general planning balance the benefits of the scheme in terms of the large-scale generation of renewable energy and its contribution to sustainable development objectives substantially outweigh the limited harms which have been set out above."

67. In chapter 10 of its report, the Examining Authority summarised its conclusions for the purposes of applying the provisions in s.104 of the PA 2008. They were in line with their conclusions in chapter 7.

The Decision Letter

68. The Defendant's decision letter mainly summarised and accepted the conclusions of the Examining Authority.

69. The Defendant regarded the contribution which would be made to the decarbonisation of the electricity generation sector as a significant benefit (DL 3.5). DL 4.3 referred to the policy in EN-1 that the assessment should begin with a presumption in favour of granting development consent for electricity generating stations in general and offshore wind farms in particular (DL 4.3 and 4.4). The Defendant added: -

> " granting development consent for the Development would be consistent with government policy and will contribute to the delivery of low-carbon and renewable energy, ensuring a secure, diverse and affordable energy supply in line with legal commitments to "net zero" and the need to address climate change. "

70. The Defendant assessed alternatives at DL 4.5 to 4.11. He agreed with the Examining Authority that NVL had undertaken a reasonable process for considering alternatives when finalising its site options (DL 4.10).

71. As to the suggestion that an offshore ring main be considered, the Defendant concluded at DL 4.11: -

> "Whilst discussions are taking place in respect of the future shape of the offshore transmission network, such discussions are at the preliminary stage. The Secretary of State considers that he must assess the Development in line with current policy as set out in the National Policy Statements. He does not consider that the decision should be delayed to await the outcome of the discussions on the offshore transmission network given the urgent need for offshore wind development as identified in the National Policy Statements."

72. The Defendant summarised the views of the Examining Authority on landscape and visual impacts at DL 4.12 to 4.49. He noted that the substation location is not within any designated landscape area (DL 4.27). In DL 4.46 the Defendant referred to the Authority's conclusions on cumulative impact in ExAR 4.5.102:-

> "The ExA notes that, while the Applicant's Landscape and Visual Impact Assessment cumulative assessment included the proposed Norfolk Boreas offshore wind farm, it was not considered by the ExA because of the limited information available on that project. The ExA concluded, therefore, that this matter should be considered in the future as part of the examination of the development consent application for the Norfolk Boreas offshore wind farm."

73. In DL 7.4 the Defendant stated: -

> "The Secretary of State notes that there were a range of views about the potential impacts of the Development with strong concerns expressed about the impacts on, among other things, the landscape around the substation, traffic and transport impacts and potential contamination effects at the site of the F-16 plane crash. However, he has had regard to the ExA's consideration of these matters and to the mitigation measures that would be put in place to minimise those impacts wherever possible. The Secretary of State considers that findings in the ExA's Report and the conclusions of the HRA together with the strong endorsement of offshore wind electricity generation in NPS EN-1 and NPS EN-3 mean that, on balance, the benefits of the proposed Development outweigh its adverse impacts. He, therefore, concludes that development consent should be granted in respect of the Development."

74. In DL 8.4 the Defendant dealt with a post-examination representation from a member of the public proposing an alternative location for the Vanguard substations: -

> "A member of the public wrote to suggest that the Secretary of State should seek to move the site of the Necton substations to a new site in the vicinity to lower its visual impact. However,

> the proposed location would need to be subject to a new application for consent (as it does not form part of the Application submitted by the Applicant) and the ExA considered that the locations of the substations proposed by the Applicant were acceptable (while acknowledging that there would be localised visual impacts). In this situation, the Secretary of State does not believe that there is any need to consider an alternative location where an existing proposal is acceptable."

The grounds of challenge: a summary of the parties' submissions

75. I am grateful to all counsel for their clear and helpful written and oral submissions. In this section I simply give a brief summary of those submissions to provide context for the conclusions I reach.

76. Mr Westaway submitted that the Defendant had unlawfully excluded from consideration the cumulative landscape and visual impacts of Vanguard and Boreas in the Necton area. He expressed this initially as a breach of regulation 3(2) of the 2009 Regulations, alternatively a failure to determine the application in accordance with policies in the NPSs (see s.104(3) of the PA 2008), or a failure to take into account an obviously material consideration (see the *CREEDNZ* line of authority). He pointed out that the ES itself had treated Boreas as a relevant project for the purposes of assessing the environmental impact of Vanguard, not least because of co-located and shared infrastructure, notably the 60 km cable corridor from Happisburgh to Necton and the National Grid connection points there. The ES assessed the cumulative landscape and visual impacts on the basis that there was sufficient information available on Boreas to enable that exercise to be carried out. It had arrived at the conclusion that the impacts were significant.

77. Mr Moules submitted for the Defendant (and Mr Phillpot QC adopted his submissions on behalf of NVL) that in this case the Defendant did take into account the material on cumulative impacts, but, because of the limited information available on Boreas, he deferred his decision on how those impacts should be evaluated and weighed to the DCO process on Boreas.

78. The Claimant submits that that decision was irrational. The same type and amount of information was available for Boreas as for Vanguard and yet the solus effects of the latter were assessed by the Defendant in his decision. The lack of information is the sole reason given for the decision to defer, but this was not raised by the Examining Authority during the examination, nor by any participant. So, it is not possible to identify any other explanation from that process. NVL plainly did not consider that the material they had provided on cumulative impacts was inadequate so that those impacts could not be assessed in the decision on the Vanguard DCO. The shared infrastructure and co-location aspects (including combined mitigation) of the two "sister" projects made it necessary for cumulative impacts to be assessed in the decision on the Vanguard DCO. Any deficiencies in the material provided should have been identified by the Examining Authority so that additional information could be requested under regulation 17 of the 2009 Regulations or rule 17 of the 2010 Rules.

79. Mr Westaway reinforces his submission by drawing attention to the effect of the decision to grant the Vanguard DCO on decision-making on the Boreas proposal. By the time the examination of the Boreas application began, the Vanguard DCO had become part of the baseline for the assessment of the environmental impacts of Boreas. Moreover, it would be said in the examination of Boreas, that that proposal should be judged on the basis that Vanguard had already been found to be acceptable. In other words, the decision on Vanguard has a "precedent" effect. He points to a Vattenfall document in the Boreas examination entitled "Implications of the Norfolk Vanguard Decision and Hornsea Three Letter on Norfolk Boreas," where the promoter relies on the similarities of its two projects and says that the Defendant would need to give very clear reasons for departing from his decision on Vanguard. At paragraph 2.2 the promoter relies upon the "consistency" principle established in the line of authorities beginning with *North Wiltshire District Council v Secretary of State for the Environment* (1993) 65 P & CR 137. The document relies upon "principles" which are common to both Vanguard and Boreas, including the sharing of the same cable corridor and the similarity of the substation development at Necton to achieve a connection to the National Grid. Mr Westaway says that the cumulative effects of both projects upon landscape and visual receptors in the Necton area were not evaluated and weighed by the Defendant before he granted consent for the first project, which decision has a significant "precedent" effect in the determination of the Boreas DCO application.

80. Under ground 2, the Claimant relies essentially upon the same arguments and submits that the reasons given by the Examining Authority and the Defendant on the cumulative impact issue were legally inadequate. Nothing was said as to why the information provided was insufficient, so that any inadequacy could be remedied, whether in the examination of Vanguard or of Boreas. Nothing was said as to why it was thought appropriate to defer the cumulative assessment, other than the unexplained "limited information" on Boreas. This is a case where the inadequacy of the reasoning creates a substantial doubt as to whether the decision-maker has erred in law (*South Bucks District Council v Porter (No. 2)* [2004] 1 WLR 1953 at [36]).

81. Mr Moules submitted that the Defendant has complied with regulation 3(2) of the 2009 Regulations. He did take into account the environmental information on the cumulative impacts, but he decided that it was unnecessary to evaluate that material in reaching a decision on whether the application for the Vanguard DCO should be granted, because only limited information on Boreas was available at that stage and because he judged that such cumulative effects would most appropriately be considered as part of the Boreas examination (paragraphs 46-47 of skeleton). Regulation 3(2) allows a decision-maker to note the existence of certain environmental information but to decide that it need not be an input into the determination of the application. There is no obligation to take into account or weigh every piece of environmental information when reaching that decision.

82. Mr Moules sought to support those submissions by relying upon the context for the decision on the Vanguard DCO. It was important for projects such as Vanguard to be approved without delay, and that decision should not be held up to enable cumulative effects to be assessed, particularly where the solus impacts of the Vanguard proposal did not affect any designated landscape area and were judged to have "limited weight", albeit they had been categorised as "significant effects." Mr Moules submitted that a

deferral of the cumulative assessment to the Boreas examination would also enable the overall benefits of the two projects to be properly weighed in the balance against any disbenefits.

83. Mr Phillpot QC submitted that the extent of the "Rochdale envelope" and mitigation for the Boreas application would be matters for the examination of that project. By contrast the material put forward in the Vanguard application on Boreas involved the making of assumptions about that project.

84. On the issue of whether the Defendant's judgment to defer consideration of cumulative impacts was irrational, Mr Phillpot QC asked the court to compare how the assessment of those impacts would differ in the separate examinations of the two projects. It is only the subsequent Boreas examination which could result in the authorisation of any cumulative impacts arising from the two projects after having determined their acceptability. If those impacts are unacceptable Boreas would be refused. If, however, they could be made acceptable by additional mitigation, that would be dealt with by imposing a "requirement" in the DCO granted for Boreas. The circumstances of the examination of Vanguard were different. That process could not have authorised cumulative impacts arising from both projects, irrespective of whether they were judged to be acceptable or unacceptable.

85. Mr Phillpot QC laid emphasis on the fact that the Defendant found the Vanguard proposal to be acceptable, leaving only to one side the cumulative impacts on landscape and visual resources at Necton. He submitted that, if instead those cumulative impacts had been taken into account and resulted in the refusal of consent for Vanguard, that would have been nonsensical if subsequently Boreas were to be refused on other grounds. Furthermore, if the solus effects of Vanguard were judged to be acceptable, but cumulative impacts with Boreas found to be unacceptable, that could not justify restricting the "Rochdale envelope" for the Vanguard project when granting development consent.

86. Mr Moules adopted those submissions to explain why it had been considered "most appropriate" to defer consideration of cumulative impact to the Boreas examination. But both he and Mr Phillpot QC accepted that this analysis could not be treated as a set of principles of general application. Instead, the analysis is sensitive to the circumstances of each case. He accepted that no such reasoning had been set out in the ExAR or in the decision letter, but submitted that the court should draw the inference that it had been in the mind of the Examining Authority and also the decision-maker. He relied upon the findings on the national need for Vanguard, the urgency of that need, the express rejection of alternatives and the acceptability of the solus impact of Vanguard.

Discussion

Introduction

87. Many challenges concerned with EIA allege a failure to address a particular subject in the ES. It is well-established that the judgment of the decision-maker on the adequacy of an ES may only be challenged on *Wednesbury* grounds (*Friends of the Earth* [2020] UKSC 52 at [142] to [143]). In the present case there is no such dispute. The ES did deal with the subject at the heart of this challenge. Moreover, NVL did not suggest that

they had encountered any difficulties in compiling information on cumulative impacts (paragraph 23 of schedule 4 to the 2009 Regulations). It did not ask for the consideration of cumulative impacts to be deferred to the subsequent examination of the Boreas application, whether that would be the "most appropriate" course of action, or because there was a limited amount of information available on Boreas, or for any other reason. Nor did any other participant in the examination raise any such matters.

88. The court was told that the first time that the view contained in paragraph 4.5.102 of the ExAR was revealed was when that report was published along with the decision letter on 1 July 2020. Up until then, participants in the examination had no reason to think that cumulative landscape and visual impacts would not be addressed in the ExAR and the decision letter, just as other cumulative impacts were. I am in no doubt that, in terms of the legal obligation on the Secretary of State to give reasons for his decision, the evaluation of cumulative landscape and visual impacts in the Necton area resulting from the Vanguard and Boreas grid connections was one of the important, controversial issues which had to be addressed in the decision on the Vanguard DCO, applying the test in *South Bucks District Council* at [27] and [36].

89. I note that the Claimant has not argued that the process followed was unfair because what emerged as paragraph 4.5.102 of the ExAR had not been raised beforehand. On the other hand, the fact that the points made by the Examining Authority were not raised before their report was published along with the decision letter means that their reasoning cannot be explained by what took place during the examination. Neither the Defendant nor NVL suggested otherwise. The Defendant has not filed any evidence to explain (in so far as might have been admissible) how paragraph 4.5.102 of the ExAR, or indeed DL 4.46, came about.

90. A number of points are common ground between the parties. First, in his decision letter the Defendant relied upon the conclusions of the Examining Authority in paragraph 4.5.102 of the ExAR without having the benefit of any further explanation from that Authority. Second, the Defendant did not find that the cumulative impacts at Necton, which the ES had identified as significant adverse effects, were of no significance and therefore could be set to one side for that reason. This stands in stark contrast, for example, to the combined visual effects of the offshore arrays proposed for Vanguard and Boreas which were screened out of the ES because they were judged not to be significant. Third, the Defendant has accepted that the cumulative effects at Necton do need to be assessed and weighed in a decision on consenting under the PA 2008, but has deferred that evaluation entirely to the decision on the application for the Boreas DCO.

The issues

91. It is convenient to deal with grounds 1 and 2 together. They give rise to three issues which I will address in the following order: -

(i) Did the Defendant's decision not to evaluate the cumulative impacts at Necton when determining the application for the Vanguard DCO breach the 2009 Regulations?

(ii) In any event, was the Defendant's decision not to do so irrational?

(iii) In any event, did the Defendant fail to give legally adequate reasons in relation to this issue?

Neither the Defendant nor NVL disputed that if the Claimant should succeed on any one of these issues, the Defendant's decision to grant the Vanguard DCO was unlawful. But they submitted that in those circumstances it would be necessary for the court to consider a further issue, namely whether the quashing order sought by the Claimant should be granted or refused.

92. Mr Westaway accepted that his alternative arguments under ground 1, that the Defendant had been obliged to assess the cumulative impacts by virtue of NPS policy and s.104(3) of the PA 2008, or because they were "obviously material" added nothing to the legal merits of the Claimant's argument. This is because they each depend upon the Claimant establishing that the Defendant's decision on this aspect was irrational.

93. Before going on to address the issues, it is necessary to deal with the difference between the reasoning of the Examining Authority and the Defendant. As Mr Moules said, there were two strands to the reasoning of the Authority. First, they considered the amount of detail available to be limited. Second, they thought it would be "most appropriate" for those impacts to be considered in the Boreas examination. However, they did not give any explanation of either factor to assist the Defendant in coming to a view on whether he should accept their judgment.

94. Ultimately, however, it is the Defendant's reasoning which matters for the purposes of determining this legal challenge. The Defendant only dealt with the deferral point in DL 4.46. The court has nothing else to go on, the topic not having been discussed during the examination. The Defendant has not simply said that he agreed with the Examining Authority. Instead, he has relied upon his own formulation as expressed in DL 4.46. The Defendant merely stated that the cumulative impacts should be considered in the Boreas examination because of the limited information available on that project. The Defendant's use of the word "therefore" makes it plain that the information on Boreas is the only reason he gave as to why the evaluation of the cumulative impacts should be deferred. But like the Authority, he has not given any clue as to why he considered the information available on Boreas to be "limited".

Was there a breach of the 2009 Regulations?

95. I accept the Defendant's submission that the 2009 Regulations did not require him to weigh every single piece of "environmental information" when deciding whether or not to grant development consent. But the material on cumulative impacts at Necton was not just any piece of environmental information. NVL's position was that they amounted to significant adverse environmental impacts falling within schedule 4. The Defendant did not disagree with that view. Furthermore, this information concerned an important controversial issue during the examination which had to be addressed by the Defendant through legally adequate reasoning as part of the reasons for his decision.

96. It is necessary to consider whether a decision to defer an evaluation and weighing of such impacts may in itself amount to a breach of the 2009 Regulations, in particular regulation 3(2).

97. I return to Directive 2011/92/EU. Recital (7) states: -

> "Development consent for public and private projects which are likely to have significant effects on the environment should be granted only after an assessment of the likely significant environmental effects of those projects has been carried out. That assessment should be conducted on the basis of the appropriate information supplied by the developer, which may be supplemented by the authorities and by the public likely to be concerned by the project in question."

98. Article 1 of the Directive provides: -

> "This directive shall apply to the assessment of the environmental effects of those public and private projects which are likely to have significant effects on the environment."

99. Article 2 of the Directive provides (inter alia): -

> "1. Member States shall adopt all measures necessary to ensure that before consent is given, projects likely to have significant effects on the environment by virtue, inter alia, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects. Those projects are defined in Article 4.
>
> 2. The environmental impact assessment may be integrated into the existing procedure for consent to projects in the Member States, or, failing this, into other procedures or into procedures to be established to comply with the aims of this Directive. "

100. Article 3 requires the EIA to "identify, describe and assess in an appropriate manner in the light of each individual case, and in accordance with Articles 4 to 12, the direct and indirect effects of a project" on a number of features including "the landscape."

101. Article 5(1) sets out requirements linked to Annex IV for the content of an ES to be provided by a developer: -

> "In the case of projects which pursuant to Article 4, are to be made subject to an environmental impact assessment in accordance with this Article and Article 6 to 10, Member States shall adopt the necessary measures to ensure that the developer supplies in an appropriate form the information specified in Annex IV in as much as:
>
> (a) the Member States consider that the information is relevant to a given stage of the consent procedure and to the specific characteristics of a particular project or type of project and of the environmental features likely to be affected;

> (b) the Member States consider that a developer may reasonably be required to compile this information having regard, inter alia, to current knowledge and methods of assessment."

102. It will be noted that paragraphs (a) and (b) provide criteria for making a judgment in each individual case as to the extent to which the items listed in Annex IV should be provided in an ES.

103. However, Article 5(3) of the Directive sets out minimum requirements for the content of an ES: -

> "The information to be provided by the developer in accordance with paragraph 1 shall include at least:
>
> (a) a description of the project comprising information on the site, design and size of the project;
>
> (b) a description of the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects;
>
> (c) the data required to identify and assess the main effects which the project is likely to have on the environment;
>
> (d) an outline of the main alternatives studied by the developer and an indication of the main reasons for his choice, taking into account the environmental effects;
>
> (e) a non-technical summary of the information referred to in points (a) to (d)."

104. That distinction between the obligatory and discretionary contents of an ES has been reflected in the definition of "environmental statement" in regulation 2(1) of the 2009 Regulations (see [19] above) and the two parts of schedule 4 to those regulations (see [20] to [21] above). The judgment as to *whether* a topic falling within part 1 of schedule 4 should be addressed in an ES is a matter for the authority responsible for deciding whether development consent should be granted. The *extent* to which the ES should contain information on any of the topics listed in either part 1 or part 2 of schedule 4 is also a matter for the judgment of that same authority. The authority has the power to require additional information to be provided by the developer (Article 6(2) of the Directive and regulation 17 of the 2009 Regulations).

105. Article 8 of Directive 2011/92/EU requires the information gathered and the results of consultation under articles 5, 6 and 7 to be taken into consideration in the development consent procedure. That is an obligation imposed on the decision-maker. That is how regulation 3(2) of the 2009 Regulations has transposed article 8 (see [17] above).

106. Article 9 of the Directive has been transposed by regulation 23 of the 2009 Regulations (see [24] above). The decision-maker is required to make available to the public a description of (inter alia) the "main measures" to mitigate "the major adverse

effects of the development". That requirement cannot be satisfied without the decision-maker evaluating those effects in his decision. This analysis aligns with the developer's obligation in Article 5(3) of the Directive and part 2 of Schedule 4 to the 2009 Regulations to include in the ES "the data required to identify and assess the main effects which the development is likely to have on the environment."

107. The parties agree that in this area of the law, Directive 2014/52/EU is substantially to the same effect as Directive 2011/92/EU. Recital (34) of the 2014 Directive does not indicate any intention to alter the law on decision-making significantly. The 2011 Directive is amended by the insertion of Article 8a. This has been transposed by regulations 21 and 30 of the 2017 Regulations. The decision-maker must (inter alia) reach a "reasoned conclusion" on "the significant effects of the project on the environment", taking into account his examination of the environmental information, and describe any measures to mitigate "likely significant adverse effects" on the environment. Those matters must be published (regulation 31). In my judgment, these parts of the 2017 Regulations simply express more clearly that which was already necessarily implicit in the 2009 Regulations. The drafting alteration from "main effects" to "significant effects" does not involve any significant alteration of the law. It only confirms that the rules on decision-making are aligned with the requirement that the process of EIA includes an assessment by the decision-maker of the likely significant effects of a project on the environment and the measures to mitigate those effects. In this way the legislation gives effect to the objective set out in recital (7) and the requirements in articles 1, 2 and 8 of Directive 2011/92/EU (see [98] to [100] and [105] above). Sullivan J (as he then was) adopted essentially the same approach in *ex parte Milne* at [104] and [113] when commenting on schedule 3 to SI 1988 No. 1189.

108. Although it is a matter of judgment for the decision-maker as to what are the environmental effects of a proposed project and whether they are significant, EIA legislation proceeds on the basis that he is required to evaluate and weigh those effects he considers to be significant (and any related mitigation) in the decision on whether to grant development consent (see e.g. *Commission v Ireland* [2011] Env. L.R. 478). It follows that if the decision-maker considers that a particular effect is not significant, he is not obliged to weigh that matter in his decision on whether or not development consent should be granted. Whether he need explicitly state that conclusion or give reasons for it will depend on the circumstances. For example, the matter may have been treated in the ES and by the parties as a significant environmental effect and become an important controversial issue in the examination. Subject to complying with any obligation to give reasons that may arise, a decision-maker's conclusion that an effect is not significant may only be challenged in the courts on *Wednesbury* grounds.

109. The next issue is whether consideration of an environmental effect can be deferred to a subsequent consenting process. If, for example, the decision-maker has judged that a particular environmental effect is not significant, but further information and a subsequent approval is required, a decision to defer consideration and control of that matter, for example, under a condition imposed on a planning permission, would not breach EIA legislation (see *R v Rochdale Metropolitan Borough Council ex parte Milne* [2001] Env. L.R. 406).

110. But the real question in the present case is whether the evaluation of an environmental effect can be deferred if the decision-maker treats the effect as being

significant, or does not disagree with the "environmental information" before him that it is significant? A range, or spectrum, of situations may arise, which I will not attempt to describe exhaustively.

111. In some cases, the decision-maker may be dealing with the environmental implications of a single project. In *R v Cornwall County Council ex parte Hardy* [2001] Env. L.R. 473 the court held that the local planning authority had not been entitled to grant planning permission subject to a condition which deferred a requirement for surveys to be carried out to identify whether a European species would be adversely affected by the development. The authority could only have decided that it was necessary for the surveys to be carried out and additional data obtained because they had thought that the species might be present and harmed. It was possible that that might turn out to be the case and so, in granting planning permission, the authority could not rationally have concluded that there would be no significant adverse effects in the absence of that data. Consequently, they were not entitled to defer that decision ([61] to [62]).

112. In other cases, it may be necessary to decide whether associated works form part of a single project. Once that decision is made, it may be obvious that consideration of the environmental effects of the associated works cannot be deferred. In *R (Brown) v Carlisle City Council* [2011] Env. L.R. 71 the Court of Appeal held that where the acceptability in planning terms of a proposal for a freight distribution centre was contingent upon the provision of improvements to the runway and terminal at Carlisle Airport (which was reflected in a planning obligation under s. 106 of the Town and Country Planning Act 1990), the airport improvements formed part of the overall project comprising the distribution centre. Consequently, the EIA was required to assess the cumulative environmental effects of that overall project and not just the distribution centre. That was the only rational conclusion ([25]). The fact that the airport improvements were to be dealt with in a separate planning application was nothing to the point. As Lindblom LJ explained in *Preston New Road Action Group v Secretary of State for Communities and Local Government* [2018] Env. L.R. 440, the airport works formed an integral part of the overall project which included the distribution centre. The environmental assessment of the airport works could not be deferred to a subsequent consenting procedure because they were intrinsic to the decision as to whether any part of the project should go ahead.

113. In some cases where the decision-maker is dealing with a single project, the issue of whether the evaluation of significant environmental effects may be deferred has not been so straightforward. For example, a project for the laying out of a residential or business estate may evolve over a number of years in a series of phases, led by changing market demand. At the outset planning permission may be sought in outline. In such cases there is a risk that if outline planning permission is granted for a proposal lacking in detail, significant adverse environmental impacts may only be identified at the reserved matters stage when the authority is powerless to go back on the principle of the development already approved and so cannot prevent it from taking place. A decision to defer the evaluation of a significant adverse effect and any mitigation thereof to a later stage may therefore be unlawful *(R v Rochdale Metropolitan Borough Council ex parte Tew* [2000] Env. L.R. 1, 28-31).

114. In order to comply with the principle identified in *Commission v Ireland*, and illustrated by *Tew* and *Hardy*, consideration of the details of a project defined in an

outline consent may be deferred to a subsequent process of approval, provided that (1) the likely significant effects of that project are evaluated at the outset by adequate environmental information encompassing (a) the parameters within which the proposed development would be constructed and operated (a "Rochdale envelope"), and (b) the flexibility to be allowed by that consent and (2) the ambit of the consent granted is defined by those parameters (see *ex parte Milne* at [90] and [93] to [95]). Although in *Milne* the local planning authority had deferred a decision on some matters of detail, it had not deferred a decision on any matter which was likely to have a significant effect (see Sullivan J at [126]), a test upon which the Court of Appeal lay emphasis when refusing permission to appeal (C/2000/2851 on 21 December 2000 at [38]). Those matters which were likely to have such an effect had been adequately evaluated at the outline stage.

115. Sullivan J also held in *ex parte Milne* that EIA legislation plainly envisages that the decision-maker on an application for development consent will consider the adequacy of the environmental information, including the ES. He held that what became regulation 3(2) of the 2009 Regulations imposes an obligation on the decision-maker to have regard to a "particularly material consideration", namely the "environmental information". Accordingly, if the decision-maker considers that the information about significant environmental effects is too uncertain or is inadequate, he can either require more detail or refuse consent ([94] to [95] and [106] to [111]). I would simply add that the issue of whether such information is truly inadequate in a particular case may be affected by the definition of "environmental statement", which has regard to the information which the applicant can "reasonably be required to compile" (regulation 2(1) of the 2009 Regulations - see [19] above).

116. The principle underlying *Tew, Milne* and *Hardy* can also be seen in *R (Larkfleet Limited) v South Kesteven District Council* [2016] Env. L.R. 76 when dealing with significant cumulative impacts. There, the Court of Appeal held that the local planning authority had been entitled to grant planning permission for a link road on the basis that it did not form part of a single project comprising an urban extension development. The court held:-

(i) What is in substance and reality a single project cannot be "salami-sliced" into smaller projects which fall below the relevant threshold so as to avoid EIA scrutiny ([35]);

(ii) But the mere fact that two sets of proposed works may have a cumulative effect on the environment does not make them a single project for the purposes of EIA. They may instead constitute two projects the cumulative effects of which must be assessed ([36]);

(iii) Because the scrutiny of the cumulative effects of two projects may involve less information than if they had been treated as one (e.g. where one project is brought forward before another), a planning authority should be astute to see that the developer has not sliced up a single project in order to make it easier to obtain planning permission for the first project and to get a foot in the door for the second ([37]);

(iv) Where two or more linked sets of works are properly regarded as separate projects, the objective of environmental protection is sufficiently secured by consideration of their cumulative effects in the EIA scrutiny of the first project, so far as that is reasonably possible, combined with subsequent EIA scrutiny of those impacts for the second and any subsequent projects ([38]);

(v) The ES for the first project should contain appropriate data on likely significant cumulative impacts arising from the first and second projects to the level which an applicant could reasonably be required to provide, having regard to current knowledge and methods of assessment ([29]-[30], [34] and [56]).

117. However, in some cases these principles may allow a decision-maker properly to defer the assessment of cumulative impacts arising from the subsequent development of a separate site not forming part of the same project. In *R (Littlewood) v Bassetlaw District Council* [2009] Env. L.R. 407 the court held that it had not been irrational for the local authority to grant consent for a freestanding project, without assessing cumulative impacts arising from future development of the remaining part of the site, where that development was inchoate, no proposals had been formulated and there was not any, or any adequate, information available on which a cumulative assessment could have been based (pp. 413-5 in particular [32]).

118. I agree with Mr Westaway that the circumstances of the present case are clearly distinguishable from *Littlewood.* Here, the two projects are closely linked, site selection was based on a strategy of co-location and the second project has followed on from the first after a relatively short interval. They share a considerable amount of infrastructure, they have a common location for connection to the National Grid at Necton (the cumulative impacts of which are required to be evaluated) and the DCO for the first project authorises enabling works for the second. In the present case, proposals for the second project have been formulated and the promoter of the first project has put forward what it considered to be sufficient information on the second to enable cumulative impacts to be evaluated in the DCO decision on the first. This information was before the Defendant. I reject the attempt by NVL to draw any analogy with the circumstances in *Littlewood* (at [32]) or with those in *Preston New Road* (at [75]). In any event, the decision-maker in the present case, unsurprisingly, did not rely upon any reasoning of that kind in his decision letter (nor did the Examining Authority in the ExAR).

119. Instead, this case bears many similarities with the circumstances in *Larkfleet.* If anything, the ability to assess cumulative impacts from the two projects in the decision on the first project was much more straightforward here and the legal requirement to make an evaluation of those impacts decidedly stronger. First, the promoter carried out an assessment identifying significant cumulative effects at Necton and it is common ground that, for this purpose, essentially the same information was provided on the two projects (see e.g. [52] to [53] above). Second, there were strong links between the two projects which were directly relevant to this subject (see [118] above).

120. The effect of Directive 2011/92/EU, the 2009 Regulations and the case law is that, as a matter of general principle, a decision-maker may not grant a development consent without, firstly, being satisfied that he has sufficient information to enable him to evaluate and weigh the likely significant environmental effects of the proposal (having regard to any constraints on what an applicant could reasonably be required to provide) and secondly, making that evaluation. These decisions are matters of judgment for the decision-maker, subject to review on *Wednesbury* grounds. Properly

understood, the decision in *Littlewood* was no more than an application of this principle.

121. In the Vanguard ES NVL assessed the cumulative landscape and visual impacts as being "significant". Neither the Examining Authority nor the Defendant disagreed with that judgment. Accordingly, this was not a case where deferral of the consideration of those impacts to a subsequent consenting procedure could have been lawful on the basis that the decision-maker considered these impacts to be insignificant (see *ex parte Milne*). The conclusion reached by the Examining Authority and the Defendant on the solus impacts of Vanguard cannot be used to support any such conclusion. Neither Mr. Moules nor Mr. Phillpot QC suggested otherwise. Thus, the court must proceed on the basis that the Defendant considered the cumulative impacts to be significant effects which still need to be evaluated in a decision on whether or not to grant development consent, albeit not in the decision granting the Vanguard DCO.

122. In the circumstances of this case, I am in no doubt that the Defendant did act in breach of the 2009 Regulations by failing to evaluate the information before him on the cumulative impacts of the Vanguard and Boreas substation development, which had been assessed by NVL as likely to be significant adverse environmental effects. The Defendant unlawfully deferred his evaluation of those effects simply because he considered the information on the development for connecting Boreas to the National Grid was "limited". The Defendant did not go so far as to conclude that an evaluation of cumulative impacts could not be made on the information available, or that it was "inadequate" for that purpose. He did not give any properly reasoned conclusion on that aspect. I would add that because he did not address those matters, the Defendant also failed to consider requiring NVL to provide any details he considered to be lacking, or whether NVL could not reasonably be required to provide them under the 2009 Regulations as part of the ES for Vanguard. It follows the Defendant could not have lawfully decided not to evaluate the cumulative impacts at Necton in the decision he took on the application for the Vanguard DCO. For these reasons, as well as those given previously, the present circumstances are wholly unlike those in *Littlewood.*

123. For the reasons set out above, ground 1 must be upheld.

124. I have referred to the Defendant's submissions on the importance of avoiding delay to an urgently needed project of national importance. For completeness, I should add that the court was not shown any provision which would enable that factor to overcome any requirement under regulation 17 to obtain additional information, where a decision-maker considers that the details in the ES are inadequate for assessing likely significant adverse environmental effects. In any event, the Defendant's decision letter did not purport to approach the matter on that basis.

125. It is also necessary for the court to deal with irrationality and the legal adequacy of the reasoning in the decision letter. All of these issues are closely inter-related.

Rationality

126. If, contrary to my view, a decision-maker may, in the exercise of his judgment, depart from the general principle set out in [120] above, by deferring the evaluation of a significant adverse environment effect to a subsequent consenting procedure, he may only do so on grounds which:-

(i) are rational in the circumstances of the case; and

(ii) satisfy the objectives and requirements of EIA legislation.

127. Irrationality is not confined to decisions which simply defy comprehension, or which are beyond the range of reasonable responses to a given set of information. It also embraces decisions which proceed by flawed logic *(R v North and East Devon Health Authority ex parte Coughlan* [2001] QB 213 at [65]).

128. There is no dispute that Vanguard and Boreas are separate projects. They did not fall to be treated as a single project for the purposes of EIA legislation. This is not a case where, for example, the developer has sought to define the development for which he seeks permission so as to avoid EIA scrutiny. I also accept the submission of the Defendant and NVL that the proposals for Vanguard and Boreas have been made on the basis that the implementation of the Vanguard DCO is not dependent upon the approval or implementation of a DCO for Boreas. Accordingly, the present case should be distinguished from *Brown v Carlisle City Council.* But none of these points address the true circumstances of this case (see e.g. [118] to [119] above) and so do not assist the Defendant and NVL in resisting this challenge to the DCO.

129. NVL included in the ES an assessment of cumulative landscape and visual impacts at Necton. They considered the information available on the two projects to be adequate for this purpose and they concluded that there were likely to be significant environmental impacts. No complaint has been made about the adequacy of the ES or of the environmental information subsequently gathered. The legal challenge in this case has simply arisen because, first the Examining Authority, and then the Defendant, decided to defer *any* evaluation of those cumulative impacts to the decision on the Boreas project. They did so without the point being discussed publicly during the examination process. They did so on the basis of reasoning which, even on a generous view, could only be described as cursory, despite the importance of the decision being taken and the substantial concerns which had been raised about the selection of Necton for co-located grid connections. A departure from the general principle set out in [120] required proper justification by the Defendant directed to the environmental information and the issues before him, *a fortiori* given the somewhat unusual circumstances of this case as described above.

130. The ES for Boreas was submitted in June 2019. Vattenfall's report on the interrelationship between the two projects explained that the Boreas ES considered two "scenarios" according to whether Vanguard either would or would not receive consent. In the former scenario, Boreas would rely upon the authorisation by the Vanguard DCO of the cable corridor and provisions at Necton (including land acquisition). In the latter scenario, the Boreas DCO was promoted on the basis that it would authorise all the works needed for that project. However, the legality of the decision letter dealing with the Vanguard DCO must be assessed in the context that it authorised shared infrastructure for both projects and, as Mr. Westaway demonstrated (and was not challenged), compulsory acquisition of land at Necton needed solely for the Boreas project. In these circumstances, the general principles in *Larkfleet* for linked projects are applicable. Absent any rational justification, cumulative impacts of both projects had to be evaluated by the decision-maker when considering whether to grant a DCO in each case, even accepting that in some cases less information about the second project may be available when deciding whether to approve the first.

131. It is inescapable that the only reason given by the Defendant for deferring *all* consideration of cumulative landscape and visual impacts to the Boreas examination was that the information available on Boreas was "limited". I am in no doubt that this bare statement was, in the circumstances of this case, illogical or irrational. It was common ground in the hearing before this court that the nature and level of information on the two projects for the purposes of assessing landscape and visual impacts of the substation development at Necton was essentially the same. Plainly, the Defendant must have proceeded on the basis that the information on the solus impacts of the Vanguard project was sufficient for him to be able to evaluate and weigh that matter. No basis has been advanced in these proceedings by either the Defendant or NVL for either (a) treating the adequacy of the environmental information on Boreas differently for an evaluation of the cumulative landscape and visual impacts or (b) not making *any* such evaluation *at all* in the Vanguard decision. The Defendant's decision is flawed by an obvious internal inconsistency. The decision was all the more perverse because, in accordance with *ex parte Milne*, NVL's approach employed a "Rochdale envelope" in order to cater for the absence of more detailed information, for the evaluation of (a) the Vanguard solus impacts and (b) the cumulative impacts of both projects in the Necton area. The decision was also irrational in other respects.

132. There were a number of features which plainly required the cumulative impacts of the substations for both projects to be assessed as part of the Vanguard decision and not simply left over to the Boreas decision. The two projects had been based on a strategy of co-location. Necton and alternative locations for the essential connection to the National Grid were assessed for their ability to accommodate the substations and infrastructure needed for both Vanguard and Boreas. That was important, if not critical, to the decision to select Necton for the grid connection and to include in the Vanguard DCO authority for the provision of a 60 km cable corridor between Happisburgh and Necton to serve both projects and compulsory acquisition of some land at Necton for Boreas (which would need to satisfy a "compelling public interest" test). Consequently, consistency required the cumulative impacts of the substation development at Necton to be evaluated in the Vanguard decision. In the circumstances of this case, it was irrational for the Defendant to defer that evaluation.

133. If the cumulative impacts in the Necton area had been evaluated when considering the application for the Vanguard DCO, one possible outcome is that they would have been found to be unacceptable. That could have led the Defendant to decide that Necton was not an appropriate location to provide a grid connection for both projects, as intended by the developer, which would also call into question the appropriateness of the co-located cable corridor leading to that connection point. Even assuming that the Defendant would still have decided all the other issues in favour of the Vanguard proposal, it would have been permissible for him to refuse to grant the DCO on the basis that the location of a grid connection at Necton to serve both Vanguard and Boreas (and the related cable corridor) needed to be reconsidered by the developer. Plainly, that ought to be determined before granting consent for the first project. In that way the promoter could reapply or modify or even abandon its strategic co-locational approach before proceeding with either project. Here, the decision to leave that issue over to consideration of the DCO for the second project prevented that course from being taken.

134. Accordingly, there is nothing "nonsensical" in requiring cumulative impacts at Necton to have been evaluated in the Vanguard decision, even if that resulted in the refusal of a DCO for that project (see NVL's submission at [85] above). Any such outcome would simply be the corollary of NVL having chosen to rely upon a co-locational strategy and the common infrastructure involved. Such a choice may have advantages and disadvantages for the promoter, depending upon which of the two projects it decides to promote first and ultimately the Defendant's assessment of their respective merits. Even if DCO consent for a second project were to be refused on other grounds, that would not render absurd the rejection of a co-location strategy advanced in a DCO application for a first project on the grounds of cumulative impact. At the very least, it would remain open to the promoter to submit a further DCO application for that first project. Unlike the situation discussed in [133] above, that outcome would not be prejudiced or pre-empted. Given that NVL itself assessed cumulative impacts in the Vanguard ES, the submission it now makes against those impacts forming a basis for refusal of the Vanguard application which the ES accompanied is, to say the least, surprising.

135. The Defendant has decided that the cumulative impacts at Necton should be assessed solely in the Boreas examination and decision and not also in the Vanguard process, despite (1) the availability of information to enable him to make an evaluation of those impacts and (2) the Court of Appeal's judgment in *Larkfleet.* The Defendant's approach has had the effect, absent consideration of those cumulative effects, of making it easier to obtain consent for Vanguard, and providing a "foot in the door" making it easier to obtain consent for Boreas. Although there is no evidence that NVL sought those outcomes, the Vanguard DCO decision has had a "precedent effect" for decision-making in relation to Boreas upon which, understandably, NVL has relied heavily in the Boreas examination. In view of the familiar *North Wiltshire* line of authority on consistency in decision-making, these were highly likely, if not inevitable, consequences of the Defendant's decision to approve the DCO for Vanguard. These were obviously material considerations which went directly to the rationality of the decision.

136. These considerations underscore the absence of any rational justification in the Vanguard decision letter for refusing to make *any* evaluation of the cumulative impact issue at that stage. The single, perfunctory reason given for deferral, the limited amount of information available on Boreas, could not, in the circumstances of this case, justify by itself leaving the issue entirely to the second examination, particularly where the information was in front of the Defendant, NVL considered it to be adequate and no one suggested the contrary.

137. In any event, the Examining Authority and the Defendant had powers to obtain further information. Indeed, if the Authority had considered the application of regulation 17 of the 2009 Regulations and decided that additional material should have been included in the ES, they would have been obliged to require that information to be provided and suspend the examination in the meantime.

138. Even putting that regulation to one side, and looking at the matter more broadly in the context of rule 17 of the 2010 Rules, the Defendant's decision was unlawful. A bare, unexplained statement that the information on Boreas was "limited", without any attention being given to an obvious solution, namely to ask for more material, or at the very least to consider the pros and cons of taking that step, could not rationally justify

departing from the requirement that the significant adverse cumulative impacts at Necton should be evaluated and weighed before deciding whether to grant a DCO for the first of the two linked projects.

139. The submissions by Mr. Moules and Mr. Phillpot QC in [82] to [83] above do not lend any support to their contention that the Defendant's decision to defer the cumulative impact issue was rational. They suffer from a number of flaws. First, there is no evidence that the points advanced by counsel were in the minds of the Examining Authority or of the Defendant, or that any of these matters had been raised during the examination and, therefore might have been taken into account by the decision-maker even tacitly. With respect, these submissions amounted to no more than an *ex post facto* justification of the decision, or, to put it more directly, an impermissible attempt to rewrite the ExAR and the decision letter. Second, even if those matters had been taken into account by the decision-maker, they do not overcome the points set out above as to why the decision to defer in this case was irrational. For example, it is common ground that the information on both projects was of the same nature and level of detail and so it was illogical, in any event, to treat the information on Boreas as inadequate when the decision-maker was content to rely upon that supplied on Vanguard.

140. The analysis by Mr Phillpot QC and Mr Moules of the differences between an assessment of cumulative impacts in the Vanguard examination as opposed to the Boreas examination (see [84] to [86] above) proves too much. The same approach could be applied to the consideration of the cumulative visual impacts of any two projects where the consenting of one is determined before the other. In other words, the analysis would amount to a set of legal principles. However, Mr. Phillpot QC and Mr Moules rightly eschewed that outcome. It would conflict with the 2009 Regulations and established case law (e.g. *Larkfleet*). But, as they accepted, the only way of avoiding that problem is to treat the points they made as depending upon the application of judgment to the circumstances of each case. But, of course, that judgment has to be made by the decision-maker and there is no evidence whatsoever, whether in the decision letter or elsewhere, that the Defendant had any of these considerations in mind, let alone that he decided how much weight to give to any of them. In any event, I am not persuaded that the analysis by counsel overcomes the various aspects of irrationality in the decision to defer as explained above.

141. For these additional reasons, ground 1 must be upheld.

Adequacy of reasons

142. From the discussion of the issues arising under ground 1, it is apparent that the reasons given for the decision to defer evaluation of cumulative impacts to the Boreas examination were legally inadequate. Having regard to the various matters discussed under ground 1 above, there must be, at the very least, a substantial doubt as to whether the decision was tainted by an error of public law, namely a breach of the 2009 Regulations and/or irrationality. For that reason alone, ground 2 must be upheld.

143. Furthermore, even if it be assumed that it was legally permissible to defer the evaluation of the cumulative impacts at Necton to the examination of the Boreas DCO application, any such decision had to be adequately reasoned. The bare statement in this case that the information on Boreas was "limited" did not come anywhere near

discharging that requirement, particularly as the Boreas information did not differ materially from that available on Vanguard and no party had raised this suggestion during the examination. There was no explanation as to why an evaluation could not have been made by the Defendant in accordance with regulation 3(2) of the 2009 Regulations.

144. Furthermore, the decision letter gave no indication as to what was meant by "limited information" so that the issue could be addressed properly in the Boreas examination. As Mr. Moules rightly accepted, if the Vanguard application for a DCO had been refused because information for assessing cumulative impacts at Necton was thought to be "limited", without more, NVL would have been entitled to have that decision quashed. There is no reason why that flaw should be treated any differently by the court when the party prejudiced by the lack of reasons is an objector to the proposal (see e.g. *South Bucks District Council* at 30-32). None has been suggested. The objector has no real idea as to why the EIA process has not been completed in accordance with the 2009 Regulations. The Claimant and other objectors, especially those concerned about the cumulative impacts of substation development at Necton, cannot be adequately assured that the decision on deferral was taken on relevant and material grounds (see Lord Bridge in *Save Britain's Heritage v Number 1 Poultry Limited* [1991] 1 WLR 153, 170G).

145. For all these reasons, ground 2 must also be upheld.

Whether relief should be granted or refused

146. The Claimant is entitled to an order quashing the decision to grant the DCO unless there is any proper legal basis for the court to withhold that relief. The Defendant and NVL rely upon s.31(2A) of the Senior Courts Act 1981: -

> "The High Court—
>
> (a) must refuse to grant relief on an application for judicial review, and
>
> (b) may not make an award under subsection (4) on such an application,
>
> if it appears to the court to be highly likely that the outcome for the applicant would not have been substantially different if the conduct complained of had not occurred."

147. Where a decision is flawed on a point of EU law, the bar for the withholding of relief is set higher than under s.31(2A) (see e.g. *R (Champion) v North Norfolk District Council* [2015] 1 WLR 3710 at [57] to [58]). Two recent cases have raised the issue whether section 31(2A) is overridden or disapplied by the EU legal test where the latter is applicable, without finding it necessary to decide the point *(R (XSWFX) v London Borough of Ealing* [2020] EWHC 1485 (Admin) and *Gathercole v Suffolk Country Council* [2020] EWCA Civ 1179).

148. I am grateful to Mr Moules for producing a very helpful note on these issues and the implications of the European Union (Withdrawal) Act 2018 and the European

Union (Withdrawal) Act 2018 (Relevant Court) (Retained EU Case Law) Regulations 2020 (SI 2020 No. 1525). Counsel for the Claimant and for NVL agreed with the note. In a nutshell, their agreed position is that the High Court is bound by EU retained case law to apply the more exacting EU law test where a challenge succeeds on an EU point of law.

149. Here the Claimant has succeeded in establishing a breach of the 2009 Regulations, as well as a domestic error of public law (irrationality) and a breach of the duty to give reasons (which straddles both EU and domestic law, the 2009 Regulations and the PA 2008).

150. Because I have reached the firm conclusion that, applying the test in s.31(2A) of the Senior Courts Act 1981, there is no justification for withholding the quashing order the Claimant seeks, the same would follow if I were to apply the EU law test.

151. The central issue under s. 31(2A) is whether, if the error identified by the court had not occurred, it is highly likely that the decision on whether or not to grant the DCO would not have been substantially different; in other words, the DCO would still have been granted. The arguments for the Defendant and NVL proceeded on the basis that the court should consider what would be "highly likely" to have happened if, in his decision on the Vanguard DCO, the Defendant had evaluated cumulative impacts from the Necton infrastructure for both projects.

152. The Court of Appeal has laid down principles for the application of s.31(2A) in a number of cases, including *R (Williams) v Powys County Council* [2018] 1WLR 439; *R (Goring-on-Thames Parish Council) v South Oxfordshire District Council* [2018] 1 WLR 5161; and *Gathercole.* The issue here involves matters of fact and planning judgment, and so the court should be very careful to avoid trespassing into the Defendant's domain as the decision-maker, sometimes referred to as "forbidden territory" (see e.g. *R (Smith) v North Eastern Derbyshire PCT* [2006] 1 WLR 3315 at [10]). Instead, the court must make its own objective assessment of the decision-making process which took place. In this case it was common ground that the Court should consider whether the Defendant's decision would still have been the same by reference to untainted parts of the Defendant's decision (as in *Goodman Logistics Developments (UK) Limited v Secretary of State for Communities and Local Government* [2017] J.P.L. 1115).

153. Although the test in s.31(2A) is less strict than that which applies in the case of statutory reviews (see *Simplex GE (Holdings) Limited v Secretary of State for the Environment* [2017] PTSR 1041), it nevertheless still sets a high threshold. In *R (Plan B Earth) v Secretary of State for Transport* [2020] PTSR 1446 the Court of Appeal held at [273]: -

> "It would not be appropriate to give any exhaustive guidance on how these provisions should be applied. Much will depend on particular facts of the case before the court. Nevertheless, it seems to us that the court should still bear in mind that Parliament has not altered the fundamental relationship between the courts and the executive. In particular, courts should still be cautious about straying, even subconsciously, into the forbidden territory of assessing the merits of a public

> decision under challenge by way of judicial review. If there has been an error of law, for example in the approach the executive has taken to its decision-making progress, it will often be difficult or impossible for a court to conclude that it is "highly likely" that the outcome would not have been "substantially different" if the executive had gone about the decision-making process in accordance with the law. Courts should also not lose sight of their fundamental function, which is to maintain the rule of law. Furthermore. although there is undoubtedly a difference between the old *Simplex* test and the new statutory test, "the threshold remains a high one" (see the judgment of Sales LJ as he then was, in *R (Public and Commercial Services Union) v Minister for the Cabinet Office* [2018] ICR 269, para 89)."

154. Both the Defendant and NVL submitted that the decision was taken to grant the DCO for Vanguard after taking into account all material considerations, other than cumulative impacts at Necton, and after striking the balance in s.104(7) of the PA 2008. Accordingly, the question is whether if those cumulative impacts had been taken into account, the court is satisfied that it is highly likely that the Defendant would still have granted the DCO.

155. In support of their contention that the answer to that question is yes, the Defendant and NVL emphasised a number of conclusions in the decision letter, including the strength and urgency of the need for the development as set out in the NPSs, the benefits which would flow from the development, the rejection of alternatives, and the assessment that the solus impacts of the Vanguard substations on landscape and visual receptors would be localised (i.e. within a 1.2m radius) and attracted only limited weight.

156. However, the consequence of the legal errors made by the Defendant is that the court does not have any notion as to what the evaluation of cumulative impacts by the Defendant would have been if he had considered the matter. The court does not even have an idea as to how the Examining Authority evaluated the cumulative impacts, because they too decided not to do so. It would be impermissible for the court to make findings on that issue for itself. To do that would involve entering forbidden territory.

157. So instead, the court is being asked to deduce from the Defendant's conclusions on the solus impacts of the Vanguard development at Necton and the way in which the overall balance was struck that it is highly likely that the outcome would have been the same if the cumulative impacts had been evaluated as well.

158. In my judgment, there is a fundamental flaw in the argument relying upon s.31(2A) which cannot be overcome. It flies in the face of the conclusion which the Defendant actually reached, namely that he would not assess cumulative impacts at Necton because the information on Boreas was "limited". This criticism by the Defendant makes it impossible to deduce what his conclusion would have been if he had evaluated those impacts. But even if that point is put to one side, there are other flaws.

159. First, I note that when the Defendant struck the overall balance in DL 7.4, he said that "on balance" the benefits of the Vanguard development outweighed its adverse impacts, looking at the proposal as a whole. No indication was given as to how far those findings tilted the balance in favour of granting the DCO, not even in broad terms.

160. More importantly, the Defendant and NVL are inviting the court effectively to infer that because the ES assessed the cumulative impacts at Necton as falling within a radius of 1.2 km from the proposed substation, that impact would have been treated in the decision as "localised" and would therefore have attracted only "limited weight", just as the Examining Authority and the Defendant had evaluated the solus impacts of the Vanguard substations.

161. However attractively these submissions were presented, they cannot disguise the reality that the court is being asked to take on an inappropriate fact-finding role to supply conclusions which, unlawfully, are missing from the decision letter. This would conflict with the separation of powers between the courts and the executive, the "fundamental relationship" referred to in *Plan B Earth.*

162. This is illustrated by Mr. Westaway's submission, which I endorse, that if more development is concentrated within the 1.2 km radius (which itself is only an assessment tool), it does not follow that any so-called "localised effect" would attract only "limited weight". That argument could be repeated if the additional development within that area was substantially greater than even the doubling of the Vanguard substations which the Boreas project would entail. That would be nonsensical. Instead, the evaluation of the cumulative impacts is a matter for proper fact-finding by the person responsible for taking the decision on the DCO, and not something capable of being deduced by a judge from the decision letter in this case.

163. The addition of further substation development is to some extent a matter of degree, but it also involves other considerations, such as the effect of the nature and scale of the development on the character of the rural area, including the village of Necton. In part, this comes back to the straightforward points made by Breckland Council in its Local Impact Report (which the Defendant was obliged to take into account under s.104(2) of the PA 2008) that the scale of the Vanguard and Boreas substation developments would be disproportionate in relation to the village of Necton and this rural area. These were important concerns for members of the public objecting to the Vanguard scheme, which they were entitled to have evaluated by the Defendant as the decision-maker responsible, before he decided whether or not to grant the DCO for that project.

Conclusions

164. For the above reasons I uphold grounds 1 and 2 of the challenge. There is no justification for the court to withhold the relief sought by the Claimant and so the Defendant's decision letter dated 1 July 2020 to grant a development consent order for the Norfolk Vanguard Offshore Wind Farm together with SI 2020 No. 706 must be quashed.

165. The court's order is being made at a time when the application for a DCO in respect of Norfolk Boreas remains to be determined. The Defendant will need to give

careful consideration as to how the evaluation of cumulative impacts relating to development at Necton for both projects should be approached in each decision and whether, and if so, to what extent, the examination of the Vanguard project needs to be re-opened. The court was not asked during the hearing to express its opinion on those matters.

Addendum: the Court’s order

166. The Claimant has submitted that the court’s order should contain specific directions on how the implications of this judgment should be handled procedurally in both the Vanguard and Boreas DCO applications. The Defendant and VNL oppose that suggestion. I conclude that the court’s order should not include any formal directions of that kind. I will explain my reasons in relation to the submissions which have been made.

167. First, the Boreas application has not yet been determined and is not currently the subject of any proceedings in this court. Second, the Defendant states through counsel that, in accordance with well-established convention, he can be expected to comply with the terms of this judgment without the need for any mandatory order. That is an important consideration. Third, there may be more than one way in which the defendant can properly give effect to the law stated in this judgment, and any other relevant legal principles or requirements, and so it would be inappropriate now for the court to prescribe how such matters should be handled.

168. The Defendant and NVL also rely upon rule 20 of the 2010 Rules which provides:-

> “Where a decision of the Secretary of State in respect of an application is quashed in proceedings before any court, the Secretary of State—
>
> (a) shall send to all interested parties a written statement of the matters with respect to which further representations in writing are invited for the purposes of the Secretary of State's further consideration of the application;
>
> (b) shall give all interested parties the opportunity of making representations in writing to the Secretary of State in respect of those matters.”

169. The Defendant submits that “unusually, and unlike the situation in respect of “ordinary” planning applications, Parliament has addressed its mind to the redetermination of DCO applications and prescribed a procedure”. It is submitted that rule 20 provides a complete statement of the steps required for a fair redetermination of the application.

170. In deciding not to grant the additional relief sought by the Claimant, it should be clearly understood that I do not accept these additional submissions.

171. First, it has been well-established for many years that procedural rules such as the 2010 Rules are generally *not* exhaustive of the requirements of procedural fairness or

other public law requirements (see e.g. *Lake District Special Planning Board v Secretary of State for the Environment* 1st January 1975 and noted at [1975] JPL 220; *Bank Mellat v HM Treasury (No. 2*) [2014] AC 700 at [35]; *Hopkins Developments v Secretary of State for Communities and Local Government* [2014] PTSR 1145 at [62]; De Smith's Judicial review (8th edition) at paras. 7-012 to 7-016).

172. Rule 20 imposes *minimum* procedural requirements. The language of rule 20 should not be misread as laying down an exclusionary rule in relation to any additional steps that might be required in order to satisfy the duty to act fairly in a particular case. Furthermore, the court has not been shown any statutory provision indicating that Parliament intended the 2010 Rules to be an exhaustive code which excludes, or is incompatible with, additional requirements arising from that duty.

173. Second, the 2010 Rules are not unusual. Rules of this kind have existed for some time. They deal with *some* of the consequences of the quashing of decisions in the planning sphere. For example, the Town and Country Planning (Inquiries Procedure) (England) Rules 2000 (SI 2000 No. 1624) applies to certain planning appeals and called-in planning applications. I note that rule 19 expressly provides for the re-opening of a public inquiry as well as for written representations. However, it cannot be inferred that, simply because the 2010 Rules only mention the making of written representations, the re-opening of an examination is excluded where any quashing order is made under s. 118 of the PA 2008. The requirements of natural justice, which are often fact-sensitive, may require additional procedural steps to be taken beyond those contained in such rules.

174. The procedural consequences of a quashing order will normally depend upon the nature of the legal error or errors which have led to it being made. It is not too difficult to think of a fundamental error affecting the application process from the outset, which would therefore require the matter to be rewound to the beginning, notwithstanding rule 20 of the 2010 Rules.

175. In view of the submissions which have been made it is necessary to refer here to some of the issues arising from this judgment which need to be addressed. There may be others which the parties would wish to raise.

176. First, part of the problem has been the failure of both the Examining Authority and the Defendant to explain in what respects the information on Boreas was thought to be "limited", so that the parties involved in either examination process could address that point. That calls for an explanation from the Defendant, including any implications for the operation of regulation 17 of the 2009 Regulations, before any representations could sensibly be made by interested parties on matters of either procedure or substance.

177. Second, there are procedural implications arising from the failure of both the Examining Authority and the Defendant to evaluate the cumulative impacts in the Necton area. Likewise, the obviously material considerations referred to in [132] to [136] above, were not addressed by either the Authority or the Defendant. Consequently, the findings and the recommendation in the report which the Authority was required to make under s. 74 of PA 2008 (and rule 19 of the 2010 Rules), and which the Defendant is required to take into account, have not been based upon those factors.

178. Furthermore, the points in [132] to [136] above, which go to the relationship between the two projects, may have implications for the timing of the decisions on both projects.

179. In these circumstances, it is very doubtful whether the Defendant could properly proceed to re-determine the Vanguard application, or to determine the Boreas application, without at least giving a reasonable opportunity for representations to be made by interested parties on the implications of this judgment for the procedures now to be followed in each application, considering those representations, and then deciding and explaining what course will be followed.

180. Paragraph 11c of NVL's submissions relies upon "the importance in the public interest of determining applications for nationally significant infrastructure projects such as this without undue delay" as a factor influencing the timing of the Defendant's decision. That does indeed reflect one of the purposes of the PA 2008 and the procedural timetables it contains (see also the case law cited in [9] above). But that consideration does not override the need for compliance with EIA legislation and with principles of public law and procedural fairness. It is most unfortunate that there has been a failure to grapple with an important issue in the Vanguard decision (and before the Boreas decision) and that this has resulted in delay to the determination of an important application. But that only serves to underscore the need for care now to be taken to avoid future procedural steps in relation to either project being impugned.

From:	[redacted]
To:	Norfolk Boreas
Cc:	[redacted]
Subject:	Response to SoS BEIS Letter 22 September 2021 - Offshore Transmission Network Review (OTNR)
Date:	20 October 2021 22:10:19
Attachments:	ESO Open Letter on the OTNR 27 September 2021.pdf EN010005-000012-Secretary of State decision letter and statement of reasons.pdf IOTP (East) Network Design.docx 4. Network Cost Impact of New Offshore Wind in 2030..docx

References:

A. Secretary of State Business, Industry & Industrial Strategy (SoS BEIS) Letter dated 22 September 2021 (Published 22/09/2021)
B. Norfolk Boreas Ltd - Response to Secretary of State Letter dated 9 July 2021 - Offshore Transmission Network Review (Published 23/08/2021)
C. Integrated Offshore Transmission Project [IOTP] (East) Report dated August 2015.
D. OWIC – Enabling Efficient Development of Transmission Networks for Offshore Wind Targets dated November 2019.

Attachments:

1. ESO Open Letter on OTNR dated 27th September 2021.
2. Triton Knoll Offshore Windfarm - SoS Decision Letter & Statement of Reasons dated 11 July 2013.
3. IOTP (East) 2015 Network Design August 2015.
4. Network Cost Impact of New Offshore Wind in 2030.

Dear Planning Inspectorate,

In response to the SoS BEIS's letter at Reference A, whereby:
"The Secretary of State considers the information provided by the Applicant in response to those letters to contain new environmental information and invites comments from the Applicant and ***Interested Parties*** *on the representations received."*
The Applicant has spread this new environmental information across several representations which we will respond to in turn, starting with the Offshore Transmission Network Review (OTNR) at Reference B.

We have the following responses to the Applicant's statements (in blue) made in their submission EN010087-002848:

- *"During an open floor hearing on 2 July 2020 interested parties raised the topic of integrated approach to connections for offshore wind farms is required. Norfolk Boreas Limited (the Applicant) set out its position at that time with regards to an integrated approach to an offshore transmission network* [OTN] *for connection of offshore wind farms to the national grid. This position is recorded in point 5 of the Applicant's response to Open Floor Hearing 2 [REP13-014]."*
    - In the above response to Open Floor Hearing 2, the Applicant made the following statements:
        - *"The Applicant's position remains that significant progress needs to be made before defined proposals can be put forward for consent, let alone*

before the point of certainty that they will be implemented".

We contend that the OTNR has made such *'significant progress'* that the Applicant, and ExA, are now obliged to consider the **OTN** as a viable **Alternative** within the terms of the NPSs and that the SoS BEIS is at liberty to explore the **OTN** as an **Alternative** transmission system by re-opening the examination for the Norfolk Boreas application.

- *"As the expected construction time-frame for Norfolk Boreas is between 2024 and 2030, the Applicant considers that it would be impossible for an integrated offshore ring main* [now universally referred to as the OTN] *approach to be developed, consented and delivered in time for Norfolk Boreas' first power generation".*

  The *"expected construction time-frame for Norfolk Boreas is between 2024 and 2030"* is important in comparison to the projected timescales of the OTN which we contend would still deliver Norfolk Boreas as a contributor to the OTN before 2030, if the Applicant were to opt in and become a "Pathfinder" project along with the so called "sister project" Norfolk Vanguard.

  We contend that it would be entirely possible for Norfolk Boreas to meet all of the requirements for connection to the OTN before 2030 and contribute positively if the Applicant were either compelled to do so or the Environmental Impacts of the proposed onshore transmission system were given sufficient negative weight in the planning balance to deny the onshore transmission system's consent.

  We respectfully ask that the SoS BEIS considers the consent for Norfolk Boreas application be split into: consent for the Offshore Windfarm Project with separate consent for the Onshore Transmission System and Substation, pending further consultation is carried out regarding the damaging environmental impacts of the Applicant's onshore proposals.

- *The Applicant has participated proactively in the Offshore Transmission Network Review (OTNR) process, including the 'Early Opportunities' workstream run by the ESO on an 'opt-in' basis, since its initiation in July 2020.*

  The ESO's 'Open Letter' at Attachment 1 contains the details for which offshore projects are suitable for 'opt-in' as:

  "Any offshore projects which have previously been through the full CION process but have not achieved both planning consent and a Contract for Difference (or equivalent) will generally be considered to be within scope of the Early Opportunities workstream. Those projects can opt-in with a pathfinder proposal to consider coordination and further information on opting-in can be found here."

  Therefore, Norfolk Boreas:

  a. Does not have planning consent, and importantly had not submitted its DCO application before the Early Opportunities Workstream commenced.
  b. Does not have a Contract for Difference (CfD) and is unlikely to be able to commit to the next CfD auction.

c. Has been through the full CION process with the award of Necton substation as its connection point which is at the very crux of the onshore environmental damage that the project will cause if granted consent.

We contend there is no logical or environmental reason why Norfolk Boreas should not op-in as a pathfinder project for the OTN. Also, an opt-in to the OTN would contribute more positively to the planning balance being that the OTN will be more efficient for all connections whilst generating savings for both the consumer to the order of £6 billions, and the environment by precluding any onshore environmental damage from the project.

"As these projects are at an advanced stage of development where much of the detailed network design and planning consent work has already been completed, opting-in to a coordinated design is currently voluntary".

We ask that the SoS BEIS considers the environmental impacts of consenting the on-shore development of the Norfolk Boreas application in comparison to enabling the project to become part of a collaborative and coordinated network, which is what the ESO would clearly enable.

- *"The Early Opportunities workstream aims to identify and facilitate opportunities for increased coordination in the near term; focused on in-flight projects which are advanced in their development and where requirements for significant transmission regime change would be inappropriate within project timescales, and which could compromise the Government's ability to meet its 2030 targets."*

We contend that, as has been the case for the duration of the consultations for both Norfolk Boreas and Norfolk Vanguard, the Applicant has refused to accept that the OTN (or ORM in its previous guise) is a viable **Alternative** and continues to be so. Further, it is not for the Applicant to speculate on the impact upon Government targets. However, we contend that the 2030 target is not in statute and therefore, to coin a phrase, has limited weight in the planning balance when the environmental impact of the on-shore transmission system is taken into account. Furthermore, there is no empirical evidence to suggest that Norfolk Boreas would not be online by 2030 if the project were to opt-in to the OTN.

"As the Norfolk Boreas project is in very late-stage development, the Applicant has been working with the ESO to explore Early Opportunity options that could be Offshore Transmission Network Review Norfolk Boreas Offshore Wind Farm delivered within the project timelines and which could be incorporated into the existing project as defined by the parameters of the Norfolk Boreas development consent application, existing regulatory frameworks, and using available technology, without risking the delivery of the UK Government's targets."

We contend that the Norfolk Boreas project is **not** in a "***very** late stage of development*" and is at the very stage of development that the ESO requires a project to be in order to become a pathfinder project for the OTNR within the Early Opportunities workstream.

The ESO provides further detail (as in Attachment 1):

"The intention of this [Early Opportunities] *workstream is to provide an avenue for offshore developers to consider opportunities for these projects to work together to determine whether there is a more coordinated option available than that*

previously identified through the traditional CION approach, especially in regions where several projects are expected to connect. If identified and agreed to be deliverable under Early Opportunities, connection contracts will then need to be updated to provide for this coordination."

We contend that the Applicant is in a position to accept that connection contract but is refusing to do so for an undisclosed reason and this refusal will ultimately have a damaging environmental impact upon rural Norfolk.

We ask the SoS BEIS to again consider consenting the windfarm but not the transmission system for Norfolk Boreas as per the precedent set by the Triton Knoll DCO as at Attachment 2.

- *"The Applicant is supportive of the OTNR's aim to deliver greater coordination of our onshore and offshore transmission networks in order, as far as possible, to reduce environmental impacts and deliver cost savings for consumers as we seek to decarbonise our energy system in line with the Government's target of 40GW of offshore wind by 2030, and potentially 100GW by 2050, to support net zero."*

If the Applicant's intent were indeed to "*deliver greater coordination of our offshore and onshore transmission networks"* and *"to reduce environmental impacts and deliver cost savings to the consumer"* then the logical decision would be for the Norfolk Boreas project to opt-in and become a Pathfinder Project. The biggest reduction in environmental impacts for any offshore project is by collaboration with a coordinated connection to the OTN – fact! The biggest cost saving for the consumer is also for any offshore project is by collaboration with a coordinated connection to the OTN – fact! It is disingenuous for the Applicant to attempt to make a compelling case that the planned transmission system is anything other than damaging to the onshore environment.

We contend that, despite the efforts of the Applicant to bolster the case for a radial transmission system, this is just not the case either environmentally or beneficial to the UK consumer and, on balance, there is a better alternative via the OTNR.

- *"As with all OTNR explorations for solutions under any of the discrete workstreams, including "Early Opportunities", parties enter into discussions with BEIS, OFGEM and the ESO commercially in confidence. However, the Applicant can state that it has identified and put forward solutions that could potentially enhance offshore coordination, and /or reduce the need for onshore grid reinforcement for future projects. For example, should as yet unidentified projects come forward, within an appropriate timeframe, there is a possibility that if infrastructure is consented for Vattenfall's Norfolk Projects this may be engineered to accommodate some additional capacity."*

  "Notwithstanding the above, as the development of the project began in 2015/16, the Applicant has necessarily worked within the regulatory bounds of the current system, which has been designed around radial offshore connections. Prior to the OTNR, and in consultation with local stakeholders, the Applicant has proactively provided a coordinated '3.6GW Norfolk Project' and has continuously sought to reduce the onshore impact of the transmission works. The alternatives considered in this respect and the decision to take a strategic approach to minimise impacts is summarised in Table 5.1 of the Design and Access Statement (document 8.3, Version 5, [REP14-014])."

We ask again how any discussion for public scrutiny and consultation could be held as being *"commercially in confidence,"* the confidentiality is misplaced as is the imposition of Non-Disclosure Agreements (NDAs) such as that imposed on the design of the crossing point of the Applicants cables with those from Hornsea Project 3. We contend that the environmental impact of many parts of the development are being hidden behind such agreements and discussions.

The Applicant's parent company, Vattenfall, was a contributor to the IOTP (East) 2015 review as at Reference C, producing a design concept as at Attachment 3. Therefore, the Applicant was fully aware that a coordinated and integrated system would create vast savings for the environment and the consumer. Coordinated infrastructure was considered in the IOTP (East) in 2015 and there is nothing new, other than the burgeoning number of interconnectors and offshore windfarms competing for the UK's lucrative electricity market. If the Applicant's intent was ever to enhance offshore coordination and/or reduce the need for onshore reinforcement then their opportunity to do so was back in 2015. Indeed, the basis for the 'Holistic' design of the OTN was completed in 2015 but not adopted due to the lack of any foresight or responsibility from Ofgem or the then Energy Department – their dereliction of responsibility being another matter for another day!

We contend that, as at Attachment 3, there is nothing new in offshore coordination other than the Government setting a target for 40GW from offshore by 2030 rather than the ESO's woeful underestimation of just 10GW in 2015. However, we can state that the Applicant has known about offshore coordination, and collaborated in reviews of integration for many years before the Norfolk Boreas application. Therefore, the contention that an 'Alternative' design for the transmission system was not available is at best disingenuous. The DAS the Applicant refers to is nothing more than a statement of facts. The contentious element for the environment being the decision to utilise HVDC and the environmental impact of requiring convert halls at the substation; the Applicant does not explore the 'alternatives' with regards to relocating the substation in Scenario 2 to lower ground or Topp Farm for instance.

We ask that the SoS BEIS considers that the Applicant's connection to the OTN as a viable 'Alternative' with specific regards to the environmental impact of consent for the onshore transmission system and substation development at Necton.

We also respectfully request that the SoS BEIS removes any NDAs covering any part of the application or design whilst allowing the public to view the non-disclosed information by re-opening the consultation.

- *"The Applicant would note that, as with many of the examples put forward in OFGEM's consultation document (published 14/07/2021 – "Changes intended to bring about greater coordination in the development of offshore energy networks") – the solutions put forward do not change the principle of needing infrastructure to enable connection of offshore projects into the National Grid."*

This statement is misleading. There is no doubt that sharing infrastructure will reduce the environmental impact of offshore wind developments. For instance, of the 5 developments (Hornsea 3, Norfolk Vanguard, Norfolk Boreas, Dudgeon Extension Project [DEP] & Sheringham Shoal Extension Project [SEP]) with environmental impacts on Norfolk there would, on current proposals, be 5 intersecting radial connections requiring hundreds of kilometres of onshore cabling. Whereas, if these 5 projects alone were to integrate and collaborate only 2 landfalls and 2 connections would be required.

The Government has recently recognised the over development issue but has done little to bring forward a solution with successive SoSs consenting developments despite the recommendations from the respective ExRs not to consent. Radial connections from offshore to onshore are environmentally damaging and the continuance of the ESO to grant such connections is counter intuitive to the whole approach of the ONTR. Indeed, the Network Constraints Costs, as indicated at Attachment 4, would preclude any further connections to the NETS in Norfolk, including Norfolk Boreas, which needs consideration in the planning balance.

At Attachment 4 the ESO demonstrates the variation of network constraint costs for the connection of a 1.5GW offshore wind farm at different locations. Of note, the grid connections at Norwich Main (Zone F), and Friston in Suffolk, are more constrained than connections at either Walpole (Zone E) or Isle of Grain (Zone G). Of note, these constraint costs are paid for by the consumer. Being that an OTN will likely be available before 2030, the connection of 3.6GW at Necton could place both Norfolk Boreas and Norfolk Vanguard out on a limb and in receipt of only constraint payments for the remainder of their operational period making them economically unviable. Therefore, the economic solution would be, once again, for the Applicant to connect via the OTN with an unconstrained integrated connection.

At Reference D, OWIC also identified that constraints on the NETS in East Anglia preclude further radial connections, including those that, for some inexplicable reason, the ESO have recently approved. Commensurately, we do not accept that the Applicant's contribution to 40GW by 2030 as being a reasonable argument for continuing with the onshore radial connections in East Anglia, especially knowing these would constrain the NETS with costs to the consumer, and cause damage to the onshore environment. Further, with regards to constraints, OWIC's opinion is also counter to the Applicant's: *"Given the currently visible issues and that NGESO's study concerned a single Round 4 project only, it is difficult to understand how the current onshore grid can accommodate the high volumes of offshore wind that are expected over coming decades or how combined on and offshore solutions can be identified, developed and evaluated."*

We ask that the SoS BEIS includes in the planning balance consideration for the constraint of the onshore network, imposed by the continuance of radial connections from offshore windfarms, especially when removing the imposition of radial connections, such as Norfolk Boreas, will have a positive environmental impact.

- *"The Applicant considers that, within the confines of the current regulatory regime, delivery of both the Norfolk Vanguard and Norfolk Boreas projects via one shared underground cable corridor and a single landing point for both projects, as well as one onshore enabling works campaign, with buried ducts being installed in sections for the entire capacity of both projects at the same time, will provide the most coordinated approach to installing 3.6 GW of offshore wind undertaken in the UK to date."*

As described previously, there is nothing within the current regulatory regime which would deny Norfolk Vanguard or Boreas connecting via the OTN. The Applicant has failed to demonstrate any restraint, mitigation or understanding of the environmental damage that would be caused by drilling through the sand cliffs at Happisburgh and trenching 60km inland to connect to the NETS with a vast industrialised substation at Necton. Furthermore, "*the most coordinated approach*" could never be by individual radial transmission systems, albeit in the same trench! The most coordinated approach would be via the OTN or at the very least collaboration with other windfarms within the East Anglian Zone.

We ask the SoS to consider denying consent for the onshore development and transmission system of Norfolk Boreas in favour of the more environmentally acceptable integrated, collaborative, more efficient and more cost effective OTN.

- *"Pre-ducting reduces wholesale trenching activities from 8 years to 2 years and a sectionalised approach minimises disruption to a localised area. In addition, the decision to deploy HVDC transmission technology has reduced the width of the onshore temporary easement from 100m to 45m (by 55%) with a reduction in the permanent easement from 54m to 20m (by 63%). This has also reduced the required number of onshore cables from up to 36, to up to 8 cables in total, for both Norfolk Vanguard and Norfolk Boreas."*

The Applicant's statement does not make any sense. If it would take 2 years to trench from landfall to substation, why would it take 6 years to perform exactly the same, along the same route, for a subsequent development? The Applicant's submissions are riddled with such bold and confusing statements which are not supported by any empirical data or substance. Whilst we agree that the utlisation of HVDC for cabling and trenching is better for the environment, the development of a HVDC substation in a rural environment is patently not and the Necton area will be dominated by a very large industrial complex.

"These commitments have the effect of saving resources and energy, minimising impact footprint and reducing installation time, with the overall effect of minimising environmental impacts. In this manner, if both the Vanguard and Boreas projects are consented, the coordinated approach and use of HVDC transmission technology, reduces environmental impacts overall, whilst increasing certainty on delivering renewable energy in line with the UK's targets and providing cost savings to the UK consumer."

If the intent of the Applicant were to save resources, improve efficiency (saving energy) minimise impact footprint, reduce installation time with the overall effect of minimising environmental impacts, then, there would be a serious consideration for Norfolk Boreas to be a Pathfinder Project.

We have maintained throughout the consultation for both projects and in our submissions to the High Court Judicial Review (JR) of the Norfolk Vanguard DCO that the Applicant's claim that Vanguard and Boreas are separate projects, is false. For the Applicant to now claim that they are two *"coordinated"* projects is false; the developer is attempting to distort the current drive towards coordination for their own means.

We contend that the Norfolk Boreas application should have been made as one application with the Norfolk Vanguard application and, despite there being no direction as such from the JR, we respectfully ask that the SoS BEIS consider the environmental impacts of both the Norfolk Boreas project with the Norfolk Vanguard project as if they were a whole. The splitting of the DCOs, and approving either project 'in solus,' is counter intuitive for the overall environmental impacts, especially at the Necton substation.

- *The Applicant is working with other developers to secure appropriate co-ordination of construction activities (and related impact mitigations) at and around the locations where onshore cable corridors will eventually cross.*

  We reiterate that the location where the Norfolk Boreas cable corridor crosses with the Hornsea Project 3 cable is subject to an NDA between Vattenfall and Ørsted. Therefore, there is no data on the environmental impacts or indeed the technical construction of the crossing point for consultation.

- *The Applicant is progressing a Co-operation Agreement with the developer of the Hornsea Project Three scheme, addressing a number of areas where there is potential to reduce local onshore impacts. These topics include:*
  - *co-ordination of construction programmes, to minimise and mitigate periods of co-incident peak haulage activity for the two projects where possible;*
  - *co-ordination of stakeholder engagement plans and activities to minimise stakeholder time investment*
  - *sharing of pre-construction survey works in relation to the crossing point and access routes to minimise on-site activities; and*
  - *shared responsibility for implementation and operation of temporary traffic management schemes in sensitive locations close to the crossing.*

The Norfolk Vanguard/Norfolk Boreas project and Hornsea 3 Project have been in almost parallel development since inception. However, both developers have given scant regard towards the interaction of their projects and any coordination, especially with reference to the environmental impact. By way of example, the HIV Scheme is inadequate to deal with the volume of traffic through the villages of Oulton and Cawston. The claim that: *"sharing the pre-construction survey works in relation to the crossing point"* as being a cooperative measure is laughable; how could the cables be crossed if both developers did not have the same survey!? The developers have yet to divulge even basic environmental information regarding the crossing point for consultation i.e.: which cables will be the deepest and which the shallowest? This information is important as HVDC cables run hot, they have a maximum operational depth and will be further heated by interacting with the other adjacent cables.

The impact of having potentially 6GW of electrical energy (the maximum output of Sizewell B being 1.2GW – ergo five times the output of a nuclear power station) just below the surface of a field and in close proximity to the population has not been exorcised and neither the design nor the environmental impacts divulged.

We ask the SoS to consider delaying the DCO decision for Norfolk Boreas until the Applicant has removed all NDAs covering any element of the development and provided details for the environmental impact of both the Norfolk Boreas and Norfolk Vanguard cables with those of Hornsea 3. We reiterate that the separation of DCO applications for Vanguard and Boreas is problematical as the overall environmental impacts have not been considered which the crossing point is testament to.

- *Many commitments are already secured within the relevant DCO (draft DCO in the case of Norfolk Vanguard and Norfolk Boreas) construction and traffic management plans where all three parties have sought to take a consistent approach to commitments as far as possible in relation to the themes identified above. The Co-operation Agreement represents the overarching document which will formalise the mechanisms to work together to deliver those commitments secured throughout the project plans.*

  Without a view of the 'Co-operation Agreement' and it being available for consultation then the public will never be able to trust the planning process. As we have maintained throughout consultations for all three developments, the developers will exploit the UK's permissive legislation.

  We ask the SoS BEIS to delay the DCO decision for Norfolk Vanguard until all documentation, especially such details as 'Co-operation Agreements' with implications for environmental impacts are provided for scrutiny.

- *The Applicant and Norfolk Vanguard Limited have also engaged with Equinor to understand proposals in relation to cable crossing points between Norfolk Boreas and Norfolk Vanguard and the Dudgeon and Sheringham Shoal Extension Projects (DEP and SEP). The Applicant (and Norfolk Vanguard Limited) will continue to engage with Equinor with a view to securing a crossing agreement in due course. The Applicant has also responded to the recent DEP and SEP Section 42 consultation to identify key areas of overlap between the projects and will continue to engage on these matters so that any potential for coordination can be identified where appropriate as the construction plans for DEP and SEP (currently in the early stages of development) continue to develop.*

  The crossing of Norfolk Boreas' cables with three other offshore windfarm projects is unprecedented and indicative of the level of environmental impact and disruption Norfolk and its inhabitants will endure. Of course these impacts would disappear at a stroke if the offshore windfarms were compelled to connect via an integrated, collaborative, efficient and environmentally sound transmission system, that being the OTN.

  We implore the SoS BEIS to consider the overall impacts multiple radial connections will have on rural Norfolk and, within the environmental impact consideration, any potential DCO for the Norfolk Boreas to be for the windfarm if only to enable a more environmentally friendly transmission system to be developed.

In this submission, the Applicant is being obdurate and has provided little evidence that there has been any meaningful engagement with the OTNR. The real issue is the adverse environmental impact that the Norfolk Boreas onshore transmission system and substation will have. There is little detail within this submission that would support the application, especially when coupled with the Norfolk Vanguard application and the combined environmental impacts. However, all of the issues could be removed at a stroke if the SoS BEIS were to consent the offshore development in isolation.

Yours faithfully,

Ray & Diane Pearce

nationalgridESO

Website Publication

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Monday 27th September 2021 [redacted]

Electricity System Operator (ESO) Open Letter on the Offshore Transmission Network Review (OTNR)

Dear colleagues,

One of the key areas of regulatory development at this time is the effort to bring about greater coordination in the development of the offshore transmission system through the OTNR, which was launched in July 2020 by the Minister of State for Business, Energy and Clean Growth to support the offshore wind target of 40GW by 2030[1].

Within the OTNR we are working collaboratively with key stakeholders, including the Transmission Owners (TOs). We have published this open letter in our role as the chair of the newly established Central Design Group (CDG) within the OTNR Pathway to 2030 workstream. It has been drafted in collaboration with the TOs and the content is supported by Scottish and Southern Electricity Networks Transmission (SSEN-T), Scottish Power Energy Networks (SPEN) and National Grid Electricity Transmission (NGET) as key members of the CDG

This open letter provides an update to offshore project developers on how the OTNR could impact on their current offshore connection contracts or any future offshore applications / modifications. In this context, and given the aims of the OTNR, 'offshore' refers to applications and connection contracts for access to and use of the transmission system for either generation or demand projects which are not located onshore. As a result, offshore encompasses projects with offshore infrastructure, including offshore wind farms, offshore demand, interconnectors and Multi-Purpose Interconnectors (MPIs) even though they are not classed as offshore transmission.

The OTNR has been structured in workstreams[2] and the impact of each of these on connections is different. We have set out our current position on each workstream as follows.

Early Opportunities Workstream

Under the current arrangements, connection offers have been made on the basis that the design of the transmission works (onshore and offshore), and specifically the interface between these transmission works, have been established through the 'Connection and Infrastructure Options Note process' i.e. the CION process[3]. This CION process is usually fully undertaken after the connection offer has been entered into by the developer and the ESO.

Any offshore projects which have previously been through the full CION process but have not achieved both planning consent and a Contract for Difference (or equivalent) will generally be considered to be within scope of the Early Opportunities workstream. Those projects can opt-in with a pathfinder proposal to consider coordination and further information on opting-in can be found here. As these projects are at an advanced stage of development where much of the detailed network design and planning consent work has already been completed, opting-in to a coordinated design is currently voluntary.

The intention of this workstream is to provide an avenue for offshore developers to consider opportunities for these projects to work together to determine whether there is a more coordinated option available than that previously identified through the traditional CION approach, especially in regions where several projects are

1 [redacted]
2 Early Opportunities, Pathway to 2030, Enduring Regime and MPIs.
3 A 'connection offer' is the contractual documentation provided to a developer following a licenced 'connection process', whereas the 'CION process' is an associated process which only applies to some connection offers. More information can be found here and here.

expected to connect. If identified and agreed to be deliverable under Early Opportunities, connection contracts will then need to be updated to provide for this coordination.

We will inform relevant project developers if their current/planned project is considered to be in-scope for the Early Opportunities workstream.

We expect that any offshore projects considered to be connecting prior to the Early Opportunities workstream scope will likely continue under the status quo connection process and contract arrangements. This category includes any offshore project which has concluded their post-signature CION process (if required) and has relevant planning consents and a Contract for Difference, or equivalent.

Pathway to 2030 Workstream

As set out above, a CDG has been set up under the OTNR for the Pathway to 2030 workstream which will allow the ESO to produce a Holistic Network Design (HND) in consultation with the TOs in respect of the connection of in-scope offshore projects and/or agreed future capacity requirements. A draft of the Terms of Reference for the CDG can be found within the recent Ofgem consultation related to Early Opportunities, Pathway to 2030 and MPIs here.

Projects in-scope for the HND and Pathway to 2030 workstream are primarily The Crown Estate Leasing Round 4[4] and ScotWind[5] projects. These projects will be considered in the HND which is aiming to be delivered as per the CDG Terms of Reference. We anticipate that the workstream scope will also include offshore projects within the Celtic Sea[6] and a handful of other offshore projects which are spatially and/or temporally relevant to other in-scope projects for the HND and Pathway to 2030 workstream. We will inform relevant project developers if their current/planned project is considered to be in-scope for the HND and Pathway to 2030 workstream, with additional connection contract clauses added into relevant contracts. This will only be to the extent that they are necessary to account for the potential future changes due to the HND and Pathway to 2030 workstream.

The approach to ensure connection offers include the overall efficient, coordinated and economical solution remains and is now reinforced by the objectives of the OTNR, including the HND as per the Terms of Reference as above. The traditional CION process reflects a more limited approach to coordination than is now envisaged under the HND and Pathway to 2030 workstream. This traditional approach will therefore be adapted for in-scope projects and the connection design and post CION offer will instead be based on the outputs of the HND and this will be provided for in updated connection contracts in future.

Once the HND is available we will work with TOs and in-scope developers to update connection contracts as a result of the HND (e.g. the interface site, connection date, etc.) and also as a result of any changes to the offshore delivery model, as has recently been consulted upon by Ofgem within the above referenced consultation.

We will continue to engage with in-scope project developers over the coming months. This includes holding the first of a programme of regular webinars for in-scope project developers in the near future and more information, including on the date and time of this first webinar (which will be mid-October 2021), will be provided in the near future. Further information on process and timescales will be provided and you can register your interest here.

A high-level overview of the key process steps to develop the HND, is included within Appendix 1.

Enduring Regime Workstream

For offshore projects which are not within scope of a prior workstream there will still be project impacts as the Enduring Regime continues to be developed.

As such, in the short-term any new offshore applications considered to be intending to connect within the Enduring Regime timescales (i.e. subsequent to Early Opportunities and Pathway to 2030) will be progressed

[redacted]

on a 'pre-CION' basis. Whilst this will tentatively identify the transmission works and resulting connection date (etc), further work will be required to validate or amend these at a later date.

The connection offer will therefore be subject to the outcome of the development of the Enduring Regime, including the process for identifying the overall efficient, coordinated and economical solution and the available offshore delivery models.

We will keep the post-acceptance position/process for projects in-scope for the Enduring Regime under review, as we expect them to be delivered through the approach developed in this workstream rather than through the traditional or adapted CION approach as above. This will be recognised and provided for in any connection contracts offered in future. An initial consultation related to the Enduring Regime is expected to be published by the Department for Business, Energy and Industrial Strategy (BEIS) in the near future.

We will inform relevant project developers if their current/planned project is considered to be in-scope for the Enduring Regime workstream and we expect that additional connection contract clauses will be incorporated into relevant connection offers as a result of the Enduring Regime workstream.

Next Steps

We recognise that the above will create uncertainty for current and future offshore developers. As you may appreciate, matters are evolving and we hope that this open letter starts to provide clarity, especially for projects in-scope for Pathway to 2030 in relation to the key process steps included within Appendix 1.

As well as the expected Pathway to 2030 webinars mentioned above, we will be publishing an Autumn Offshore Coordination progress update in mid-October 2021 and subsequently holding a progress update webinar shortly thereafter and further information on both will be provided in the near future.

We will continue to keep you updated and engage you as the OTNR is progressed across all workstreams.

In the meantime, if you have any questions about the potential impacts on your current or planned future offshore projects please get in contact with your ESO Connections Contract Manager or the Offshore Coordination Team at box.OffshoreCoord@nationalgridESO.com.

Yours sincerely

[redacted]

Graham Stein

Offshore Coordination Senior Manager and CDG Chair

APPENDIX 1

The HND will be developed in close engagement with key stakeholders and offshore project developers are one of those key stakeholders. We expect that offshore project developers will have relevant information and insights in relation to the development of the HND in support of the ESO and TOs. Therefore, we expect that the CDG will regularly engage and consult with impacted offshore project developers at key points throughout the HND development process via a variety of channels e.g. bilateral discussions, webinars, periodic update publications, etc. This engagement will continue beyond the publication of the HND. So far, we have produced a high-level overview of the key process steps in respect of the development of the HND.

Step 1: Onshore Network Update

Update of the onshore network model to incorporate additional network reinforcement schemes to support 40GW of offshore wind by 2030. Development of a Cost-Benefit Analysis (CBA) methodology against which the options will be considered in relation to the HND as per the CDG Terms of Reference.

Step 2: Onshore and Offshore Network Planning and Coordination

a. 2030 counterfactual offshore design
    - Analyse the counterfactual design i.e. radial connections for in-scope projects.
b. 2030 coordinated offshore design
    - Develop the strategic medium-term coordinated offshore network design for 2030. This design will only consider in-scope offshore wind anticipated to connect up to 2030.
c. 2030 coordinated offshore design with a 2050 outlook
    - Develop a strategic outlook coordinated offshore network design for 2030. This design will consider the 2030 network in the context of the development of offshore wind across three future energy scenarios to 2050.

Step 3: CBA and Least Worst Regret Analysis

The CBA will be undertaken to identify the preferred HND for projects in-scope. This will involve appropriate consideration of each of the four Network Design Objectives within the CDG Terms of Reference.

Step 4: Single HND and Final Report with Recommendations

The results and supporting information will be included within a Final Report in respect of the HND.

Step 5: HND Design Iteration

There will likely be a need to refine some of the HND once the outcome of the ScotWind leasing round is known in January 2022.

Step 6: Connection Contract Update Programme[7]

Connection contracts will be updated as and where required as a result of the HND e.g. in respect of any onshore and offshore works, the interface point, the connection date, etc.

Step 7: Detailed Network Design (Post-HND)

Once the HND stage formally concludes, subject to the above referenced Ofgem consultation, onshore TOs will (for onshore work not already within this stage) take relevant onshore transmission system works into the detailed network design stage. The relevant offshore transmission works will be taken into the detailed network design stage by the appropriate party in accordance with such Ofgem consultation.

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[7] Subject to Step 5 being required and concluded and any potential interactions with the outcome of the offshore delivery model consultation. We will continue to develop Step 6 and aim to provide potentially impacted developers with a more robust and granular plan in relation to the connection contract update programme in Q4 2021.

Engagement and close working with projects in-scope will occur over the coming months and also ahead of the Final Report becoming available. We will also endeavour to share any interim views and outputs with key stakeholders. Current and planned engagement with projects in-scope includes:

- Engagement on offshore unit costs
- Engagement on offshore constraints
- Engagement on any proactive coordination proposals for the HND from projects in-scope

For the avoidance of doubt, we are happy to engage in respect of projects in-scope more broadly than in relation to the above points and we are also happy to engage with other interested stakeholders beyond those directly impacted by the HND.

Stakeholders will be informed and engaged at appropriate stages throughout the above process.

Further information in relation to such engagement will be provided to in-scope projects in the near future.

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Mr J Hain
Triton Knoll Offshore Wind Limited
Auckland House
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Your ref:
Our ref: 12.04.09.04/173C

11 July 2013

Dear Mr Hain

PLANNING ACT 2008
APPLICATION FOR THE PROPOSED TRITON KNOLL OFFSHORE WIND FARM ORDER

I. Introduction

1.1. I am directed by the Secretary of State for Energy and Climate Change (the "Secretary of State") to advise you that consideration has been given to the report of Panel of Examining Inspectors forming the Examining Authority ("the Panel"), Gideon Amos, Jim Claydon and Rynd Smith, who conducted an examination ("Examination") into the application (the "Application") dated 31 January 2012 by Triton Knoll Offshore Wind Farm Limited ("TKOWFL") for a Development Consent Order ("the Order") under section 37 of the Planning Act 2008 ("the 2008 Act").

1.2. The Examination of the Application began on 23 July 2012 and was completed on 21 January 2013. The Examination was conducted on the basis of written evidence submitted to the Panel and discussed at Open Floor hearings held in Skegness on 6, 7, 8 and 13 November 2012.

1.3. The Order, if made, would grant development consent for the construction and operation of the Triton Knoll Offshore Wind Farm situated on the bed of the North Sea approximately 33km off the coast of Lincolnshire and 46km off the coast of Norfolk, and situated within the UK's Renewable Energy

Zone designated for energy production. The proposed wind farm would consist of up to 288 wind turbines with a capacity of up to 1,200MW.

1.4 Enclosed at **Annex A** to this letter is a copy of the Panel's report and annexed Errata Sheet (Ref. EN01005) of corrections agreed by the Panel prior to a decision being made. References in this letter to the report are to the report subject to those corrections. The Panel's findings and conclusions are set out in section 5 of the report, and its recommendation is at section 6.

II. Summary of the Examining Authority's report and Recommendations

2.1. The Panel's report included their findings and conclusions on the following 11 principal issues:

- impacts of the infrastructure connection elements;
- European Sites and protected species impacts;
- species and habitats protected by other law and policy;
- fish and fishing impacts;
- landscape, seascape and visual impacts;
- historic environment impacts;
- impacts on the marine aggregates industry;
- shipping, operational, navigational safety and lighting impacts;
- socio-economic and transportation impacts;
- design and phasing; and
- other important and relevant impacts.

2.2. The Panel's recommendation is as follows:

"6.0.1 The Panel concludes that making the attached Order would be in accordance with National Policy Statements EN-1 and EN-3 and would also be in accordance with the Marine Policy Statement, relevant emerging Marine Plans, the development plan and other relevant policy, all of which have been taken into account by the Panel in this Report.

6.0.2 The Panel concludes that making the attached Order, with requirements for onshore consents and a traffic management plan, would fully take into account the Local Impact Report from East Lindsey District Council [LIR1].

6.0.3 The Panel finds that all potential transboundary impacts have been assessed, have been made known to the relevant EEA [European Economic Area] *states and would be appropriately mitigated were the recommended Order to be made.*

6.0.4 The Panel concludes that in making the attached Order, the SoS [Secretary of State] *would be fulfilling his duties under the relevant EU Directives as transposed into UK law by regulation, as well as the biodiversity duty under the NERC [Natural Environment & Rural Communities] Act, subject to Habitat Regulation Assessment.*

6.0.5 Whilst the SoS is the competent authority under the Offshore Habitat Regulations, the Panel finds that in its view the proposal would not adversely affect European Sites, species or habitats and the Panel has taken this finding into account in reaching its recommendation.

6.0.6 Some matters within representations related to the merits of policy set out in a national policy statement. In accordance with s87(3) of the PA2008 these matters have been disregarded. In regard to all other representations however, the Panel found no relevant matters of such importance that they would individually or collectively lead to a different recommendation to that below.

6.0.7 The Panel concludes that making the attached Order would not lead the United Kingdom to be in breach of any of its international obligations, nor lead the SoS to be in breach of any duty imposed on him under any enactment, and would not be unlawful by virtue of any enactment. It also finds that the adverse impact of the proposal would not outweigh its benefits, nor does it find there is any condition prescribed for deciding the application other than in accordance with the relevant National Policy Statements.

6.0.8 For all the above reasons and in the light of the Panel's findings and conclusions on important and relevant matters set out in this Report, ***the Panel recommends the Secretary of State for Energy and Climate Change to make the Triton Knoll Offshore Wind Farm Order in the form set out at Appendix E."***

III. Secretary of State's decision on and consideration of the Application

3.1. **The Secretary of State has decided under section 114 of the 2008 Act to make with modifications an Order granting development consent for the proposals in the Application.** A copy of the Order is attached at **Annex B** and the Habitats Regulations Assessment is attached at **Annex C**.

3.2. The Secretary of State's consideration of the Panel's report is set out in the following paragraphs. His consideration of representations received after the close of the Examination is also set out below. All paragraph references, unless otherwise stated, are to the Panel's report ("ER") and references to

Requirements and Deemed Marine Licence (DML) conditions are to those in Part 3 of Schedule 1 and Part 1 of Schedule 2 to the Order.

3.3. Except as indicated otherwise in the paragraphs below, the Secretary of State agrees with the findings, conclusions and recommendations of the Panel as set out in its report, and the reasons for his decision are those given by the Panel in support of their conclusions and recommendations. This letter should therefore be read with the Annexes A, B and C. This letter with enclosed Annexes A, B and C constitutes both the statement of reasons for the Secretary of State's decision for the purposes of section 116 of the 2008 Act and the notice and statement required by regulation 23(2)(c) and (d) of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009.

3.4. In reaching this decision, the Secretary of State is satisfied that in the absence of any adverse effects which are unacceptable in planning terms, making the Order would be consistent with energy National Policy Statements EN-1 (Overarching NPS for Energy) and EN-3 (NPS for Renewable Energy Infrastructure), which set out a national need for development of new nationally significant electricity generating infrastructure of the type proposed by TKOWFL.

<u>Impacts of the Infrastructure Connection Elements</u>

<u>The Application</u>

3.5. The Secretary of State notes that the Application does not include subsea export cabling or onshore grid connection infrastructure, which would be subject to subsequent consenting applications [ER 1.0.4 & 2.4.1]. The adequacy of coverage of the grid connection in the Environmental Statement (ES) was raised during Examination by the Panel and interested parties, as there was no detailed proposal for a connection [ER 4.1.5]. TKOWL's reason for this was that National Grid's (NG) prospective grid connection points changed during pre-application stage [ER 4.1.19] and it had taken the decision to proceed with the preparation of the ES and application with reference to an indicative grid corridor to avoid significant delay [ER 4.1.21].

3.6. The Secretary of State notes it was subsequently confirmed during Examination that TKOWFL was offered an onshore connection point at the Bicker Fen by National Grid and this was included in TKOWFL's indicative cable statement provided in support of the application [ER 4.1.21], which included an indicative 'Electrical Infrastructure Area of Search' extending from the proposed wind farm across the sea to the shore and across the south coast of Lincolnshire where it is approximately 15km in width. Whilst TKOWFL were unable to provide precise details of the route and only an indicative corridor at sea and on land to its preferred connection point at Bicker Fen, within this there were other optional areas of search for the landfall site for connecting cables [ER 4.4.1]. The Panel also considered it was clear that there remain other potential routes to Bicker Fen and alternatives to that point of connection with the National Grid [ER 5.1.4]. It is also noted that TKOWFL had not yet finalised the nature of the cable connection (which could, for example, be alternating current (AC) or high-voltage direct current (HVDC)) and this choice would have implications for selection, siting and design of associated equipment and substations [ER5.1.3].

Local Objections

3.7. Although not part of the Application, the Secretary of State notes that the Panel records that *"one of the most widely perceived concerns put before the Panel related to the choice and location of landfall sites and the manner in which a grid connection would be developed between landfall sites and the eventual connection to the national grid. Even though it was clear that grid connection proposals did not form part of the application, numerous representations were received relating to the possible effects of the onshore connection associated with this proposal."* [ER 5.1.7]

3.8. The Secretary of State also notes that *"Residents, parish councils, local authorities and interest groups raised objections to the landscape and visual impact of overhead lines, cables and substations; the disruption to tourism and the rural economy by the construction of infrastructure, burying of cables and traffic; the impact on wildlife, heritage, human health and the tranquillity of the rural environment; as well as questioning the practicality of crossing miles of low lying, complex land drainage systems which exist in this part of Lincolnshire."* [ER 5.1.8] These concerns are expanded in subsequent paragraphs in the Examining Authority's report [ER 5.1.9 - 5.1.43].

Environmental Impact Assessment (EIA) and the adequacy of Environmental Statement

3.9. The Secretary of State notes that the adequacy of the ES to cover treatment of the effects from consequential development (connecting infrastructure) outside the Order application site and not provided for within the Order was raised by interested parties and the Panel during the Examination [ER 4.1.18]. He notes Natural England also questioned the degree to which it was possible to assess the whole proposal in the absence of clarity about the detail of the grid connection [ER 4.1.22]. The National Policy Statement for Renewable Energy Infrastructure EN-3 provides that where the precise location of cabling routes/substations is not known, a cabling/substation corridor should be identified and the EIA should assess the effects of including this infrastructure within that corridor [ER 4.1.24]. Overarching National Policy Statement for Energy EN-1 also clearly envisages that an applicant can proceed with a proposal without a firm grid connection offer, whilst noting that the commercial risks associated with taking such a step rests with the applicant alone, but in such circumstances the applicant needs to provide sufficient information to comply with EIA Directive 2011/92/EU[1], including indirect,

[1] Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment

secondary and cumulative effects, encompassing information on grid connections [ER 4.1.27].

3.10. It is accepted that Article 5.1 (a) and (b) of EIA Directive 2011/92/EU enable the requirement for EIA information to be limited to that *'which is relevant to a given stage of the consent procedure and to the specific characteristics of a particular project or type of project and of the environmental features likely to be affected'* [ER 4.1.25]. Similarly, Article 5.1(b) of the Directive enables the submitted information to be limited by the current state of knowledge. The EIA Directive is implemented in the UK by the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009[2]. Regulation 2 and Schedule 4 of those Regulations provide that the information required here is limited to that which can be *"reasonably required*", having regard *"in particular to current knowledge*" [ER 4.1.26].

3.11. The Secretary of State agrees with the Panel's broad conclusions on the environmental information submitted by TKOWFL and EIA process undertaken [ER 4.4.1 &4.4.2] and also considers it is adequate for the purposes of his consideration of the Application and that sufficient information has been provided to enable him to fulfil his duties as competent authority under the Offshore Habitats Regulations[3]. He is also satisfied that it was not necessary or indeed possible for TKOWFL to submit detailed information about the anticipated grid connection for the proposal as part of the Application or to assess this in the supporting ES, given in particular that any grid connection will have to be the subject of subsequent approval(s) and assessment(s) [ER 4.4.1].

National Policy Statements and the Requirement for Mitigation of Indirect, Secondary and Cumulative Impacts

3.12. The Panel states that paragraph 4.9.3 of Overarching National Policy Statement EN-1 is clear that indirect, secondary and cumulative impacts should be assessed [ER 5.1.31], and the Secretary of State also agrees that paragraph 4.9.3 of EN1 requires that wherever possible, applications for new generating stations and related infrastructure should be contained in a single application. He also agrees that where applicants decide to put in an application that seeks consent only for one element but contains some information on the second, applicants should explain the reasons for the separate application. He also agrees applicants must ensure they provide sufficient information to comply with the EIA Directive including the indirect, secondary and cumulative effects, which will encompass information on grid connections.

3.13. The Secretary of State also agrees with the Panel's statement that in paragraphs 5.1.2 and 5.1.3 of EN-1 (which are generic statements about mitigation of adverse impacts) "*it is clear that the Secretary of State should*

[2] As amended by SI 20011/2741 and SI 2012/635
[3] The Offshore Marine Conservation (Natural Habitats, &c) Regulations 2007 as amended

consider mitigation of such impacts through requirements and conditions" [ER 5.1.31].

3.14. However, the Secretary of State notes the Panel has concluded that the ES provides adequate assessment of indirect, secondary and cumulative effects of the development and *"on grid connections to the extent necessary for this offshore proposal"* [ER 4.1.30]. He also notes the Panel is satisfied that there are no obvious reasons why the connection elements of the project would be likely to be refused, given the applicant would be able to bring forward a number of alternative routes or solutions to those indicated and given the lack of any substantive evidence from relevant authorities on this matter [ER 5.1.43]. The Secretary of State considers that paragraph 4.9.3 of EN1 sets out the way in which decisions should be made where there is a secondary element to a development which has not been included in the application. It states that *"If this option is pursued, the applicant(s) accept the implicit risks involved in doing so, and must ensure they provide sufficient information to comply with the EIA Directive including the indirect, secondary and cumulative effects, which will encompass information on grid connections. The [Secretary of State] must be satisfied that there are no obvious reasons why the necessary approvals for the other element are likely to be refused. The fact that the IPC has decided to consent one project should not in any way fetter its subsequent decisions on any related projects."*

3.15. The Secretary of State notes that the Panel found that issues of short-term construction and long-term visual, economic and environmental impacts could not be addressed directly in the Application because the applicant had been unable to accept a formal offer of grid connection [ER5.1.32]. Taking account of the representations received, the Panel also found that if the wind farm were consented without any requirements that would mitigate the likely impacts of the connection works, there were likely to be *"serious consequences for both local communities and landowners"* and in particular *"drainage interests and the ability of landowners in the vicinity of the connection infrastructure area of search to raise funding for investment, were likely to be compromised" [ER5.1.33].*

3.16. In view of the above, the Panel has recommended inclusion of a requirement in the Order that no works on the offshore generating station or associated offshore development shall commence until the Secretary of State has confirmed in writing that all the necessary consents for the connection and transmission works have been obtained [ER Appendix E, Requirement 21 in Part 3 of Schedule 1]. The Secretary of State also notes the Panel also considered that without a requirement there would be risk that any financial contributions made under any section 106 agreement pursuant to a future permission would be restricted in scale only to the subsequent applications for the grid connection infrastructure and would not relate to the project as a whole. The Panel also considers that, whilst not binding on future decisions, it secures *"functional and consenting link between two elements of the same project"* and would allow onshore and offshore elements to be considered cumulatively when the onshore impacts of the wind farm are better known at time of subsequent applications for connection elements. The requirement would also better ensure *"that subsequent permissions and/or 106 agreements could relate to and mitigate the impacts of, the project cumulatively."* [ER 5.1.38].

<u>The Secretary of State's view on mitigation in relation to grid connection infrastructure</u>

3.17. The Secretary of State does not consider that EN-1 requires that a Grampian-style requirement of the kind recommended by the Panel is imposed simply because the application envisages further onshore development. Rather, EN1 envisages that any impacts of such further development will normally be dealt with in the consenting procedure for that development.

3.18. In the Secretary of State's view, the consenting procedures in place in relation to the onshore infrastructure are sufficiently robust to ensure that the impacts of the infrastructure are appropriately mitigated. In particular, the Secretary of State notes that any subsequent supporting EIA assessment for grid connection infrastructure would also need to consider cumulative impact with the offshore wind farm development.

3.19. The Secretary of State is also not convinced that it is necessary to link the offshore and onshore elements of the development in order to ensure that any financial contributions made under a future s.106 agreement relate to the project as a whole rather than only the subsequent grid connection infrastructure applications. In the case of the Triton Knoll project, the offshore generating element would be located 33km off the coast of Lincolnshire and 48km off the coast of North Norfolk. The Panel found that the visual impacts of the offshore development are very limited [ER 5.5.41], and that to the extent that a judgment can be made, the limited onshore effects of construction in the DCO area, due to its distance from the shoreline, will significantly limit cumulative effects as observed from the same coastal locations [ER R.5.42]. The Secretary of State therefore considers that the potential cumulative impact of the offshore element of the overall project is not likely to be a significant component of the impact of the onshore element of the project. He does not consider therefore that it is appropriate to impose a Grampian-style requirement in order to ensure that such cumulative impacts are taken into account when assessing the scale of contributions under a section 106 agreement. Nor is it clear how a Grampian-style requirement of the type suggested would achieve such a linkage.

3.20. For the reasons set out above, the Secretary of State has decided therefore that it is not necessary to include the Grampian-style requirement recommended by the Panel.

IV Habitats Regulations Assessment: European Sites and Protected Species Impacts

4.1. Regulation 25 of the Offshore Marine Conservation (Natural Habitats & c.) Regulations 2007 (as amended) ("the Offshore Habitats Regulations") requires the Secretary of State to consider whether the proposed Development would have a likely significant effect ("LSE") on a European Site as defined in such Regulations. If such an LSE is identified, then he must undertake an Appropriate Assessment ("AA") to determine whether or not the project will adversely affect the integrity of the European Site in view of its conservation objectives. The AA should take into account the impacts of the proposed project alone and also in combination with other plans and projects. If the Secretary of State cannot ascertain the absence of an adverse effect on site integrity within reasonable scientific doubt, then under the Offshore Habitats Regulations, alternative solutions should be sought. In the absence of an acceptable alternative, the project can proceed only if there are imperative reasons of overriding public interest.

4.2. The Secretary of State agrees that an AA is required under the Offshore Habitats Regulations to consider impacts of the proposed wind farm with other plans and projects. He is satisfied that sufficient information is available to enable him to make an AA.

4.3. A copy of the Habitats Regulations Assessment containing the Secretary of State's AA is attached to this decision letter and has been prepared on the basis of the Panel's Report together with the Report on Implications for European Sites (RIES) produced by PINS, and consultation responses on the RIES from Natural England and the applicant (which were in broad agreement with the RIES in all significant effects) [ER 5.2.10-5.2.11].

4.4 The Secretary of State notes that the Panel's Report and RIES contained a typographical error that referred to '9' Sandwich tern mortalities. The Errata Sheet produced by PINS confirms that this figure should instead be '8' sandwich tern mortalities. The Errata Sheet states that *"At paragraphs 5.2.40 and 5.2.51 the Examining Authority has incorrectly referred to the mortality figure for ALL Sandwich tern mortalities ((9) as identified in the Applicant's HRA report see Tables 14 and 15, page 63). The reference should in actual fact be to the 8 additional ADULT Sandwich tern mortalities identified in the DECC Southern Wash AA, relied upon by the Applicant in their report to inform the HRA and accurately identified at Table 5.3 of the Examining Authority's report. In addition Matrix 3.1 (g) of the RIES incorrectly referred to the mortality figure for ALL Sandwich tern mortalities 9. The reference should in actual fact be to the 8 additional ADULT Sandwich tern mortalities."*

4.5 The Secretary of State has taken PINS' Errata Sheet into consideration and reached his conclusions on the basis of the correct figure of '8' Sandwich tern mortalities.

4.6 The Secretary of State agrees with the Panel's *"first tier"* conclusion [ER 5.2.13] that the potential for LSE cannot be excluded in respect of five European sites:

- North Norfolk Coast Special Protection Area (SPA) and Ramsar;
- Flamborough Head and Bempton Cliffs SPA;
- Inner Dowsing, Race Bank & North Ridge candidate Special Area of Conservation (SAC);
- Humber Estuary SAC; and
- The Wash and North Norfolk Coast SAC.

4.7 The Panel concluded that there will be no adverse effects on the integrity of any of the above sites as a result of the Project alone or in combination [ER 5.2.51, 5.2.61, 5.2.67, 5.2.75, 5.2.79, 5.2.81]. The Statutory Nature Conservation Bodies (SNCBs), agreed with the Panel's conclusions for four of the five sites. However, they raised concerns that there could be an adverse effect on the North Norfolk Coast SPA/Ramsar due to Sandwich terns colliding with turbines in combination with other wind farms in the Greater Wash. They questioned the collision risk model and modelling parameters adopted by TKOWFL (which are the same as applied by the Secretary of State on the Greater Wash AA in 2012).

4.8. Having assessed the evidence, the Secretary of State concludes that the collision risk model and modelling parameters adopted by TKOWFL in relation to Sandwich terns is robust. This is an accord with his judgement in the Greater Wash AA[4] and with the findings of the Panel [ER 5.2.46-5.2.51]. He is not aware of any new scientific evidence that would lead him to depart from his previous judgement nor of any demonstrable unreasonableness in that decision.

4.9. The Secretary of State finds no reason to disagree with the Panel's conclusions of no adverse effects for any of the five European Sites. The reasoning behind this is set out in the attached Habitats Regulations Assessment. This conclusion takes account of relevant mitigation measures included in the DCO and DML requirements.

[4] The Appropriate Assessment produced in connection with the Secretary of State's development approval under section 36 of the Electricity Act 1989 for wind farms at Race Bank and Dudgeon, made on 6 July 2012.

V Developments since the close of ExA Examination

5.1. The Secretary of State notes that Lincolnshire County Council wrote to RWE Npower Renewables Limited on 1 March 2013 (i.e. after the close of the ExA's Examination) to express *"grave concerns"* regarding the Company's pre-submission consultation on the location of an onshore electricity substation and intermediate electrical compound. The Council considers that the consultation on the four search zones for the substation and three for the compound *"within sensitive areas of Boston and East Lindsey respectively"* is *"presented as a fait accompli in which only site details are open to consideration and is not consistent with how a consultation should be conducted i.e. by asking pertinent questions with alternative options".* The Secretary of State also notes Lincolnshire County Council wrote the Secretary of State for Communities and Local Government on 12 June 2013 to express their concerns regarding energy infrastructure development in Lincolnshire, including proposed substation locations for the Triton Knoll project.

5.2. As Lincolnshire County Council's letter relate to consultation on the onshore grid connection infrastructure, which will be subject to further consents and assessments, the Secretary of State is satisfied that they raise no new issues that require reference back to parties.

5.3. The Secretary of State has also received a letter from Mark Simmonds MP dated 14 May 2013, on behalf of his constituents Mr and Mrs Slaughter, regarding concerns relating to the proposed Bicker Fen substation on Bicker Village. Similarly, as the letter relates to the onshore grid connection infrastructure, which will be subject to further consents and assessments, the Secretary of State is satisfied that it raises no new issues that require reference back to parties.

VI Secretary of State's conclusions and decision

6.1. For the reasons given in this letter, the Secretary of State considers that there is a compelling case for authorising the Triton Knoll offshore wind farm project, given the added contribution that it would make to the production of renewable energy He considers granting consent would be consistent with energy National Policy Statements EN-1 (Overarching NPS for Energy) and EN-3 (NPS for Renewable Energy Infrastructure), which set out a national need for development of new nationally significant electricity generating infrastructure of the type proposed.

6.2. Having carried out a Habitats Regulations Assessment containing an AA, which is attached to this letter, the Secretary of State considers that there will be no adverse effects on the integrity of: the North Norfolk Coast SPA/Ramsar; the Flamborough Head and Bempton Cliffs SPA; the Inner Dowsing, Race Bank and North Ridge candidate SAC, the Humber Estuary

SAC; and the Wash and North Norfolk Coast SAC, either alone or in combination with other plans and projects.

6.3. The Secretary of State has therefore decided to accept the Panel's recommendation at ER 6.0.8 to make the Order granting development consent and imposing the requirements as proposed by the Panel, but subject to the modifications described in section 7 below. He confirms that, in reaching this decision, he has had regard to the Panel's Report, as amended by the Errata sheet referred to in paragraph 1.4 above, the local impact report submitted by the relevant local authority and to all other matters which he considers important and relevant to his decision as required by section 105 of the 2008 Act. The Secretary of State confirms also for the purposes of regulation 3(2) of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 that he has taken into consideration the environmental information as defined in regulation 2(1) of those Regulations.

VII Modifications to the Order

7.1. For the reasons set out in paragraphs 3.17 - 3.20 above, the Secretary of State has decided not to include Requirement 21 in the draft Order in Part 3 of Schedule 1 at Appendix E to the ER *(*headed *"Consents for connection and transmission works"*).

7.2. He has also decided not to include Requirement 19 in Part 3 of Schedule 1 to the draft Order *(*headed *"Decommissioning"*), as he understands this requirement was included in error and is duplicated by Requirement 24 in Part 3 of Schedule 1 to the draft Order at Appendix E to the ER (also headed *"Decommissioning"*).

7.3. The Panel also asked the Secretary of State to consider whether SNCBs should be removed from the provisions for arbitration covered by Article 12 of the draft Order at Appendix E (headed *"Arbitration"*) [ER 5.11.20] To maintain consistency with other offshore wind farms approved under the Planning Act 2008 since the close of the Panel's Examination, the Secretary of State has decided that the arbitration provisions should apply to SNCBs and has therefore modified the article in the Order accordingly.

7.4. In relation to transference of the Order to another undertaker, the Panel has asked the Secretary of State to consider whether Article 6(5) of the draft Order at Appendix E should be modified to also require electricity licence holders to notify him of a transfer [ER 5.11.21]. To maintain consistency with other offshore wind farms approved under the Planning Act 1998 since the close of the Panel's Examination, the Secretary of State has decided not to modify the transference provisions in the Order.

7.5. In addition to the above, the Secretary of State has decided to make various minor changes to the form of the draft Order as set out in Appendix E of the ER which do not materially alter its effect, including changes to conform with the current practice for Statutory Instruments (e.g. modernisation of language), changes in the interests of clarity and consistency, and changes to ensure that the Order has the intended effect.

VIII Challenge to decision

8.1. The circumstances in which the Secretary of State's decision may be challenged are set out in the note attached at the Annex to this letter.

IX Publicity for decision

9.1. The Secretary of State’s decision on this application is being publicised as required by section 116 of the 2008 Act and regulation 23 of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009.

Yours sincerely

Giles Scott
Head of National Infrastructure Consents

ANNEX
LEGAL CHALLENGES RELATING TO APPLICATIONS FOR DEVELOPMENT CONSENT ORDERS

Under section 118 of the Planning Act 2008, an Order granting development consent, or anything done, or omitted to be done, by the former Infrastructure Planning Commission or the Secretary of State in relation to an application for such an Order, can be challenged only by means of a claim for judicial review. A claim for judicial review must be made to the High Court during the period of 6 weeks from the date when the Order is published. The Triton Knoll Offshore Wind Farm Order as made is being published on the date of this letter on the Planning Inspectorate website at the following address:
http://infrastructure.planningportal.gov.uk/projects/east-midlands/triton-knoll-offshore-wind-farm/

These notes are provided for guidance only. A person who thinks they may have grounds for challenging the decision to make the Order referred to in this letter is advised to seek legal advice before taking any action. If you require advice on the process for making any challenge you should contact the Administrative Court Office at the Royal Courts of Justice, Strand, London, WC2A 2LL (0207 947 6655

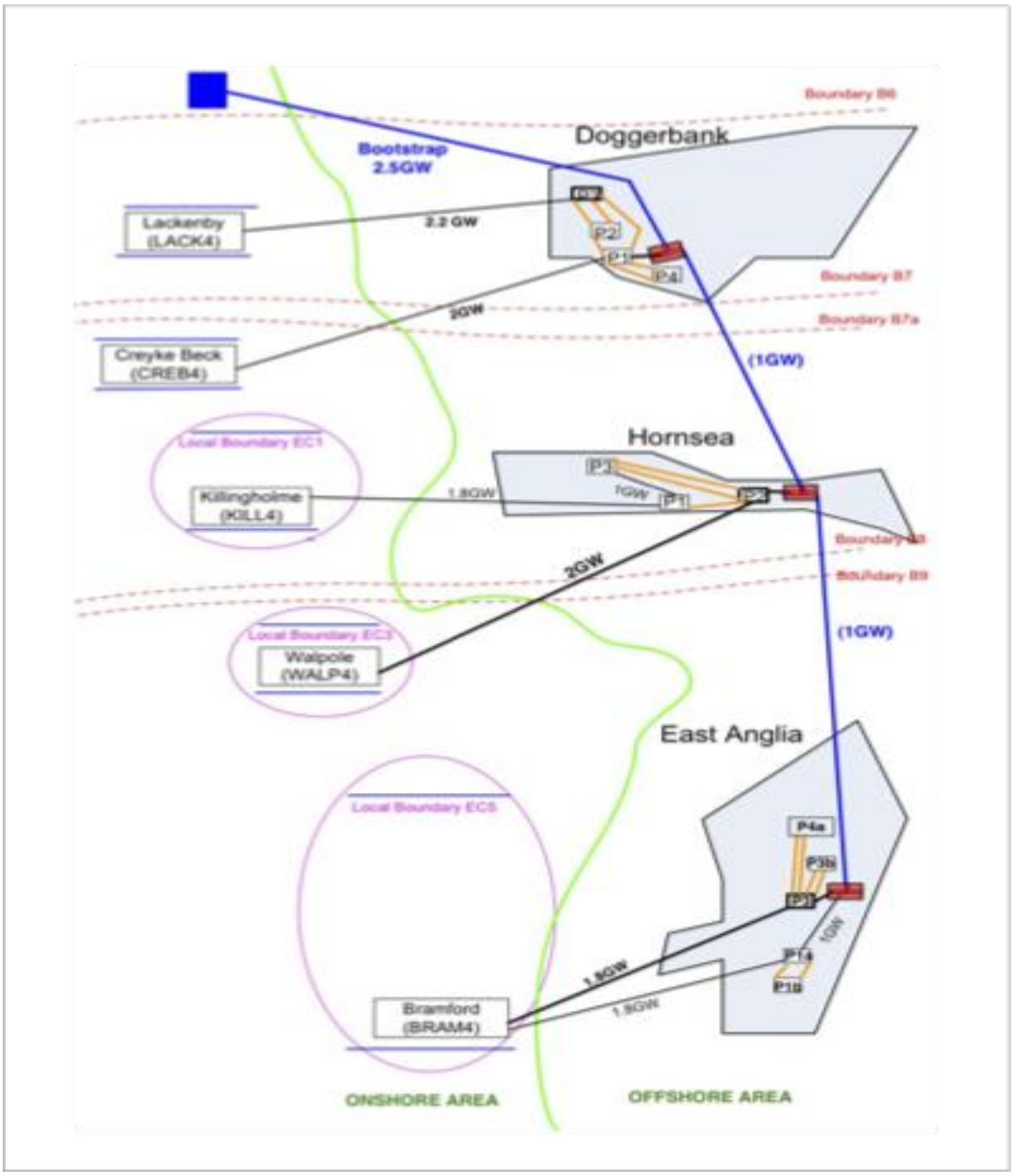
ERRATA SHEET – Triton Knoll Offshore Wind Farm

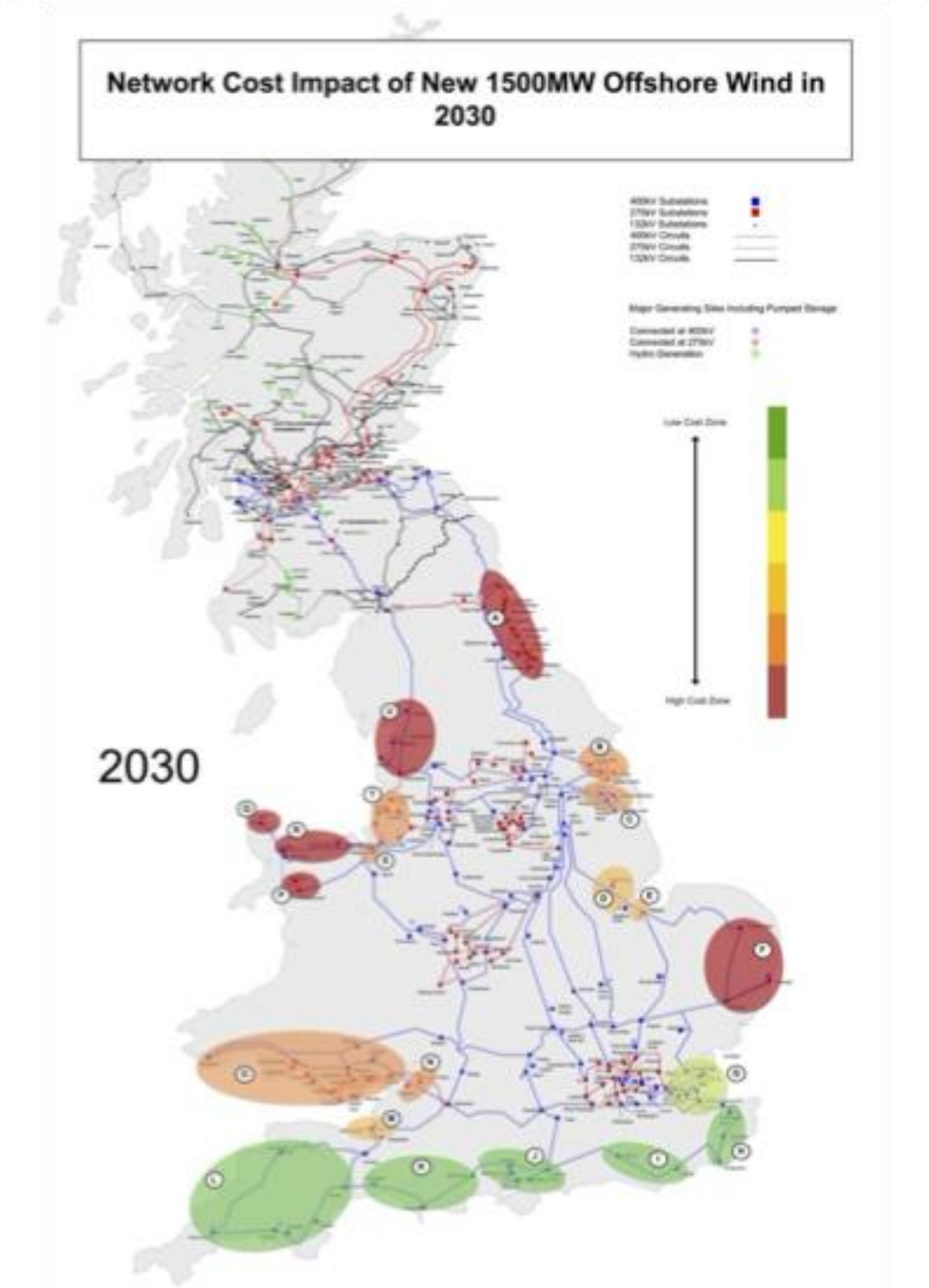
Planning Act 2008 (as amended)

Secretary of State's decision letter and statement of reasons dated 11 July 2013

Page No.	Paragraph	Error	Correction
12	7.4	Incorrect date.	Replace "Planning Act 1998" with "Planning Act 2008".

IOTP (East) 2015 Network Design




Network Cost Impact of New 1500MW Offshore Wind in 2030
2030

From:	[redacted]
To:	Norfolk Boreas
Cc:	[redacted]
Subject:	Response to SoS BEIS Letter 22 September 2021 - In Combination Effects DEP / SEP
Date:	21 October 2021 12:04:14
Attachments:	EN010078-003859-SEAS Campaign formal complaint to PINS 20210214.pdf GoldsworthyElectromagnetic_fields_2007[1].pdf British Geological Survey of Acquifers.pdf

References:

A. Secretary of State Business, Energy & Industrial Strategy (SoS BEIS) Letter dated 22 September 2021 (Published 22/09/2021).
B. Norfolk Boreas Ltd – Response to Secretary of State Letter dated 9 July 2021 - Updated information on cumulative and in combination effects with the Dudgeon and Sheringham Shoal Extension Projects (Published 23/08/2021).

Attachments:

1. British Geological Survey – Groundwater Systems & Water Quality
2. SEAS Complaint to PINS dated 14 February 2021.
3. The Biological Effects of Weak Electromagnetic Fields by Andrew Goldsworthy 2007.

Dear Planning Inspectorate,

In further response to the SoS BEIS's letter at Reference A we have the below comments on the Applicant's submission regarding the "Updated information on cumulative and in combination effects with the Dudgeon and Sheringham Shoal Extension Projects" as at Reference B.

We have the following responses to the Applicant's statements (in blue) made in their submission EN010087-002849:

General

- *DEP and SEP will make landfall at Weybourne in North Norfolk and propose to install a 60km buried cable system which heads in a southerly direction between the landfall at Weybourne and the grid connection south of Norwich. Three build out scenarios are described within the PEIR showing the earliest construction start date for DEP and SEP as 2025, but construction could start as late as 2028.*

  Norfolk Boreas will make landfall at Happisburgh in North Norfolk, with a 60km onshore buried cable system that heads in a westerly direction between landfall at Happisburgh and the grid connection point near Necton. The Norfolk Boreas onshore construction works are programmed to be undertaken between 2023 and 2026, under the worst case scenario, Scenario 2, which assumes that Norfolk Vanguard would not proceed to construction. Under Scenario 2 peak construction activity would occur in 2023/2024 associated with the cable duct installation and substation civil engineering works.

  The declared timing of construction work is at odds with statements made elsewhere in the Applicant's submissions, such as: in response to Open Floor Hearing 2 the Applicant stated: *"… the expected construction time-frame for Norfolk Boreas is between 2024 and 2030 …"* Therefore, there could be an overlap between peak construction activity if

Norfolk Boreas does not commence work in 2023 and DEP/SEP makes its earliest start date of 2025.

- *The Norfolk Boreas onshore substation location near Necton is approximately 30km from the proposed DEP and SEP onshore substation site options at Norwich; however, there is a physical overlap of the Norfolk Boreas and DEP and SEP onshore cable routes where they cross in the area to the east of Cawston.*
  Given that there would be no overlap of peak construction activities between DEP and SEP and Norfolk Boreas (which are programmed to be at least a year apart, under the worst case Scenario 2) there is limited scope for any significant cumulative impacts to be realised.

  The Applicant is not at liberty to make this statement (see above) and irrespective of the location of the individual substation sites, HGV and ancillary traffic would still operate from the potentially collocated Construction Compounds at Oulton where the cumulative impacts would be significant.

- *In any event the majority of potential cumulative impacts would be localised to the area in proximity to the crossing point of the onshore cable routes, which is located in arable land away from any sensitive receptors. However, given some impact types extend beyond this localised area, for example impacts on the road traffic network and impacts to river catchments, each of the onshore EIA topics is considered below for completeness.*

  The potential cumulative impacts surrounding three NSIPs have been, and continue to be, understated by the Applicant. The environmental impact of two intersecting cable trenches is significant especially with respect to the loss of land production, habitat and agriculture.

Ground Conditions & Contamination

- *Following a review of the available information provided within the DEP and SEP PEIR the Applicant concludes that there would be no likely significant cumulative effects, given that there would be no overlap of peak construction activities, and that both DEP and SEP and Norfolk Boreas commit to the use of appropriate working practices and the use of PPE.*

  The Applicant is again not at liberty to state when the peak construction activities **wIll** occur. Therefore, it would be appropriate for the Applicant to reissue it's comments based on worse case scenarios, especially if peak activities were to overlap. We contend that the activities around the crossing points for the Norfolk Boreas cable will be significant especially if both projects are in construction at the same time.

Water Resources and Flooding Risk

"Norfolk Boreas proposes to cross five watercourses using open cut methods, and DEP and SEP proposes to cross two watercourses using the open cut method. The total of seven open cut crossings remains a low magnitude of effect, therefore the cumulative effect of both Norfolk Boreas and DEP and SEP in the River Bure catchment will not increase the impact reported for Norfolk Boreas alone, i.e. no greater than minor adverse significance. It should also be noted that these activities would be undertaken in different years, with Norfolk Boreas proposing to undertake watercourse crossings in 2023/2024, and DEP and SEP proposing to undertake them at the earliest in 2025, in effect meaning that there would be no mechanism to realise any potential cumulative impact."

As above, the Applicant continues to make assumptions with regards to timing of events. Therefore, we reiterate, the Applicant should resubmit its responses on a worst case scenario.

The Applicant has omitted to comment on the most important 'Water Resource' from which the inhabitants of Norfolk draw their domestic water – the Norfolk aquifers. A British Geological study of the Norfolk aquifers, 'Groundwater and Water Quality' at Attachment 1 makes for interesting reading, with the following comments:

"Groundwater issuing from springs has been regarded since the earliest recorded history as something pure, even sacred. In its natural state, it is generally of excellent quality and an essential natural resource. However, the natural quality of groundwater in our aquifers is continually being modified by the influence of man. This occurs due to groundwater abstraction and the consequent change in groundwater flow, artificial recharge and direct inputs of anthropogenic substances."

The Applicant has made no attempt to understand the impact that a large disruption of land by trenching, especially at the crossing points, will have on the aquifers; this land has remained relatively undisturbed other than by arable agriculture for centuries. We contend that the water entering the aquifer could potentially be modified by the activity of the Applicant (*the influence of man).*

"Norfolk Boreas proposes to cross five watercourses using open cut methods, and DEP and SEP proposes to cross two watercourses using the open cut method. The total of seven open cut crossings remains a low magnitude of effect, therefore the cumulative effect of both Norfolk Boreas and DEP and SEP in the River Bure catchment will not increase the impact reported for Norfolk Boreas alone, i.e. no greater than minor adverse significance."

The study at Attachment 1 notes the following:

"Groundwater flows and seepages are also vital for maintaining summer flows in rivers, streams and wetland habitats, some of which rely solely on groundwater, especially in eastern and southern England. The quantity and quality of groundwater is therefore extremely important to sustain both water supply and sensitive ecosystems."

Therefore, irrespective of the Applicant's assertion regarding the interaction of the two projects at the crossing points and the need to open cut cross the rivers in Norfolk, the seepage of groundwater contaminated with disturbed substances from the trenching activity will exist. The impact of trenching on Norfolk's rivers and ecosystems has not been properly researched and the Applicant's submission is therefore, incomplete.

We contend that the disruption of 180kms of stable and ancient arable land (60kms for Boreas / Vanguard , 60kms for Hornsea 3 and 60kms for DEP/SEP) with trenches up to 60m wide, will impact the aquifers and potentially have an adverse impact on public health. By way of example, the Sneddon Law windfarm development in Scotland was stopped by a civil court action for poisoning the local water supply. Further, in 2013, legal action was taken against Scottish Power who "lied and obfuscated" about the harm their windfarm was causing to human health through contamination of the watercourse.

At the crossing points, there is a significant risk of disturbing the watercourse as, one of the cable trenches will have to be dug deeper to avoid physical and electrical interference between the cables. Therefore, the Applicant needs to provide clear and unequivocal research that their activity will not contaminate the Norfolk aquifers which lie close to the surface.

Land Use & Agriculture

- *Norfolk Boreas and DEP and SEP both commit to use a specialist drainage contractor to locate existing drainage systems and develop detailed preconstruction drainage plans. Cables from both projects would be installed at a depth below the level of typical field drainage pipes to minimise impacts and interaction with agricultural drainage post-construction. In addition, both projects commit to seek private agreements (or provide compensation in line with the compulsory purchase compensation code) with affected landowners/occupiers and the land will be reinstated to preconstruction condition.*

*The DEP and SEP PEIR assesses that there is **no residual cumulative impact** to agricultural farming practices or agricultural drainage systems associated with the construction of Norfolk Boreas and DEP and SEP.*

There are Norfolk landowners with the experience of the Dudgeon cable trench being dug across their land in 2015 and the above statements are not the case. It is 6 years since the reinstatement of the land by a specialist drainage contractor, employed by Dudgeon developers, but the land is still disrupted, does not drain and several of the active drains have hot water flowing out of them.

The "private agreements" which the Applicant deploys will effectively silence any objections that the landowners may have to either development. The use of CPA agreements have been employed to effectively deny landowners the right to dispute the disruption of their land. Such was the consternation of Interested Parties (IPs) to the EA2 ExA that a formal complaint was made, see Attachment 2.

We contend that private agreements between the Applicant and landowners could be used to hide any negative ongoing impacts of their cable trench and, as such, should be made illegal.

We respectfully ask that it is not left up to the developers or Applicants to assess the cumulative impacts their activities will have on huge swathes of Norfolk countryside and that the SoS BEIS undertakes an independent review of the potential for untold damages.

Ecology

*The DEP and SEP PEIR does not provide a cumulative impact assessment for onshore ecology as ecological surveys are continuing through 2021. However, given the Norfolk Boreas ecology survey findings and the low ecological value of the arable land that the two projects cross, the Applicant concludes that there would be **no likely significant cumulative effects** upon onshore ecological receptors within the arable land where the cable routes from both projects cross.*

We contend that the Applicant cannot make this conclusion until the results of the DEP/SEP assessment are known.

Traffic & Transport

- *Following a review of the available information provided within the DEP and SEP PEIR the Applicant concludes that there are **no likely significant cumulative effects** for traffic and transport because, there would be little overlap of construction activities, Norfolk Boreas construction traffic generation during 2025 would be extremely low, and DEP and SEP has committed to avoid routing any construction traffic through Cawston.*

The HIV Scheme for the proposed construction works of five NSIPs (Boreas, Vanguard, Hornsea 3, DEP & SEP) cannot merely be broken down and disregarded by the Applicant with the above conclusion. The Applicant needs to review the peak flow of traffic at worst case and make a proper assessment of the significant cumulative effects; the whole item submitted in their response is woefully inadequate. If there were to be a further delay to Norfolk Boreas but no delay to DEP/SEP the village of Cawston would be cut off from the remainder of Norfolk by construction traffic with a crossing point for Boreas with Hornsea 3 being to the West of the village and a crossing point for Boreas with DEP/SEP being to the East of the village. Furthermore, all of the construction traffic for all 5 projects could be disgorging from the Construction Compounds at Oulton during the same period or without overlap for a prolonged period; the impact for both scenarios is still significant.

The impact of the construction periods for the five projects being spread out in time, and not overlapping, will still have an impact for construction traffic upon all the surrounding villages, but especially Cawston and Oulton, and for a significant period of time of up to a decade. However, it is frustrating, disingenuous and fallacious for the Applicant to continue to underplay the cumulative impact the 'Traffic and Transport' generated by Norfolk Boreas alone will have on the area around the crossing points.

We ask that the SoS BEIS takes time to review and understand the figures, maps and cumulative impact that the HIV Scheme will have on the receptors of 'Traffic and Transport' living in Cawston and Oulton, and, adjacent to the crossing points; we are confident that such a review will expose a significant negative impact often understated by the Applicant.

Traffic Borne Noise

- *In the absence of mitigation, two road links were identified as having potentially significant cumulative traffic borne noise impacts (cumulatively between Norfolk Boreas (Scenario 2) and Hornsea Project Three) during the peak construction year (2023) – Link 34 (B1145 through Cawston) and Link 68 (The Street at Oulton). This is presented in Chapter 24 Traffic and Transport [APP-237]. A scheme of mitigation has been secured for each of these road links within the Outline Traffic Management Plan [REP18-021] that introduces a suite of measures to mitigate the potential for construction traffic noise impacts, including resurfacing of the road surface, temporary speed limits and a cap to the maximum number of HGVs that may use these routes. This limits the number of HGVs associated with the Norfolk Boreas construction that may use The Street to 40 daily HGV deliveries (80 daily HGV movements). This is combined with a commitment from Hornsea Project Three to not exceed 59 daily HGV deliveries (118 daily HGV movements) and represents an overall limit of 99 daily HGV deliveries (198 daily HGV movements) across projects to avoid significant cumulative impacts along Link 68 (The Street). With these measures in place there would be no significant cumulative residual impacts between Norfolk Boreas and Hornsea Project Three. Outside of the peak cumulative construction period no significant traffic-borne noise impacts associated with Norfolk Boreas were identified.*

Once again, the Applicant understates the cumulative impact of the traffic and noise generated around Oulton and Cawston; to be clear, these are rural Norfolk villages where the residents park their cars on the side of the road outside of their homes. Taking the highest figure of 198 HGV movements daily equates to one HGV movement approximately every 3 minutes! This must also be coupled with the non-HGV traffic, service vehicles and general transport vehicles that will be travelling in and out of the area during the working day; it is a nonsense to state that there would be "*no significant impacts*". The Applicant appears not to understand what cumulative means – *"increasing or increased in quantity, or force by successive additions."*

We implore the SoS BEIS to reconsider the submission of the Applicant, who contends that the impacts of traffic in and around the crossing points Norfolk Boreas will have with DEP/SEP and Hornsea 3 as being *"insignificant".* It would be impossible to add one HGV every 3 minutes to any Class B rural road in England without there being a significant impact; the problem here is that the Applicant is allowed to make the assessment! The cumulative impacts for traffic, vehicle noise and vehicle pollution are obvious, even to the "uninformed reader!" These must be included as having a significant negative cumulative impact in the planning balance, irrespective of the opinions of the Applicant.

Also, once again, the Applicant is not at liberty to assume that the Norfolk Boreas project construction will not overlap with DEP/SEP with regards to traffic.

Human Health

- Following a review of the available information provided within the DEP and SEP PEIR the Applicant concludes that there are **no likely significant cumulative human health effects** during construction.

The Applicant demonstrates no understanding for human health. By way of example, would the Applicant consider that an elderly person living on either Oulton Street or Cawston High Street with an HGV rumbling past every 3 minutes have their health impacted by the construction traffic. Or maybe the Applicant would consider the fumes from the diesel generated by hundreds of extra vehicles passing through Cawston, and residential properties, as not having an impact on the people who are used to breathing fresh country air.

There will be a considerable impact on human health for the stress from noise, depression, pollution associated disease and general well -being of the Norfolk population if the Norfolk Boreas DCO is consented; this is counter intuitive to all of the health initiatives the Government is promoting. We ask the SoS BEIS to take a step back and empathise with the people facing the prospect of what the Applicant, and other developers, will impose on a significant number, especially when the solution for Norfolk Boreas to connect via the OTN would remove every single negative impact on human health which, we contend, are not insignificant.

The impact on human health for receptors living near to cables carrying up to 6GW of electrical energy (5 times the maximum output of Sizewell B) and emitting large EMFs at the crossing points is poorly researched and taken as an "insignificant" given by the Applicant. The impact of EMFs on human tissue is discussed at Attachment 3. However, when we introduced this, or any other research, in our direct discussions with the developer, we were informed that: "…it is not peer reviewed evidence …" and it was discarded. Nevertheless, there is nowhere in the UK where 6GW of electricity is buried 1.2 metres below the surface making any assessment of the cumulative impacts from EMFs purely theoretical.

We ask the SoS BEIS to ensure that research on the cumulative impacts of such high EMFs, especially HVAC EMFs, is conduted as matter of urgency.

Landscape & Visual Impacts

- *Following a review of the available information provided within the DEP and SEP PEIR the Applicant concludes that there are **no likely significant cumulative effects**, given that there would be no overlap of peak construction activities between DEP and SEP and Norfolk Boreas, the short timescale that construction would be present in any one location (2-3 weeks) and that it would not be possible for both DEP and SEP and Norfolk Boreas to have a construction presence at the cable crossing at the same time.*

The Applicant has made the statement based on the assumption of Scenario 2. However, a delayed Scenario 1 assumption could well cause trenching to take place for a significantly longer period. The Applicant should be compelled to state the worst case scenario.

Socio Economics

- *Following a review of the available information provided within the DEP and SEP PEIR the*

*Applicant concludes that there is the potential for **likely significant beneficial cumulative effects** associated with the operation of all these schemes related to job creation and the supply chain. Should DEP and SEP be constructed and become fully operational it would further reinforce the area as a hub of offshore operations in the UK which could have an additional multiplier effect to the cumulative beneficial impacts in relation to job creation reported for Norfolk Boreas.*

We question the logic of the Applicant's assessment and note that any possible negative cumulative impacts are classified as *"no effect"* or "*insignificant*" whilst the one positive impact is "*likely significant beneficial*"! Currently there are 74 Parish Councils (PCs) and Town Councils (TCs) across Norfolk subscribed to "The Norfolk Parish Movement for the OTN" with another group of MPs and County Councillors named OFFSET, being in opposition to the construction of onshore transmission systems in favour of the OTN. Therefore, our local leaders and politicians across the County do not agree with the Applicant that the job creation and supply chains will, on balance, outweigh the very negative impacts from building of radial transmission systems and are campaigning against them, irrespective of any perceived socio-economic benefits.

We contend that there could be centres of excellence for technical expertise around the East Anglian ports, such as Great Yarmouth and Lowestoft, in order to build and service a "World leading" OTN; these jobs would be sustainable. However, the Applicant's argument that any permanent jobs will create a "hub" from digging cable trenches is flawed; these jobs will be transient and awarded to the lowest contract bidder. The hinterland of the towns surrounding the ports will become the "hubs" and not the County!

We ask that the SoS BEIS considers the overall cumulative impacts of Norfolk Boreas and DEP/SEP and asks the Applicant to resubmit its response to 'Cumulative and in Combination Effects' with worse case substantiated assessments and not merely by hedged opinion.

Onshore Summary

- *The potential for likely significant effects to arise cumulatively between DEP and SEP and Norfolk Boreas was considered following a review of the DEP and SEP PEIR published in April 2021. The DEP and SEP PEIR concluded **no adverse likely significant cumulative effects** with Norfolk Boreas for any of the onshore topic areas assessed. Having reviewed the information provided within the DEP and SEP PEIR, and as identified in the table above, the Applicant concludes that there are **no adverse likely significant cumulative effects**.*

There are clearly adverse cumulative impacts from the crossing of HV electricity cables regardless of the Applicant's specific assessment for Boreas with DEP/SEP, especially in this scenario with regards to the increase of traffic, noise and pollution impacting Oulton and Cawston villages should the projects' construction phases overlap. Furthermore, the impact of NSIP developments, such as Norfolk Boreas and DEP/SEP, on human health, are poorly researched, and importantly, the impact on the Norfolk aquifer water supply has not been adequately considered. The Applicant has made unsubstantiated assessments of vital elements of the cumulative impacts whilst relying on the assumption that the projects' construction phases will not overlap.

In conclusion, we respectfully ask the SoS BEIS to consider that the assessment carried out and submitted by the Applicant is inadequate. Therefore, we request that the Applicant be compelled to resubmit for worst case scenarios, with substantiated reasons for its assessments, with a comprehensive assessment of the impact of its trenching activities on the watercourse and aquifers which will undoubtably be adversely impacted.

Yours faithfully,

Ray & Diane Pearce

From: SEAS Campaign: info@suffolkenergyactionsolutions.co.uk

To: PINS Examination Team, for the attention of Rynd Smith, Lead Examiner

CC:
Secretary of State for HC&LG: [redacted]@communities.gov.uk
Secretary of State for BEIS: beiscorrespondence@beis.gov.uk;
[redacted]@beis.gov.uk; secretary.state@beis.gov.uk
Solicitors Regulatory Authority: transparency@mail.sra.org.uk
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Leader of East Suffolk Council: [redacted]@eastsuffolk.gov.uk

14 February 2021

Dear Mr Smith

<u>Introduction: The Complaint</u>

1. This complaint is made on behalf of Suffolk Energy Action Solutions (SEAS).

2. It concerns efforts being made by Scottish Power Renewables (SPR) to prevent persons who would otherwise have a reason to object and provide support to groups and associations opposing SPR's application in respect of EA1N and EA2, from opposing the application for consent.

3. The nub of the complaint concerns the fact that in the course of concluding agreements with landowners, SPR is including a clause which makes agreement conditional upon the individual landowner concerned not opposing the application and withdrawing any evidence already given. The clause is as follows:

> "The Grantor shall not make a representation regarding the EA1N DCO Application nor the EA2 DCO Application (and shall forthwith withdraw any representation made prior to the date of this Agreement and forthwith provide the Grantee with a copy of its withdrawal) nor any other Permission associated with the EA1N Development or the EA2 Development and shall take reasonable steps (Provided that any assistance is kept confidential) to assist the Grantee to obtain all permissions and consents for the EA1N Works and the EA2 Works on the Option Area (the Grantee paying the reasonable and proper professional fees incurred by the Grantor in connection with the preparation and completion of such permissions and consents)."

4. This clause has the effect of undermining the integrity of the planning process. Further, the object and effect of this clause is to substantially undermine the efforts of those opposing consent.

5. This clause contains a prohibition on making any representation regarding the application. The word "representation" is very broad. A person could not speak to a friend, or relative or neighbour about their concerns over the application. They could not speak to or support an association or organisation opposing the application. They could not speak to the press or an MP or a local authority planning officer. And it clearly prohibits a person from submitting evidence to the Examination.

6. It also means that if a person has already made a representation, including that given before

the agreement is signed, it must be withdrawn. So, a letter of complaint to an MP must be withdrawn. A complaint to a friend must be taken back. Any evidence given to the Examination must be withdrawn.

7. SPR will no doubt argue that this is a "normal commercial term".

8. It is clearly normal to pay landowners for land otherwise subject to compulsory purchase, often in advance of the statutory purchase process occurring. It is also normal for a developer to pay a landowner for access to carry out appropriate test and surveys etc. Payments to secure these ends are directly related to the development.

9. But it cannot be argued to be <u>legitimate</u>, even if commonplace and commercial, for a developer to impose a condition upon the grantor of a right over land related to the development which is specifically designed to undermine the planning process. There is no proper connection between the two.

10. The clause set out above in effect: (i) prevents the giving of evidence to the inquiry; (ii) prevents the person concerned from supporting associations opposing the application by giving support; (iii) requires the person if they have already given evidence formally to withdraw that evidence and provide proof to SPR that this has been done.

<u>Impact upon planning process</u>

11. There can be **<u>no</u>** justifiable planning basis for the making of payments and/or the imposing of conditions which undermine a statutory planning inquiry conducted in accordance with public law principles. If, for instance a person to criminal proceedings were to pay a witness to refuse to support the prosecution or to withdraw evidence this would amount to the crime of perverting the course of justice. If in civil proceedings a litigant paid an opposing witness to withdraw their evidence this might amount to contempt of court.

12. The present proceedings are statutory and governed by ordinary public law principles.

13. The Examining Authority is in charge of this process and has a duty in law to guarantee that it is fair, transparent and objective.

14. The effect upon those individuals and groups seeking to oppose this application is substantial. The volume of material that SPR has submitted, and continues to submit, very late on in the process, is enormous and imposes a near intolerable strain upon the resources of those who oppose the application. To mount opposition to this development requires considerable human and financial resources.

15. The DCO procedure is one which, by its nature, supports applicants. The effect has been to undermine the ability of legitimate objectors to put forward evidence and submissions, in particular by instructing and paying for legal and technical experts. This clause has had a chilling effect. Many individuals have stopped talking to our organisation. They do not reply to emails. They do not respond to calls.

16. The Examination Authority will know that those who are most affected by the proposed development, and accordingly in principle the most likely to wish to object, are also those most likely to be the subject of SPR compulsory purchase and other powers. By linking discussions over legitimate matters with payments to undermine the process, SPR maximises its ability to prevent opponents obtaining support and putting evidence before the

Examination Authority.

17. The Examining Authority cannot permit an applicant to use the leverage that it has in relation to the compulsory planning rules to undermine the investigation. It is unacceptable that this already difficult process should be made even more difficult by the deep pockets and financial muscle of the applicant.

The facts

18. The information that forms the basis of this complaint concerns the case of Dr Alexander Gimson, who represents his mother, Mrs EP Gimson, [redacted], near Thorpeness and over whose land the cable trench may pass.

19. SEAS has been aware for some considerable time that potential opponents to the application have been persuaded, by the offer of substantial payments from SPR, to enter agreements which compel them to withdraw opposition and refrain from commenting in public. It is understood that a part of the payment which is then recorded in the formal agreement is attributable to the non-opposition clause set out above. But in any event, there can be no proper basis for developers suppressing evidence in this way.

20. Until Dr Gimson brought the attached documentation to the attention of SEAS, it has not been possible to make this complaint.

21. The Option Agreement that SPR seeks to have with Dr Gimson relates to land at [redacted], a property which is situated on the cliffs near Thorpeness.

22. Dr Gimson believes that the overall payments, which he has been offered under the Option Agreement, amount to thousands of pounds. But quite regardless Dr Gimson objects to the agreement upon the basis that it is conditional upon him not being able to oppose the application. Dr Gimson is a vociferous opponent of SPR's proposed Onshore development plans and has spoken twice at the Examination Hearings, on 21 and 22 January 2021. Under the agreement he would have to withdraw that evidence and provide support for SPR even though its application will, if consented, severely impact his elderly mother's home.

23. Dr Gimson is determined not to be silenced.

Next Steps

24. The consenting process is now moving towards its latter stages. SEAS is of the view that the integrity of the process has already been badly compromised. We ask you to respond to this complaint as a matter of urgency. We invite the Examination Authority to take the following steps:

    24.1. Convene a special hearing to enable all affected parties to put their case on this matter.

    24.2. Take immediate steps to investigate fully what has occurred.

    24.3. Inform SEAS and all other parties of the steps it intends to take to investigate.

    24.4. Place its decision on this complaint on the PINS EA1N and EA2 website.

Conclusion

25. Those who oppose the application have no equality of arms with SPR, whose war chest appears unlimited. The ability of opponents to contest the process has been substantially hindered by the withdrawal and non-cooperation of persons who otherwise would have been active supporters and funders. Financial and human resources are strictly limited and massively overstretched.

26. This inability is exacerbated by the fact that SPR's application keeps changing and mountains of new, complex, material is lodged on a more or less rolling basis and on occasion at the eleventh hour.

27. Our complaint is therefore a very practical one. SPR's policy undermines the ability to represent those who oppose the application and undermines the integrity of the statutory planning process.

28. We therefore await your urgent response.

The wider public interest

29. This is an issue of public significance. It is our intention to refer this to the Secretaries of State who have overall statutory responsibility for the integrity of the planning process, and of course for the decision on the DCO application.

30. We also intend to refer the same material to The Rt Hon Dr Therese Coffey MP PC and ask her to make inquiries including asking relevant questions in the House of Commons.

31. Given that the contractual clause in question has been drafted by the legal advisers acting for SPR we intend further to refer the same material to the Solicitors Regulatory Authority to invite them to conduct an investigation into the facts and to decide whether, in the light of any findings they make, it is proper for legal advisors to promote the use of these clauses. If this practice is commonplace, then because of its effect which is to undermine a statutory investigation conducted in the public interest, it is an issue of high importance.

Yours sincerely

[redacted]

Fiona Gilmore

For and on behalf of

Suffolk Energy Action Solutions

Please send your response to: info@suffolkenergyactionsolutions.co.uk

Electromagnetic fields 2007

The Biological Effects of Weak Electromagnetic Fields

Andrew Goldsworthy 2007

What the power and telecoms companies would prefer us not to know

Foreword

There have been many instances of harmful effects of electromagnetic fields from such seemingly innocuous devices as mobile phones, computers, power lines and domestic wiring. They include an increased risk of cancer, loss of fertility and unpleasant physiological symptoms. The power and mobile phone companies, hoping to avoid litigation, often assert that because the energy of the fields is too low to give significant heating, they cannot have any biological effect. However, the evidence that electromagnetic fields *can* have "non-thermal" biological effects is now overwhelming. In this article, I will explain how these effects arise. I have included key references that should enable the more inquisitive reader to delve deeper. If you do, you will often find contradictory assertions and that the reproducibility of several experiments is only mediocre. As we will see, this is almost certainly because of differences in the genetic and physiological condition of the biological material and its ability to defend itself against electromagnetic insults. Defence mechanisms have evolved by natural selection over countless millions of years of exposure to natural electromagnetic radiation, such as that from thunderstorms. They can often hide the underlying effects of man-made fields so we do not always see them in our experiments. We therefore have to concentrate on the experiments that give positive results if we are to discover the mechanisms. In this context, negative findings (frequently published in work financed by the telecoms and power companies) have no meaning.

Abstract

1. Well-replicated studies have shown that weak electromagnetic fields remove calcium ions bound to the membranes of living cells, making them more likely to tear, develop temporary pores and leak.

2. DNAase (an enzyme that destroys DNA) leaking through the membranes of lysosomes (small bodies in living cells packed with digestive enzymes) explains the fragmentation of DNA seen in cells exposed to mobile phone signals. When this occurs in the germ line (the cells that give rise to eggs and sperm), it reduces fertility and predicts genetic damage in future generations.

3. Leakage of calcium ions into the cytosol (the main part of the cell) acts as a metabolic stimulant, which accounts for reported accelerations of growth and healing, but it also promotes the growth of tumours.

4. Leakage of calcium ions into neurones (brain cells) generates spurious action potentials (nerve impulses) accounting for pain and other neurological symptoms in electro-sensitive individuals. It also degrades the signal to noise ratio of the brain making it less likely to respond adequately to weak stimuli. This may be partially responsible the increased accident rate of drivers using mobile phones.

5. A more detailed examination of the molecular mechanisms explains many of the seemingly weird characteristics of electromagnetic exposure, e.g. why weak fields are more effective than

strong ones, why some frequencies such as 16Hz are especially potent and why pulsed fields do more damage.

Introduction

The strange non-thermal biological effects of electromagnetic fields have puzzled scientists for decades and, until now, there has been no clear explanation. In this article, I will outline a new theory, based on experimental evidence gathered over many years, that explains how virtually all of these effects arise.

Firstly, it is not only humans that are affected. Well-researched responses in other organisms include the more rapid growth of higher plants (Smith et al. 1993; Muraji et al. 1998; Stenz et al. 1998), yeast (Mehedintu and Berg 1997) and changes in the locomotion of diatoms (McLeod et al. 1987). The last two are significant because they are both single cells, implying that the effects occur at the cellular level. Furthermore, we can explain virtually all of the electromagnetic effects on humans in terms of changes occurring at the cellular level that may then affect the whole body.

A few basic facts

Field strength: - An electromagnetic field consist of an electrical part and a magnetic part. The electrical part is produced by a voltage gradient and is measured in volts/metre. The magnetic part is generated by any flow of current and is measured in tesla. For example, standing under a power line would expose you to an electrical voltage gradient due to the difference between the voltage of the line (set by the power company) and earth. You would also be exposed to a *magnetic* field proportional to the current actually flowing through the line, which depends on consumer demand. Both types of field give biological effects, but the magnetic field is more damaging since it penetrates living tissue more easily. Magnetic fields as low as around one microtesla (a millionth of a tesla) can produce biological effects. For comparison, using a mobile (cell) phone or a PDA exposes you to magnetic pulses that peak at several tens of microtesla (Jokela et al. 2004; Sage et al. 2007), which is well over the minimum needed to give harmful effects. Because mobile phones are held close to the body and are used frequently, these devices are potentially the most dangerous sources of electromagnetic radiation that the average person possesses.

Frequency: - The fields must vary with time, e.g. those from alternating currents, if they are to have biological effects. Extremely low frequencies (ELF) such as those from power-lines and domestic appliances are more potent than higher frequencies. There is usually little or no biological response to the much higher frequencies of radio waves, unless they are *pulsed* or *amplitude modulated* at a biologically active lower frequency (i.e. when the radio signal strength rises and falls in time with the lower frequency). Regular GSM mobile phones and PDAs emit both pulsed radio waves (from the antenna) and ELF (from the battery circuits), and are especially dangerous. So how do these non-thermal effects electromagnetic fields arise?

Weak electromagnetic fields release calcium from cell membranes

The first clue came from Suzanne Bawin, Leonard Kaczmarek and Ross Adey (Bawin et al. 1975), at the University of California. They found that exposing brain tissue to weak VHF radio signals modulated at 16Hz (16 cycles per second) released calcium ions (electrically charged calcium atoms) bound to the surfaces of its cells. Carl Blackman at the U.S. Environmental Protection Agency in North Carolina followed this up with a whole series of experiments testing different field-strengths and frequencies (Blackman et al. 1982) and came to the surprising conclusion that weak fields were often more effective than strong ones. The mechanism was unknown at the time and it was thought to be a trivial scientific curiosity, but as we will see, it has huge significance for us all.

The loss of calcium makes cell membranes leak

Calcium ions bound to the surfaces of cell membranes are important in maintaining their stability. They help hold together the phospholipid molecules that are an essential part of their make-up (see Ha 2001 for a theoretical treatment). Without these ions, cell membranes are weakened and are more likely to tear under the stresses and strains imposed by the moving cell contents (these membranes are only two molecules thick!). Although the resulting holes are normally self-healing they still increase leakage while they are open and this can explain the bulk of the known biological effects of weak electromagnetic fields.

Membrane leakage damages DNA

Leaks in the membranes surrounding lysosomes (tiny particles in living cells that recycle waste) can release digestive enzymes, including DNAase (an enzyme that destroys DNA). This explains the serious damage done to the DNA in cells by mobile phone signals. Panagopoulos et al. (2007) showed that exposing adult *Drosophila melanogaster* (an insect widely used in genetic experiments) to a mobile phone signal for just six minutes a day for six days broke into fragments the DNA in the cells that give rise to their eggs and half of the eggs died. Diem et al. (2005) also found significant DNA fragmentation after exposing cultured rat and human cells for 16 hours to a simulated mobile phone signal. See also the "Reflex Project" in an on-line brochure entitled "Health and Electromagnetic Fields" published by the European Commission. You can find it at [redacted] . It shows that exposing human cells for 24 hours to simulated mobile phone signals gave DNA fragmentation similar to that due to the gamma rays from a radioactive isotope! (Gamma rays also make lysosome membranes leak).

DNA damage may cause cancer

There have been many studies suggesting that exposure to weak electromagnetic fields is associated with a small but significant increase in the risk of getting cancer (Wilson et al. 1990). This could be caused by gene mutations resulting from DNA damage. A gene is a section of DNA containing the information needed to make a particular protein or enzyme. There is also a section that can turn the gene on or off in response to outside signals. The growth of an organism from a fertilised egg involves a hugely complex pattern of switching genes on and off that regulates growth, cell division and differentiation into specific tissues. DNA damage can sometimes give unregulated growth to form tumours. However, the effect may not be immediate. Cancer following exposure to chemical carcinogens such as asbestos may take many years to become rampant. The affected cells seem to go through several stages of ever-increasing genetic and molecular anarchy before they finally reach the point of unstoppable growth and division. When assessing any carcinogenic effects of electromagnetic exposure, we must bear in mind that there may be a similar delay. It may be some years before we know the full carcinogenic effects of the recent explosive growth in the use of mobile phones.

DNA damage reduces fertility

The biological effects of electromagnetically induced DNA fragmentation may not be immediately obvious in the affected cells, since fragments of broken DNA can be rejoined and damaged chromosomes (elongated protein structures that carry the DNA) can be reconstituted. However, there is no guarantee that they will be rejoined exactly as they were. Pieces may be left out (deletions) joined in backwards (inversions) swapped between different parts of the chromosome (translocations) or even attached to the wrong chromosome. In most cases, the new arrangement will work for a while if most of the genes are still present and any metabolic deficiencies can often be made good by the surrounding cells. However, things go badly wrong when it comes to meiosis, which is the process that halves the number of chromosomes during the formation of eggs and sperm.

During meiosis, the chromosomes line up in pairs (one from each original parent) along their entire length so that corresponding parts are adjacent and can be exchanged (this gives each of the daughter cells a unique combination of genes). However, if the arrangement of their genes has been altered by electromagnetic exposure, they cannot align properly and the chromosomes may even tie themselves in knots in the attempt. Such mal-formed pairs are usually torn apart unequally in the later stages of meiosis so that the eggs or sperm have an incomplete or unbalanced set of genes, may not function properly and so reduce fertility. There is evidence from several independent studies in Australia, Hungary and the United States that this is already occurring. Heavy mobile phone use appears to reduce both the quantity and viability of sperm. The results for the most recent study by Dr Ashok Agarwal and co-workers at the Cleveland Lerner College of Medicine can be seen at [redacted]. They found that using a mobile phone for more than four hours a day was associated with a reduction in sperm viability and mobility of around 25 percent. The statistical probability of these results being due to chance errors was one in a thousand. There is every reason to believe that human *eggs* may be similarly affected, but since they are formed in the embryo before the baby is born, the damage will be done during pregnancy but will not become apparent until the child reaches puberty.

<u>**There may also be permanent genetic damage**</u>

Believe it or not, the electromagnetically induced loss of fertility is the *good news* since it means that badly damaged embryos are less likely to be conceived. The *bad news* is that any damaged genes needed for embryo development but not for normal egg or sperm function will not be weeded out in this way. They can still find their way into the foetus and cause permanent genetic damage. The effect may not be apparent in the first generation since a non-functioning gene from one parent can often be offset if the other parent provides a good version of the same gene. In fact, serious trouble may not arise for many generations until by chance two faulty versions of the same gene end up in the same foetus. What happens then depends on the gene concerned, but it is unlikely to be beneficial and may be lethal.

The overall conclusion is that the genetic damage from exposure to electromagnetic radiation can have an almost immediate effect on fertility, but damage to the offspring may take several generations to show up. If we do nothing to limit our exposure to electromagnetic radiation, we can anticipate a slow decline in the viability of the human genome for many generations to come. It is ironic that having only just discovered the human genome, we have already set about systematically destroying it.

<u>**Effects on metabolism**</u>

Another major effect of electromagnetic radiation is the leakage of *free* calcium ions, either through the cells' external membranes or those surrounding internal "calcium stores". This can have dramatic effects on many aspects of metabolism and explains most of the mysterious but well-documented physiological effects of electromagnetic fields. These include stimulations of growth, an increased risk of cancer, symptoms suffered by electrosensitive humans and why using a mobile phone while driving makes you four times more likely to have an accident.

How calcium controls metabolism

Apart from its role in maintaining membrane stability, the calcium concentration actually inside cells controls the rate of many metabolic processes, including the activity of many enzyme systems and the expression of genes. The concentration of calcium ions in the cytosol (the main part of the cell) is normally kept about a thousand times lower than that outside by metabolically-driven ion pumps in its membranes. Many metabolic processes are then regulated by letting small amounts of calcium into the cytosol when needed. This is normally under very close metabolic control so that everything works at the right time and speed. However, when electromagnetic exposure increases membrane leakiness, unregulated amounts of extra calcium can flood in. Just what happens then depends on how much gets in and what the cells are currently programmed to do. If they are growing, the rate of growth may be increased. If they are repairing themselves after injury, the rate of healing may be increased but if there is a mutant precancerous cell present, it may promote its growth into a tumour.

Calcium leakage and brain function

Normal brain function in humans depends on the orderly transmission of signals through a mass of about 100 billion *neurones*. Neurones are typically highly branched nerve cells. They usually have one long branch (*the axon*), which carries electrical signals as *action potentials* (nerve impulses) to or from other parts of the body or between relatively distant parts of the brain (a nerve contains many axons bundled together). The shorter branches communicate with other neurones where their ends are adjacent at *synapses.* They transmit information across the synapses using a range of *neurotransmitters,* which are chemicals secreted by one neurone and detected by the other. The exact patterns of transmission through this network of neurones are horrendously complex and determine our thoughts and virtually everything we do.

Calcium plays an essential role in this because a small amount of calcium must enter the neurone every time before it can release its neurotransmitters. Without it, the brain would be effectively dead. But what would happen if electromagnetically induced membrane leakage let in too much calcium? One effect would be to increase the background level of calcium in the neurones so that they release their neurotransmitters sooner. This improves our reaction time to simple stimuli (which has been experimentally proven). However, it can also trigger the spontaneous release of neurotransmitters to transmit spurious signals have no right to be there. This feeds the brain false information. Similar spurious action potentials may also be triggered in other parts of the neurone if leaks in the membrane temporarily short-circuit the normal voltage between its inside and outside. These unprogrammed action potentials will degrade the signal to noise ratio of the brain and reduce its ability to make accurate judgements.

It is technically difficult to detect these stray action potentials experimentally since they look like random noise in the measuring system and would in any case be swamped by the relatively strong electromagnetic signals used to induce them. However, similar spurious action potentials should be detectable if we removed some of structural calcium from the membrane by some other means. One way to do this is to lower the concentration of calcium ions in the surrounding medium. For example, Matthews (1986) reported that exposing nerve and muscle cells to calcium concentration about 10–20 percent below normal made them significantly more excitable, which fits with our hypothesis.

These findings also explain many of the symptoms of hypocalcemia (alias hypocalcaemia). Hypocalcemia is a medical condition, usually caused by a hormone imbalance, in which the concentration of ionised calcium in the blood is abnormally low. By removing bound calcium from cell membranes, it should (and does) give similar effects to electromagnetism.

Electrosensitivity and hypocalcemia – a possible cure

Symptoms of hypocalcemia include skin disorders, paresthesias (pins and needles, numbness, sensations of burning etc.) fatigue, muscle cramps, cardiac arrhythmia, gastro-intestinal problems and many others. A more comprehensive list can be found at [redacted] , which corresponds to the website: - http://www.endotext.org/parathyroid/parathyroid7/parathyroid7.htm.

The symptoms of hypocalcemia are remarkably similar to those of electrosensitivity. If you think you may be electrosensitive, how many of these do you have? If you have any of them, it may be worth having your blood checked for ionised calcium. It is possible that at least some forms of electrosensitivity could be due to the victims having their natural blood calcium levels bordering on hypocalcemia. Electromagnetic exposure would then remove even more calcium from their cell membranes to push them over the edge and give them symptoms of hypocalcemia. If this is correct, conventional treatment for hypocalcaemia may relieve some if not all of these symptoms.

Electromagnetic exposure and motor accidents

Only a small proportion of the population is electrosensitive in that they show obvious symptoms from electromagnetic exposure. However, everyone may affected without being aware of it, e.g. when using a mobile phone. According to the Royal Society for the Prevention of Accidents, you are four times more likely to have an accident if you use a mobile phone while driving. This is not due to holding the phone since using a hands-free type makes no difference. It is also not due to the distraction of holding a conversation, since talking to a passenger does not have the same effect. This leads us to the conclusion that the electromagnetic radiation from the phone is the most likely culprit.

This fits with the notion that spurious action potentials triggered by electromagnetic radiation creates a sort of "mental fog" of false information that makes it harder for the brain to recognise weak but real stimuli. For example, a driver using a mobile phone may still see the road ahead using the strong images from the central part of the eye but may be less aware of weaker but still important images coming from the side. He may also be less able to conduct relatively complex tasks such as judging speed and distance in relation to other moving vehicles. This needs a lot of "computing power" and will therefore be more susceptible to random interference. Although an experienced driver may do much of his driving automatically, his brain still has to do just as much work as if he were still learning; it is just that he is unaware of it. Therefore, an old hand at driving is just as likely to be forced into making a mistake when using a mobile while driving as a novice, so don't imagine you can get away with it just because you have been driving for years. Another important point is that, if this theory is correct, and the electromagnetic signal is mainly to blame, not only is it inadvisable to use a mobile yourself while driving, but your passengers should not use them either since their radiation may still affect *your own* driving.

The theory behind it all

We have seen that weak electromagnetic fields can remove calcium from cell membranes and make them leak. If we theorise about the mechanism, we can explain many of the seemingly weird characteristics of bioelectromagnetic responses. These include why weak fields can be more effective than strong ones, why low frequencies are more potent, why pulses do more damage than sine waves and what is special about 16Hz. The following hypothesis was proposed by Goldsworthy (2006).

The role of eddy currents

Before they can give biological effects, the electromagnetic fields must generate electrical "eddy currents" flowing in and around the cells or tissues. Both the electrical and magnetic components of the fields can induce them and they tend to follow low impedance pathways. These can be quite extensive; for example in the human body, the blood system forms an excellent low resistance pathway for DC and low frequency AC. It is an all-pervading system of tubes filled with a highly conductive salty fluid. Even ordinary tissues carry signals well *at high frequencies* since they cross membranes easily via their capacitance. In effect, the whole body can act as an efficient antenna to pick up electromagnetic radiation. If you need convincing, try a simple experiment. Tune in a portable radio to a weak station and see by how much you can improve reception by simply grasping the antenna. There is little doubt that signals transmitted by a mobile phone, even if it is a hands-free type, will reach all parts of the body, including the sex organs.

How calcium is released

The membrane: - Most biological membranes are negatively charged, which makes them attract and adsorb positive ions. However, these ions are not stuck permanently to the membrane but are in dynamic equilibrium with the free ions in the environment. The relative amounts of each kind of ion attached at any one time depends mainly on its availability in the surroundings, the number of positive charges it carries and its chemical affinity for the membrane. Calcium normally predominates since it has a double positive charge that binds it firmly to the negative membrane. Potassium is also important since, despite having only one charge, its sheer abundance ensures it a good representation (potassium is by far the most abundant positive ion in virtually all living cells and outnumbers calcium by about ten thousand to one in the cytosol).

The signal: - When an alternating electrical field from an eddy current hits a membrane, it will tug the bound positive ions away during the negative half-cycle and drive them back in the positive half-cycle. If the field is weak, strongly charged ions (such as calcium with its double charge) will be preferentially dislodged. Potassium (which has only one charge) will be less attracted by the field and mostly stay in position. Also, the less affected free potassium will tend to replace the lost calcium. In this way, weak fields increase the proportion of potassium ions bound to the membrane, and release the surplus calcium into the surroundings.

Why there are amplitude windows

The main effect, electromagnetic treatment is to change the normal chemical equilibrium between bound calcium and potassium in favour of potassium. Even very weak fields should have at least some effect. This effect should increase with increasing field-strength, but only up to a point. If the field were strong enough to dislodge large quantities of potassium too, there will be less discrimination in favour of calcium. This gives an *amplitude window* for the *selective* release of calcium, above and below which there is little or no observable effect.

The field strength corresponding to the amplitude window may vary with the ease with which eddy currents are induced and the nature and physiological condition of the tissue. There may also be more than one in any given tissue. Blackman et al. (1982) discovered at least two for brain slices, perhaps because the brain contains two main types of cell; the neurones and the glial cells, each of which have different membrane compositions.

Why low frequencies and pulses work better

The hypothesis also explains why only frequencies from the low end of the spectrum give biological effects and why pulses and square waves are more effective than sine waves. Only if the frequency is low will the calcium ions have time to be pulled clear of the membrane and replaced by potassium ions before the field reverses and drives them back. Pulses and square waves work best because they give very rapid changes in voltage that catapult the calcium ions well away from the membrane and then allow more time for potassium to fill the vacated sites. Sine waves are smoother, spend less time at maximum voltage, and so allow less time for ion exchange.

Frequency windows

The hypothesis also explains the curiosity that some frequencies are especially effective, with 16Hz being the most obvious. This is because 16Hz is the ion cyclotron resonance frequency for potassium in the Earth's magnetic field. (See Box). When exposed to an electromagnetic field at this frequency, potassium ions resonate, absorb the field's energy and convert it to energy of motion. This increases their ability to replace calcium on cell membranes. Although the extra energy gained by each potassium ion may be small, the fact that there are about ten thousand of them competing with just one calcium ion for each place on the membrane means that even a slight increase in their energies due to resonance will have a significant effect.

Amplitude modulated and pulsed radio waves also work

Amplitude modulated and pulsed radio waves consist of a high frequency "carrier" wave whose strength rises and falls in time with a lower frequency signal. This is the basis of AM radio transmissions, where the low frequency signal comes from an audio source. The receiver demodulates the signal to regenerate the audio. Unmodulated carrier waves usually have little or no biological effect, but if modulated at a biologically-active low frequency (such as 16Hz) they give marked effects (Bawin et al. 1975). This has posed problems for scientists trying to work out how living cells could demodulate radio signals to regenerate the low frequency and elicit a biological response.

However, we can now explain it easily. Imagine a child bouncing a ball continuously against the ground. The harder he hits it, the higher it bounces and the greater its average height. The layer of free positive ions that congregate near but are not bound to the negatively charged surface of a cell membrane will behave in the same way. They bounce against the membrane in time with the radio wave, and the average distance of the electrical centre of the layer from the membrane rises and falls with any amplitude modulation. Modulating the signal at 16Hz makes the centre of the layer rise and fall at 16Hz. It does not have to move very far since any free potassium ions in the vicinity will resonate, gradually gain energy from the oscillations and become more able to bombard and displace calcium ions bound to the membrane.

How calcium loss makes holes in membranes

Cell membranes are made of sheets of fatty materials called phospholipids surrounding islands of protein. The proteins have a variety of metabolic functions, but the main role of the phospholipids is to fill the spaces between them and act as a barrier to prevent leakage. Calcium loss weakens the phospholipid sheet and makes it more likely to leak; but how does it do this?

The membrane phospholipids are long molecules. One end consists of hydrophobic (water hating) hydrocarbon chains. The other end has a negatively charged phosphate group and is hydrophilic (water loving). In a watery medium, they arrange themselves spontaneously to form double-layered membranes with a central core made from their water hating ends. Their water loving phosphate ends face outwards towards the water. The affinity that the central hydrophobic parts have for one another helps hold the membrane together but the negatively charged phosphate groups on the outside repel each other and try to tear it apart. Normally, the membrane is stabilised by positive ions that fit in between the negative phosphate groups, so that they do not repel each other. They act as a kind of cement that helps to hold the membrane together.

However, not all positive ions stabilise the membrane equally well. Calcium ions are particularly good because of their double positive charge, but monovalent potassium, with just one charge, is only mediocre. Therefore, when electromagnetic fields swap membrane-bound calcium for potassium, it weakens the membrane (These membranes are only a hundred thousandth of a millimetre thick) and it becomes more prone to accidental tearing and the formation of transient pores. This happens to some degree all the time, even in stationary artificial membranes (Melikov et al 2001), but the membranes of living cells are often stressed by the cells' moving contents, so the effects should be much greater. Fortunately, these pores are usually self-healing and the damage to the membrane is not permanent. However, during electromagnetic exposure there will be more tears, slower repair and consequently more overall leakage. The metabolic effects of even a brief period of leakage may be much longer lasting (e.g. if dormant genes are activated) and perhaps (as in the case of DNA damage) permanent.

Defence mechanisms

Calcium pumps: - Cells have to be able to pump out any extra calcium that has entered their cytosols to reset the low cytosolic calcium level every time it is disturbed by a programmed calcium influx. They should therefore be able to respond to unprogrammed calcium influx due to electromagnetic exposure. This should minimise any unwanted metabolic effects, but the scope to do this is limited. If it were too effective, it would also prevent legitimate cell signalling.

Gap junction closure: - If calcium extrusion fails and there is a large rise in internal calcium, it triggers the isolation of the cell concerned by the closure of its gap junctions (tiny strands of cytoplasm that normally connect adjacent cells) (Alberts et al. 2002). This also limits the flow of eddy currents through the tissue and so reduces the effects of radiation.

Heat shock proteins: - These were first discovered after exposing cells to heat, but they are also produced in response to a wide variety of other stresses, including weak electromagnetic fields. They are normally produced within minutes of the onset of the stress and combine with the cell's enzymes to protect them from damage and shut down non-essential metabolism (the equivalent of running a computer in "safe mode"). When the production of heat shock proteins is triggered electromagnetically it needs 100 million million times less energy than when triggered by heat, so the effect is truly non thermal (Blank & Goodman 2000). Their production in response to electromagnetic fields is activated by special base sequences (the nCTCTn motif) in the DNA of their genes. When exposed to electromagnetic fields, they initiate the gene's transcription to form RNA, which is the first stage in the synthesis of the protein (Lin et al. 2001).

As we can see, there are several defence mechanisms against damage by electromagnetic fields and there may be more we do not know about. They probably evolved in response to natural electromagnetic fields such as those generated by thunderstorms but are now having their work cut out to respond to the continuous and all-pervading fields associated with modern living. How well they perform will depend on many factors, including environmental conditions, the physiological condition of the cells and how much energy they have to spare. Consequently, they do not always succeed. When the defences fail, we may get visible symptoms from the radiation, but when they succeed, there may be little obvious effect.

The power and mobile phone companies have seized upon this characteristic variability to discredit work on the non-thermal effects of electromagnetic fields as being due to the experimental error. Nothing could be further from the truth. Many of these experiments are highly reproducible, especially the fundamental and all-important ones on the effects of the radiation on the release of calcium from cell membranes. Secondary effects further down the line may be less reproducible since they are more likely to be mitigated by the intervention of cellular defence mechanisms. Therefore, we cannot expect rigidly reproducible results in all circumstances any more than we can expect everyone to experience exactly the same side effects from taking a medicinal drug. However, that does not mean that they can be safely ignored!

Conclusion

In the latter part of this article, I have explained how weak electromagnetic fields can interact with cell membranes to weaken them and make them more permeable. As with all theories, it will be subject to modification and refinement as time goes by, but some facts are already inescapable. There is undeniable experimental proof that weak electromagnetic fields can remove bound calcium ions from cell membranes. There is also no doubt that bound calcium ions are essential for the stability of these membranes. Consequently, their loss will increase temporary pore formation under the mechanical stresses from pressure differences within the cell and abrasion by its moving contents. This very simple conclusion can account for virtually all of the known biological effects of electromagnetic fields, including changes in metabolism, the promotion of cancer, genetic damage, loss of fertility, deleterious effects on brain function and the unpleasant symptoms experienced by electrosensitive individuals. However, it seems possible that at least some cases electrosensitivity could be due to low levels of ionised calcium in the blood exacerbating the electromagnetic effects. If so, it may be possible to relieve some or all of the symptoms by conventional treatment for hypocalcemia.

Box

Ion Cyclotron Resonance

Abraham Liboff, in the mid 1980s, developed the idea that the frequency windows for the biological effects of electromagnetic fields were in some way due to ion cyclotron resonance, but he didn’t link it to membrane stability (Liboff et al.1990). Ion cyclotron resonance occurs when ions move in a steady magnetic field such as that of the Earth. The field deflects them sideways and they go into orbit around its lines of force at a characteristic “resonant” frequency, which depends on the charge/mass ratio of the ion and the strength of the steady field. Exposing them to an oscillating electric or a magnetic field at their resonant frequency lets them absorb its energy and they gradually increase the size of their orbits and their energy of motion. The resonant frequency for potassium in the Earth’s magnetic field is close to 16Hz. According to my hypothesis, electromagnetic fields at this frequency specifically increase the ability of potassium ions to bombard cell membranes and replace bound calcium. This increases the biological hazards of electromagnetic exposure near 16Hz and has already caused concern about the safety of the TETRA mobile telecommunications system, which transmits pulses at 17.6Hz.

Footnote

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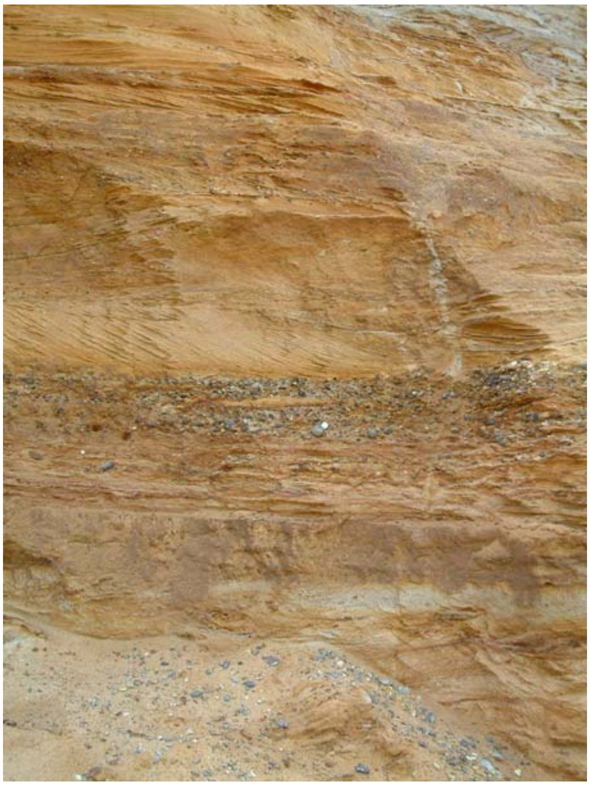

The Natural Quality of Groundwater in England and Wales
A joint programme of research by the British Geological Survey and the Environment Agency

BRITISH GEOLOGICAL SURVEY
Commissioned Report CR/06/043N

ENVIRONMENT AGENCY
Science Group: Air, Land & Water
Technical Report NC/99/74/21

Baseline Report Series: 21. The Chalk and Crag of north Norfolk and the Waveney Catchment

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FOREWORD

Groundwater issuing from springs has been regarded since the earliest recorded history as something pure, even sacred. In its natural state, it is generally of excellent quality and an essential natural resource. However, the natural quality of groundwater in our aquifers is continually being modified by the influence of man. This occurs due to groundwater abstraction and the consequent change in groundwater flow, artificial recharge and direct inputs of anthropogenic substances. A thorough knowledge of the quantity and quality of groundwaters in our aquifers, including a good understanding of the physical and chemical processes that control these, is therefore essential for effective management of this valuable resource.

About 35 per cent of public water supply in England and Wales is provided by groundwater resources, this figure being higher in the south and east of England where the figure exceeds 70 per cent. Groundwater is also extremely important for private water supplies and in some areas, often those with the highest concentration of private abstractions, alternative supplies are generally not available. Groundwater flows and seepages are also vital for maintaining summer flows in rivers, streams and wetland habitats, some of which rely solely on groundwater, especially in eastern and southern England. The quantity and quality of groundwater is therefore extremely important to sustain both water supply and sensitive ecosystems.

Until now there has not been a common approach, either in the UK or across Europe, to define the natural "baseline" quality of groundwater. Such a standard is needed as the scientific basis for defining natural variations in groundwater quality and whether or not anthropogenic pollution is taking place. It is not uncommon for existing limits for drinking water quality to be breached by entirely natural processes. This means that it is essential to understand the natural quality of groundwater to enable the necessary protection, management and restoration measures for groundwater to be adopted.

One of the main problems pertinent to groundwater remediation issues concerns the background or baseline to which remedial measures must, or can, be taken. Naturally high concentrations of some elements in particular areas may make it impossible or uneconomic to remediate to levels below the natural background which may already breach certain environmental standards. The Baseline Reports Series assesses the controls on water quality which are responsible for causing the natural variations seen in groundwater and provides a background for assessing the likely outcomes and timescales for restoration.

This report builds on a scoping study of England and Wales, carried out in 1996 by the British Geological Survey for the Environment Agency, which reviewed the approach to be adopted in producing a series of reports on the principal aquifers in England and Wales. The initial phase of this work was completed in 1998 and comprised reports on seven aquifers. This report forms part of the second phase of the work that will extend coverage to all the important aquifers in England and Wales. The Baseline reports will be of use not only to regulatory agencies but also to all users of groundwater, including water companies, industry and agriculture, and all those involved in the protection and remediation of groundwater.

BACKGROUND TO THE BASELINE PROJECT

The baseline concentration of a substance in groundwater may be defined in several different ways. For the purpose of the project, the definition is given as

> ***"the range in concentration (within a specified system) of a given element, species or chemical substance present in solution which is derived from natural geological, biological, or atmospheric sources"***

Terms such as background or threshold can have a similar meaning and have often been used to identify "anomalous" concentrations relative to typical values e.g. in mineral exploration. There may be additional definitions required for regulation purposes, for example when changes from the present day status of groundwater may represent the starting point of monitoring. This may be defined as background and such an initial condition may include some anthropogenic component in the water quality.

In order to interpret the water quality variations in terms of the baseline, some knowledge of the residence times of groundwater is required. For this purpose both inert and reactive chemical and isotopic tracers are essential. Measurement of the absolute age of groundwater presents many difficulties and radiocarbon dating is the most widely used technique. By investigating the evolution of water quality along flow lines it may be possible to establish relative timescales using a combination of geochemical and isotopic methods. Indicators such as the stable isotope composition of water may also provide indirect evidence of residence time. The identification (or absence) of marker species related to activities of the industrial era, such as total organic carbon (TOC), tritium (^{3}H), dissolved greenhouse gases -chlorofluorocarbons (CFCs) - and certain micro-organic pollutants may provide evidence of a recent component in the groundwater. The baseline has been modified by man since earliest times due to settlement and agricultural practices. However, for practical purposes, it is convenient to be able to distinguish water of different 'ages': (i) palaeowater - recharge originating during or before the last glacial era i.e. older than c.10 ka (ii) pre-industrial water (pre 1800s), (iii) water predating modern agricultural practices (pre 1940s) and (iv) modern post-bomb era (post 1963).

Thus an ideal starting point is to locate waters where there are no traces of human impact, essentially those from the pre-industrial era, although this is not always easy for several reasons. Groundwater exploitation by means of drilling may penetrate water of different ages and/or quality with increasing depth as a result of the stratification that invariably develops. This stratification is a result of different flow paths and flow rates being established as a consequence of prevailing hydraulic gradients and the natural variation in the aquifer's physical and geochemical properties. The drilling and installation of boreholes may penetrate this stratified groundwater and pumped samples will therefore often represent mixtures of the stratified system. In dual porosity aquifers, such as the Chalk, the water contained in the fractures may be considerably different chemically from the water contained in the matrix because of differences in residence time. The determination of the natural baseline can be achieved by several means including the study of pristine (unaffected by anthropogenic influence) environments, the use historical records and the application of graphical procedures such as probability plots to discriminate different populations (Shand & Frengstad, 2001; Edmunds et al., 2003). The "baseline" refers to a *specified system* (e.g. aquifer, groundwater body or formation) and is represented by a range of concentrations within that system. This range can then be specified by the median and lower and upper limits of concentration.

The BASELINE objectives are:

1. to establish criteria for defining the baseline concentrations of a wide range of substances that occur naturally in groundwater, as well as their chemical controls, based on sound geochemical principles, as a basis for defining water quality status and standards in England and Wales (in the context of UK and Europe); also to assess anomalies due to geological conditions and to formulate a quantitative basis for the definition of groundwater pollution.

2. to characterise a series of reference aquifers across England and Wales that can be used to illustrate the ranges in natural groundwater quality. The baseline conditions will be investigated as far as possible by cross-sections along the hydraulic gradient, in well characterised aquifers. Sequential changes in water-rock interaction (redox, dissolution-precipitation, surface reactions) as well as mixing, will be investigated. These results will then be extrapolated to the region surrounding each reference area. Lithofacies and mineralogical controls will also be taken into account. A wide range of inorganic constituents as well as organic carbon will be analysed to a common standard within the project. Although the focus will be on pristine groundwaters, the interface zone between unpolluted and polluted groundwaters will be investigated; this is because, even in polluted systems, the main constituents of the water are also controlled by geological factors, amount of recharge and natural climate variation.

3. to establish long term trends in water quality at representative localities in the selected reference aquifers and to interpret these in relation to past changes due to natural geochemical as well as hydrogeological responses or anthropogenic effects.

4. to provide a scientific foundation to underpin UK and EU water quality guideline policy, notably the Water Framework Directive, with an emphasis on the protection and sustainable development of high quality groundwater.

1. EXECUTIVE SUMMARY

The Cretaceous Chalk forms the most important aquifer in England, whilst the Crag is a locally important resource over its outcrop area in East Anglia. The utilisation of these aquifers in this region includes public and private drinking water supplies, irrigation of agriculture and amenity lands as well as minor industrial uses. The surface water – groundwater interaction of both aquifers at outcrop is responsible for the maintenance of flows in locally and nationally important wetland systems, including those of the Norfolk Broads.

The baseline chemistry of the Chalk groundwaters are predominantly controlled by natural reactions with the aquifer minerals. Dissolution of calcite controls the major element chemistry, and increasing residence time leads to the relative increase in concentration of other solutes which occur as impurities within the calcite (e.g. Sr, Mn). The overlying Crag and Till deposits present in the east of the study area result in longer residence times for the underlying Chalk aquifer, and increasing concentrations of total dissolved solids and other indicators of groundwater 'age'. The Crag groundwaters exhibit a locally variable chemical composition, but one dominated by natural inputs through reaction with the aquifer minerals. The concentration of solutes such as Ca and HCO_3 in solution is controlled by reactions with shelly carbonate material in the aquifer, and high concentrations of Fe by redox reactions and the occurrence of glauconite within the aquifer. In both aquifers, solutes may be enhanced over the baseline concentrations by anthropogenic perturbation of the hydrogeochemical cycle, such as nitrate which shows the greatest deviation from the baseline in the unconfined aquifer. Insufficient historical data for many solutes in both aquifers reinforces the need for adequate temporal data in order to understand the historical baseline.

2. PERSPECTIVE

The groundwater resources of East Anglia are under pressure due to the demand for good quality water for public and private supplies, irrigation and industrial use. These requirements must be balanced with the need to protect aquatic ecosystems from possible detrimental effects caused by over-abstraction or chemical deterioration. This report focuses on two different aquifers in two regions of Norfolk and Suffolk (Figure 2.1) where previous information on the quality of groundwater was often restricted to major ion chemistry, and derives from a variety of sources.

The Cretaceous Chalk forms the most important groundwater resource in East Anglia and, despite the low population density, there is a limitation of this resource on further development in some areas. The Chalk is confined in the far east of the region by argillaceous Palaeogene deposits. These are overlapped by the Neogene and early-Quaternary Crag sediments. The Crag comprises heterogeneous sediments and is a locally important private water supply, with areas of the Broadland being outside of the public distribution network. There are over 600 private supplies in Broadland and over 300 in the coastal Suffolk area (usually in drift and Crag). However, there are few public supplies: only Ludham in Broadland and a small number in Suffolk. Both these aquifers form an integral part of the aquatic ecosystems of the river networks and wetland systems in the study area, including those of the Broads National Park. The Waveney catchment passes from the Chalk in its upper reaches, to the Crag just north of Hoxne. Whilst a small number of public supply boreholes are located along the river valley and in the upper catchment, little information exists on the chemical quality of groundwaters from either the Chalk or the Crag aquifer through the wider catchment. Recent piezometer installation by the Environment Agency has provided the scope for further work. Both aquifers are covered across wide areas of their outcrop by glacial and recent sediments, which can influence groundwater recharge, flow and water quality.

These two aquifers have been studied simultaneously due to their geographical coincidence and the urgent need to obtain more information on their baseline characteristics and the interrelationships between the aquifers. The data is presented separately for the two aquifers for much of the report, in Sections 5 and 6, with a brief comparison of the two aquifers, and data collected from some superficial aquifers (Section 4) in the Waveney catchment at the end of Section 6.

2.1 North Norfolk

The 'North Norfolk' region, for the purposes of this report, extends from Fakenham in the north-west to Caister-on-Sea in the south-east, and is otherwise bounded by the Norfolk coastline (Figure 2.1). It encompasses the rivers Stiffkey and Glaven draining north to the North Sea, and the upper Wensum catchment and the Bure catchment in the Broadlands, both ultimately discharging to the sea at Great Yarmouth (Figure 2.1). The Bure and its tributaries drain much of the Broads National Park and large areas are protected sites for nature conservation with particular regard to aquatic flora and fauna. The urban centre of Norwich lies immediately to the south of the area. The population distribution of North Norfolk is otherwise concentrated in smaller towns such as Sheringham, Cromer, Fakenham, East Dereham and North Walsham. The holiday resorts of the coastal and Broads regions undergo significant population expansions in the summer months, with tourism being a major source of revenue to the whole region. More details on the county of Norfolk can be found in the Environmental Overview (Environment Agency, 1999). The seasonally high summer demand placed upon water resources is coincident with the greatest demand requirements from the agricultural sector.

Both the Chalk and the Crag aquifers in this area are largely covered by drift deposits, with only areas such as the river Yare downstream from Norwich, having Chalk outcropping at the surface. The Chalk extends to the west of the study area from a line running approximately north from Taverham (Figure 2.1); to the east of this boundary the outcrop 'solid' lithology is the Crag, although this over-steps the Palaeogene in the region east of the river Ant (Figure 2.1).

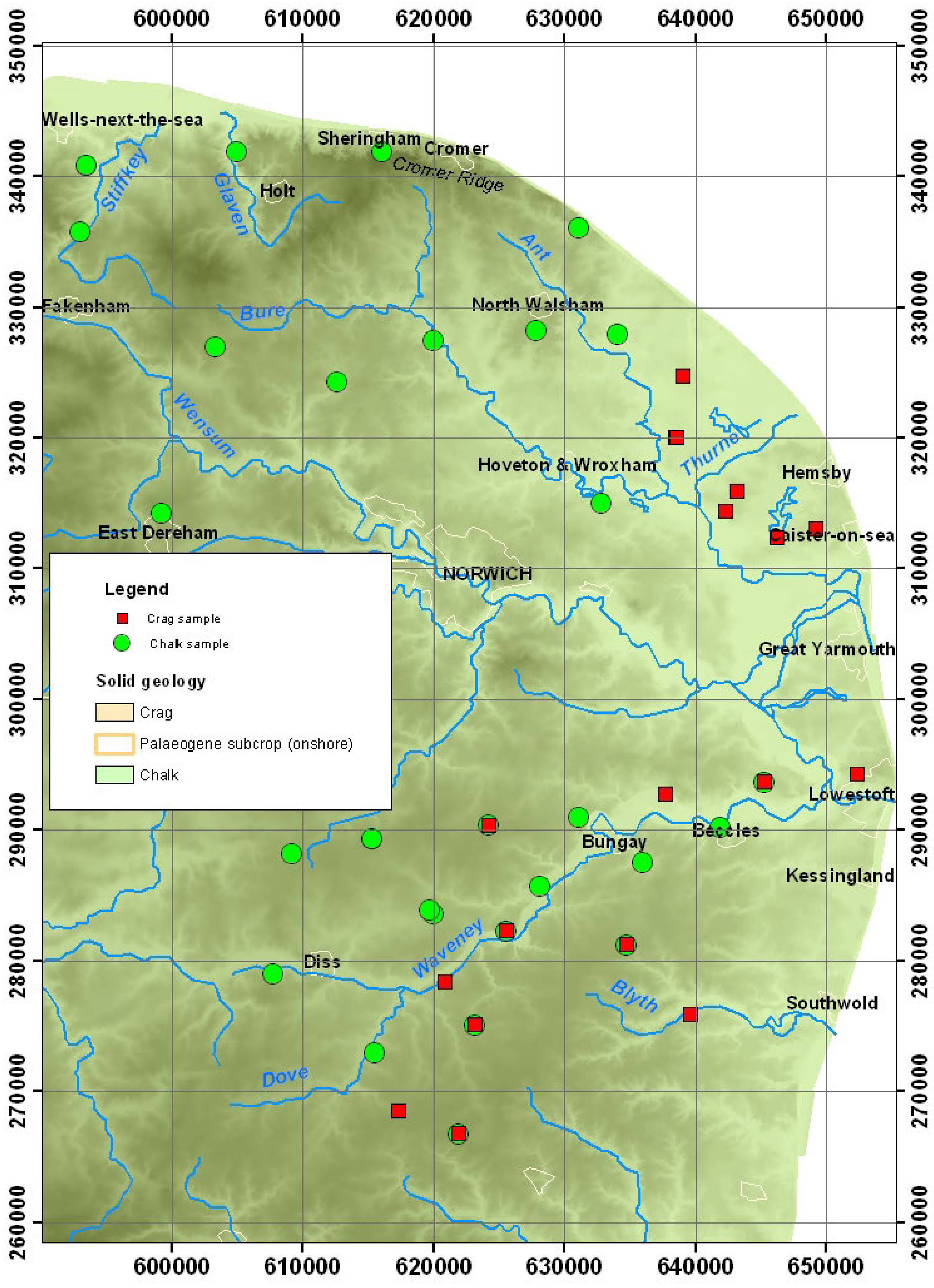


Figure 2.1 **Location of the north Norfolk and Waveney study areas**

The thematic shading represents the surface topography from sea-level (lightest colour) to a maximum altitude of 110 m (darkest colour) above sea-level. Topographical data courtesy of the Centre for Ecology and Hydrology DTM © NERC

The north coastal area is characterised by a Chalk ridge from Cromer to Syderstone (Figure 2.1), rising up to 90 m aOD; this is the highest ground in the study area. The generally subdued relief is a reflection of extensive glacial erosion and subsequent deposition of glacial and post-glacial sediments. In the Cromer and Sheringham areas, there are no northerly draining surface waters; further west the rivers Stiffkey and Glaven flow to the coastal marshes at Stiffkey and Cley-next-the-Sea respectively. Much of the area of north Norfolk is drained by the tributaries of the Wensum and Bure rivers. The headwaters of the Bure rise south of the Cromer Ridge, before becoming dominated by artificial drainage channels and the Broads south-east of Hoveton and Wroxham. The Broads National Park is an area of low lying (sometimes below sea-level) relief with reclaimed marshland and artificial drainage. These artificial drainage networks were originally powered by widespread windmills, some of which can still be seen across the landscape. The broads have been formed from the 12th and 13th Century onwards by cutting of what would have been very extensive, deep peat deposits in the lower catchments when 'natural' drainage conditions existed. They represent a remnant of one of the earliest widespread industrial processes in the area (Jennings and Lambert, 1953, Lambert, 1960). Channel modifications have been made over centuries; the River Ant was diverted from the River Thurne to the River Bure between the 11th and 14th centuries. The Broads area has also been affected by recent transgressions, the largest recorded c.2200 BP, with the largest flood in living memory having occurred in 1953 (Arthurton et al., 1994).

Where surface relief is above sea level, it can generally be assumed that in general groundwater movement is closely related to topography. The interactions between groundwater and surface water in the low-lying broads has to be conceptualised in more complex terms. Artificial drainage means that river bottoms may be above the local water table, and conversely the low relief means that any measurement of discharge of groundwater has been a very difficult undertaking. Density-dependant heads at the coastal freshwater – saline water interface also complicate physical models of groundwater flow. It has been shown that, although the groundwater discharge from the Crag to the broads may be of low total volume, this pathway can be essential in maintaining surface water levels. However, the specific hydrological pathways in any one region can be a complex series of rainwater, surface water and groundwater fed areas, which are temporally variable (Gilvear et al., 1997), and the evapotranspirative demand of the broads vegetation is also significant and temporally variable. Recent developments have improved the understanding of the hydrogeology of this aquifer (ENTEC, 2001, Holman et al., 1999).

The Chalk is exploited for public supply in this area by a wide distribution of boreholes, not all of which could be sampled during this study, although a good geographical spread was aimed for. Licensed abstraction from the Chalk in this area is ~200,000 $m^2 d^{-1}$ (Allen et al., 1997). A public water supply draws from the Crag at Ludham. The Crag (and overlying superficial deposits) provide the potable source for over 600 homes in this area. From these, care was taken to sample wells which were thought to be screened only in the Crag, as many of the supplies are combined Crag and superficial deposit sources. The Chalk is recognised as a 'major' aquifer (Allen et al., 1997). The Crag is considered a major aquifer in Norfolk under the groundwater vulnerability and Part IIA Contaminated Land classifications, although it is reported in the minor aquifer properties manual (Jones et al., 2000), and considered a minor aquifer in Suffolk due to its limited saturated thickness. The implementation of the Water Framework Directive ensures that the importance of both units as both potable resources and ecosystem components is recognised.

Regionally, agricultural practices have had a major impact on the quality of groundwater through the leaching of fertilisers, although in the Wensum catchment and on the Suffolk Crag, both intensive and outdoor pig rearing have affected water quality. There are a number of landfills which have had a local impact on groundwater quality, largely through the contribution of chlorides and ammonia.

2.2 The Waveney catchment

The river Waveney rises at Redgrave Fen and flows to the North Sea at Lowestoft (Figure 2.1), forming the boundary between Norfolk and Suffolk along its course. The only major tributary of the Waveney is the Dove, which rises to the south-west of Eye, and joins the Waveney close to Hoxne (Figure 2.1). The only settlement with significant industrial and commercial development in the catchment is the coastal town of Lowestoft. The smaller towns of Diss, Bungay and Beccles lie along the river valley, and the catchment contains a large number of small towns and villages in a predominantly rural landscape. The area generally, and the coastal area in particular, experience large seasonal changes in population as a result of the tourist industry which is an important part of the local economy. Historically, industry was more widespread in the area; the basal Red Crag of Suffolk was sufficiently phosphate rich to support the world's first commercial extraction of rock phosphate to be used as fertiliser (Balson, 1999).

The highest land, forming the watershed to the north and south, rarely rises above 60 m and the topography is subdued throughout the area. The low-lying river valley of the Waveney is characterised by wetlands along its length, some of which are protected by statutory designations for their importance to aquatic and marginal aquatic ecosystems. The headwaters rise in Redgrave Fen, which is separated from the headwaters of the westerly draining Little Ouse River by less than 100 m. The hydrological conditions at Redgrave and Lopham Fen have long been the subject of research in relation to the interactions between groundwater discharge from the base-poor superficial deposits and the Chalk (e.g. Bellamy and Rose, 1960) (Figure 2.2). It is now thought that the influence of drift geology is more significant than groundwater in relation to the base-nutrient status of the individual Fens, particularly in the supply of nutrient poor recharge waters at Redgrave Fen. Changes in land drainage practice, as well as groundwater abstraction over the last 50 years, have contributed to the changes in the hydrology in that time, resulting in a flashier response to rainfall (Environment Agency, 2004).

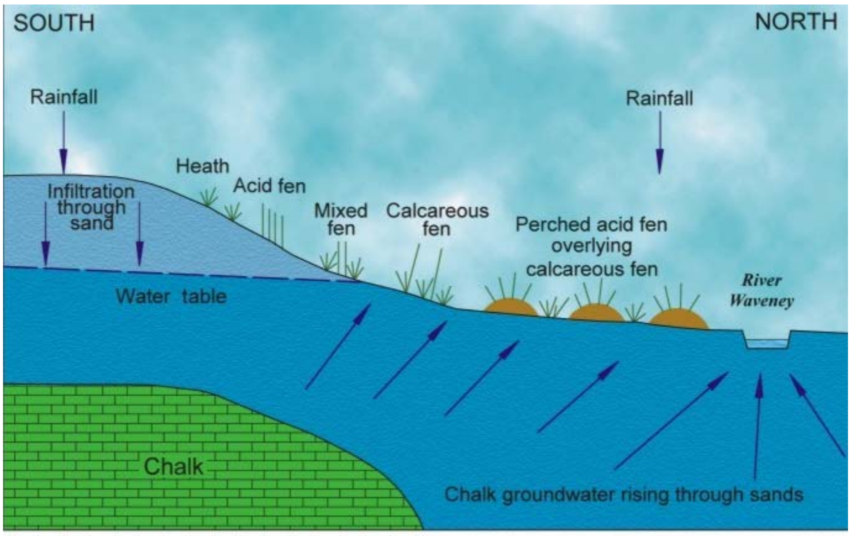


Figure 2.2 Schematic section through Redgrave and Lopham Fen
From: Groundwater Forum (1998)

The geological environment of the Waveney valley is characterised by terrace, peat and alluvial deposits laid down in a valley incised through the till plateau. These superficial deposits lie over the Chalk in the upper catchment, and the Crag downstream from the area between Scole and Hoxne. The groundwater catchment broadly reflects topography, and thus is similar to the surface water catchment. In the area around Lowestoft, the hydrology becomes more complex with artificial drainage channels, such as those linking the rivers Yare and Waveney via the New Cut. The considerations described for the Broads with respect to the complexity of the intercalated and interdigitating coarse gravels, sands and muds of the Neogene and Quaternary Crag sediments are equally valid for the Crag aquifer in the Waveney area. As is the case further north, the Palaeogene clays ('London Clay') overlying the Chalk are entirely concealed by the Crag, and act an aquitard between the Crag and Chalk aquifers.

The Chalk, Crag and superficial deposits are all exploited for public water supply in the Waveney catchment. A summary of the wider area groundwater usage is shown in Table 2.1. The groundwater sources tend to be concentrated in the upper catchment and the valley bottom. Abstraction for agriculture represents an important use of groundwater resources, and there are also sources using the Crag and Chalk for amenity (e.g. leisure parks, golf courses) and industrial use. The information derived from sampling a selection of those sources is augmented in this study by data sampled as part of the Environment Agency Waveney observation piezometer network. This recently installed network comprises some 28 piezometers in 12 different locations, with multi-level piezometers installed to intersect the different aquifers (or more than one depth in the Chalk) occurring at each location. These piezometers have well-constrained construction details, with casing designed to restrict the interval of the aquifer sampled by pumping. These piezometers are designed to increase the knowledge of the aquifers in areas where they are not otherwise possible to sample. The river terrace and glacial gravels have been exploited for aggregate extraction along the valley. Where agricultural land improvement has taken place on the very stony soils overlying these types of Quaternary sediments, this has resulted in the leaching of nutrients to groundwater.

Table 2.1 Quantity of water licensed for abstraction in the Lowestoft and Saxmundham area in October 1994, from the National Rivers Authority* (Moorlock et al., 2000)

	Public & private water supply	Spray irrigation	Industry	Other	Total
		10^6 m^3 a^{-1}			
Drift	2.8	1.6	0.1	1.1	5.6
Crag	2.3	1.7	0.2	0.3	4.5
Chalk	10.2	0.3	0.3	0.7	11.5
Total groundwater	15.3	3.6	0.6	2.2	21.6
Surface water	7.5	2.0	0.0	0.2	9.7
Total	22.8	5.5	0.6	2.4	31.3

* Now the Environment Agency

3. BACKGROUND TO UNDERSTANDING BASELINE QUALITY

The hydrochemical evolution of groundwater, from its initial source as rainfall, is dependant on complex processes in the soil and unsaturated and saturated zone of the aquifer and overlying deposits. This is largely dependent on the mineralogy and chemistry of the aquifer and mixing with existing groundwater. This evolution can also be affected by land and water-use and management. Flow systems in the aquifer will be controlled primarily by the geological and hydrogeological properties of the aquifer. This section reviews the geological, hydrological, mineralogical and some geographical information in order to provide a context for the presentation and discussion of results in chapters 5 and 6.

3.1 Geology

3.1.1 Cretaceous Chalk

The strata of the Cretaceous Chalk aquifer in East Anglia are contiguous with, and form the most easterly onshore extension of, the Chalk of the London Basin (Figure 3.1). In the present study area, the full depth of the Chalk is considerable, with the youngest onshore strata occurring in the north-east of Norfolk: the Trunch borehole [6293 3345] recorded some 462 m of Chalk. The strata which crop out in the study area are entirely Upper Chalk, and have a gentle dip (<1°) to the east (Allen et al., 1997).

The very low supply of terrigenous material (marl, clay and silt) through much of the Upper Cretaceous resulted in the deposition of very pure, fine grained micritic chalk sediment. These are composed of algal coccoliths (1-20 µm) and coccolithic fragments (laths of 0.5-1 µm), and more rarely, larger skeletal fragments (10-100 µm) e.g. foraminifera. Whilst no major unconformities are recognised on structural grounds, there are physical features which may lead to a variation in aquifer properties. The Upper Chalk of east Norfolk may contain more marl strata than are observed further west, which could account for some of the variations in aquifer properties (Allen et al., 1997). Two south-west to north-east trending depressions occur in the vicinity of Eye (including the Stradbroke Trough) (Allen et al., 1997); these structural lows in the surface of the Chalk are due to faulting or erosion (such as sea bed scour) (Bristow, 1983, Mathers and Zalasiewicz, 1988). Buried tunnel valleys are found throughout the North Norfolk Chalk region, and a deep buried channel extends from Redgrave to Stuston [6135 3790] in the upper Waveney valley (Allen et al., 1997).

The upper surface of the Chalk is frequently observed to have been softened and weathered to a ‘putty chalk’ by cryoturbation during the Pleistocene (Moorlock et al., 2000).

3.1.2 Palaeogene Clays (‘London Clay’)

The Palaeogene clays are entirely concealed by the Crag deposits (Figure 3.1). These strata are shallow marine and estuarine deposits, which are entirely argillaceous in east Norfolk, with minor arenaceous beds (of the Reading and Woolwich Formations) in east Suffolk (Moorlock et al., 2000). The strata dip 1° E, and increase in thickness from a low escarpment on the Upper Chalk at their western limit to a maximum of 72 m recorded for the onshore strata of this area (Moorlock et al., 2000).

These strata comprise predominantly argillaceous units, and are thus generally considered to act as an effective aquiclude which compartmentalises the groundwater of the underlying Chalk and overlying Crag into separate systems (Jones et al., 2000).

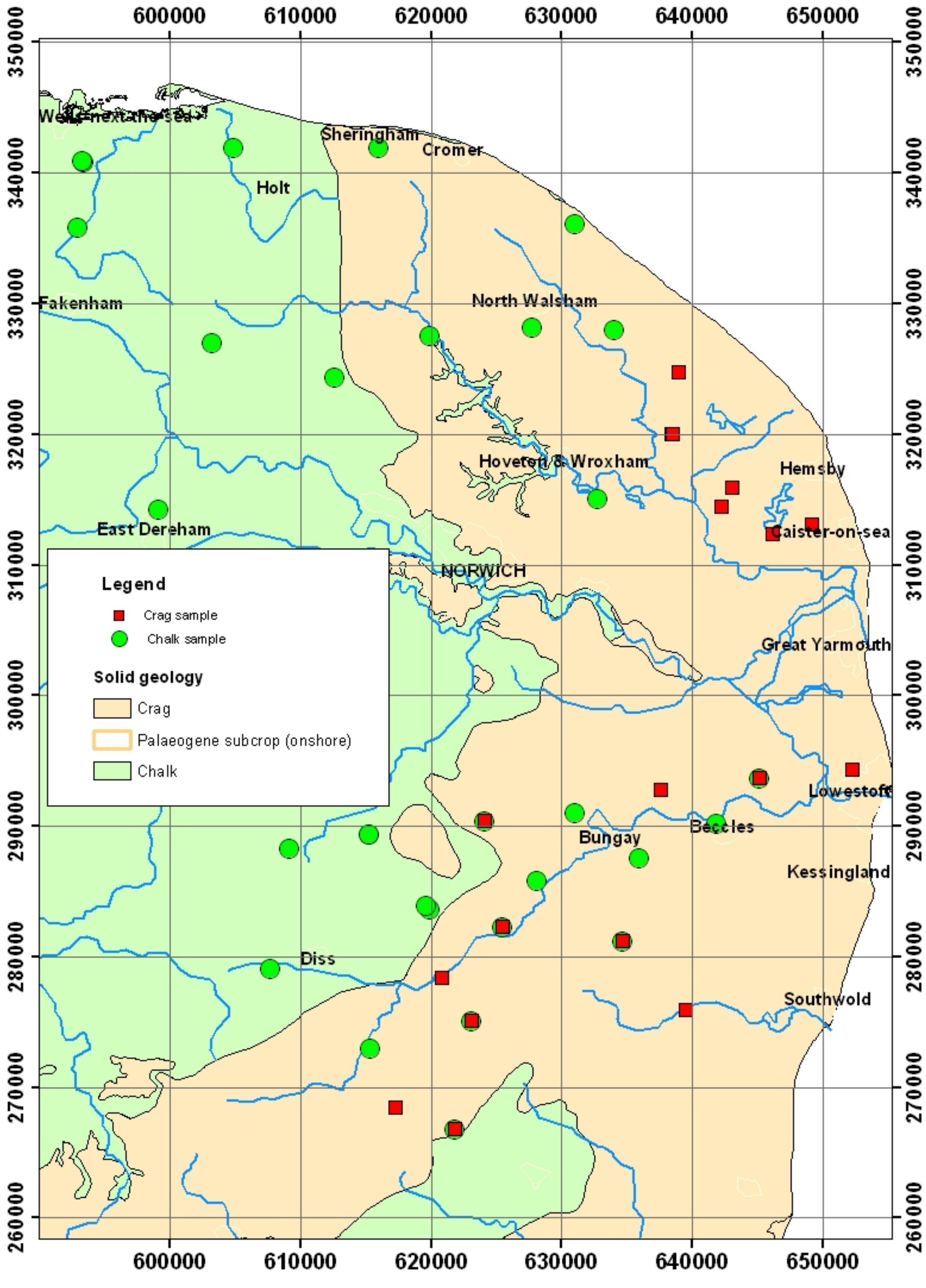


Figure 3.1 Solid geology of the study areas

3.1.3 Quaternary Crags

These strata, located in eastern Norfolk and Suffolk, consist of unconsolidated, intercalated clays, silts, sands and gravels unconformably overlying Cretaceous Chalk and Palaeogene Clays in the study area (Figure 3.1). The stratigraphical classification scheme of these strata has evolved over time, and the framework used by (Jones et al., 2000) is shown in Figure 3.2. Whilst the Crag was deposited in the Neogene and early-Quaternary, it is the Quaternary sequence which is observed in the area of study. Difficulties exist in defining the boundaries for some of these units, and it is particularly poorly represented in the hydrogeological literature. Thus, they are frequently all grouped together as 'the Crag' (Jones et al., 2000).

The stages within the Crag sediments are separated by unconformities (Figure 3.2). Where the Wroxham and Norwich Crags are observed, they overstep the older Crag deposits and have a successively decreasing angle of dip upwards through the sequence (Moorlock et al., 2002a, Moorlock et al., 2000). The original thickness of deposition is not known, but the greatest total thickness in north-east Norfolk is 58 m in Ormesby [651 314] (Moorlock et al., 2000), and over 70 m of entirely Red Crag has been observed in the Stradbroke Borehole [623 274], suggesting that the total depositional thickness would have been considerably greater.

Deposition of these sediments occurred through a period of overall shallowing sedimentation as a result of the infilling of the western North Sea. Under these conditions, the proto-Thames and Ancaster rivers drained to the North Sea across what is now Norfolk and Suffolk (Moorlock et al., 2002a, Moorlock et al., 2000). By the Beestonian Stage (Figure 3.2), the depositional environment had become fluvial (Jones et al., 2000, Moorlock et al., 2000). The oldest strata of 'the Crag' belong to the Coralline Crag which occurs only in areas to the south of the present study, and so are not considered further.

The deposition of the ***Red Crag*** occurred in a series of basins on the surface of the Chalk. It is not clear whether sedimentation post-dated trough formation or was pene-contemporaneous (Moorlock et al., 2000). Within the study area, such basins have been recorded at Ludham [638 319] and the Stradbroke Trough, with up to 30 m and 70 m of Red Crag respectively. The Red Crag is predominantly composed of shelly sands with interbedded silty-clay and clays i.e. deeper water facies than the succeeding formations (Moorlock et al., 2000). The clays can be up to 10 m thick (Jones et al., 2000). Two vertical orthogonal joint sets have been observed in the Red Crag to the south of the Waveney catchment, but it is not clear that they occur in other areas (especially where the Crag is unconsolidated over much of the area). These are thought to result from stresses induced by subsidence of the southern North Sea Basin, and are generally c.5 cm wide and 2-3 m high. Infilling occurs, with micritic calcite, but some of the fractures appear to have remained open (Balson and Humphreys, 1986).

The ***Norwich Crag*** is a tabular sheet formation, uniformly around 30 m thick with a low dip to the north-east, and has an unconformable contact with all older sequences of the Crag. It is observed beyond the southern boundary of the present study area, and is found as far north as Ludham, but is not observed in Wroxham. The Norwich Crag is predominantly composed of interbedded fine- to medium-grained sands and clays, with a upwardly decreasing proportion of shelly beds. Decalcification may have altered shelly beds, which become more frequent lower down the sequence. Mica and glauconite are common with shelly sands but the loss of these via decalcification has been questioned (Moorlock et al., 2000). Interbedded gravels of the Westleton Beds and lenticular grey-blue clays (Easton Bavents Clay) are found in the Norwich Crag, which pass laterally and vertically into sandy facies (Hamblin et al., 1997). The clays can be of considerable thickness where they do occur, 5-8 m being recorded between Beccles and Lowestoft (Hamblin et al., 1997).

The ***Wroxham Crag*** dips gently to the north-east, resting unconformably on the Norwich Crag in the Ludham area and on the Upper Chalk in the Wroxham area. The lateral extent of the deposits is not completely known, but they are known from the Lowestoft area and are thought to occur beneath superficial deposits as far south as Southwold. The maximum total thickness is recorded as 20 m. These sediments represent the outer proto-Thames estuary environment, and are a complex mixture of estuarine and freshwater strata with a much higher proportion of gravels than the older Crag sediments. The gravels, sands and clays tend to exhibit finer interbedding than the Norwich Crag, limiting the mapping of them as separate units, although clay beds up to 4 m thick have been recorded.

The ***Cromer Forest Bed*** represents freshwater and estuarine sedimentary environments, and for geological mapping purposes is considered to be ‘drift’ rather than ‘solid’ geology. However, from the hydrogeological perspective this distinction is superfluous, as these sediments are synchronous and interdigitate with the marine and estuarine Wroxham Crag strata in the North Norfolk area (Moorlock et al., 2002a). The sediments are freshwater organic muds, clays and sands with estuarine sediments also occurring.

	East Anglian Stage	**East Anglian lithostratigraphic units**	
Quaternary	Cromerian	Bacton Member Mundesley Member West Runton Member	Cromer Forest-Bed Formation
	Beestonian	Runton Member	
	Pastonian	Paston Member Sheringham Member	Wroxham Crag Formation
	Pre-Pastonian	Sidestrand Member	
	Baventian Bramertonian Antian	Westleton Beds Easton Bavents Clay Chillesford Clay Member Chillesford Sand Member	Norwich Crag Formation
	Thurnian Ludhamian	Thorpness Member	Red Crag Formation
Neogene	Pre-Ludhamian	Sizewell Member	
		Aldeburgh Member Sudbourne Member Ramsholt Member	Coralline Crag Formation

Unconformable sedimentary relationships

Figure 3.2 **Summary of the East Anglian Crag stratigraphy (Jones et al., 2000).**

3.1.4 Quaternary glacial and post-glacial deposits

These sediments form a complex sequence of glacial and post-glacial strata which occur over much of the study area (Figure 3.3). Hydrogeologically, these may act as aquifers or aquicludes providing storage or protection to the underlying Crag or Chalk aquifers.

The Anglian glaciation gave rise to two till deposits, thought to have come from separate ice-sheets, the Corton Formation and the Lowestoft Till. The ***Corton Formation*** is dominated by well-sorted, fine- to medium-grained sands, proved in boreholes of the Waveney valley and overlying the Cromer Forest-Bed in the Lowestoft area (Moorlock et al., 2000). It is synonymous with the term ‘North Sea Drift’, and derived from a proglacial lake associated with the Scandinavian Ice Sheet (Moorlock et al., 2000). The formation is up to 20 m thick, with the sands comprising up to 15 m of the total thickness, with subordinate tills at the base of the succession. The sands are dominated by quartz, but include chalk and mica fragments and calcretes in the upper sequence. Where clay occurs within the Corton Formation, it may restrict leakage and thus recharge to the Crag aquifer (Jones et al., 2000). These sediments are generally overlain by the Lowestoft Till (Moorlock et al., 2000).

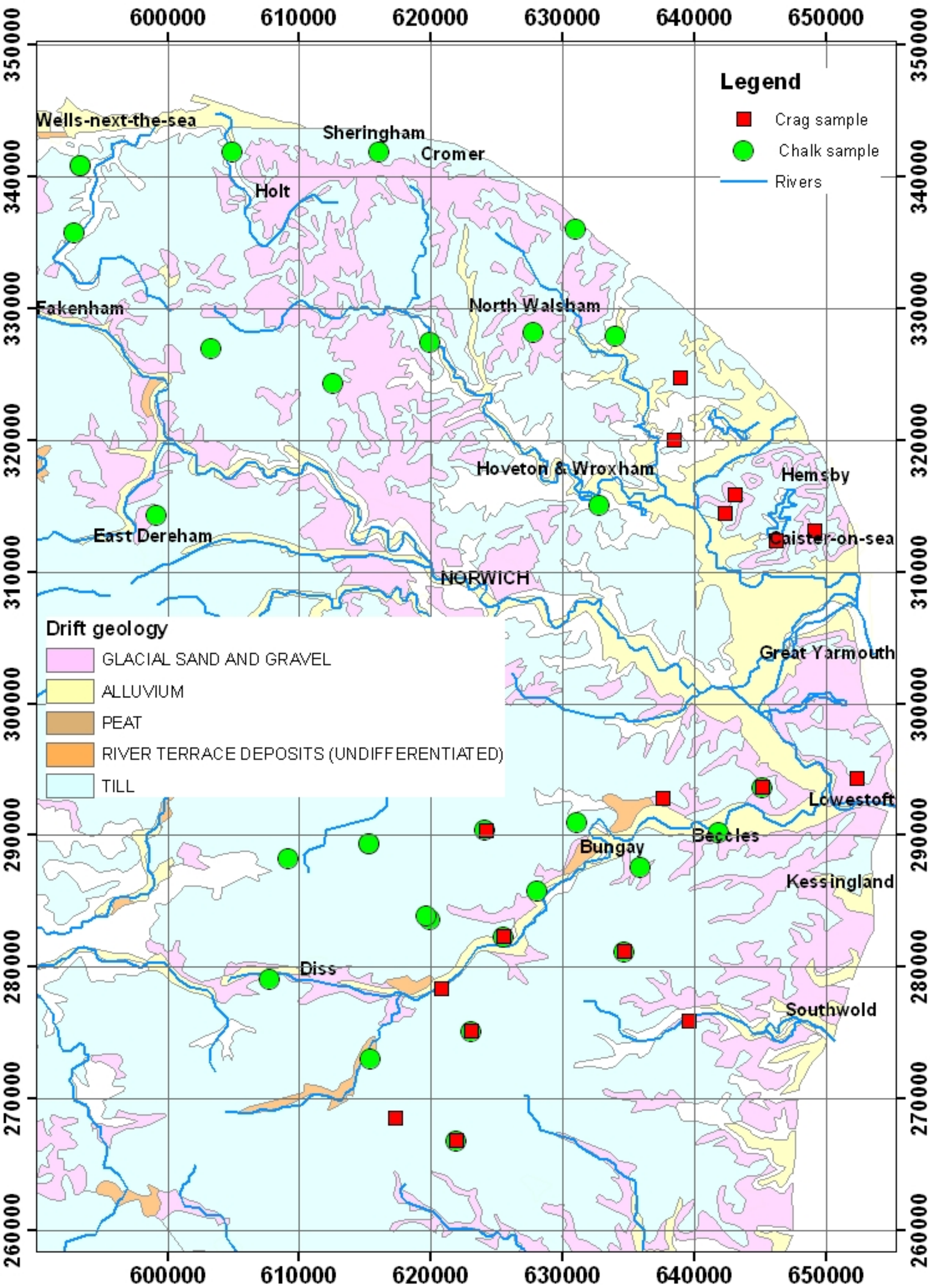


Figure 3.3 **Superficial geology of the North Norfolk and Waveney study areas.** Unshaded areas indicate an absence of superficial deposits.

The ***Lowestoft Formation (Till)*** is the most widespread till in the Waveney valley, occurring from the highest ground to the valley sides. Although largely composed of argillaceous material, it characteristically includes irregular but frequent sands and gravels (Jones et al., 2000, Moorlock et al., 2000). In the Waveney valley, the argillaceous till is recorded as having been completely eroded, with glacial sands and gravels resting on the Chalk in the Roydon area [609 280] (Mathers et al., 1993). In north-east Norfolk, this till formation becomes more chalky than further south and west in East Anglia (Moorlock et al., 2002a). The term 'Chalky Boulder Clay', widely used in the hydrogeological literature, is synonymous with the term Lowestoft Till.

The fresh boulder clay is an over-consolidated dark-grey clast-rich silty sediment. When weathered it becomes a yellow-brown mottled clay. Upper and lower contacts are typically oxidised, with pyrite occurring in the rest.

The Devensian glaciation only reached the very north coast of Norfolk, and whether deposits arise from this period is disputed (Moorlock et al., 2002a). Gravelly, clast supported eskers and kames are reported in the Glaven valley area, and are associated with till that may be Anglian or Devensian (Moorlock et al., 2002a) These sediments are limited in their lateral extent to the north Norfolk coastal area.

Subsequent interglacial and ***Holocene deposits*** are geographically restricted but river terrace deposits and alluvium are significant in the Waveney valley. During the Devensian glaciation, sea levels were considerably lower than present, with the Bure valley floor c.-7.5 mOD, the Waveney -12 mOD (Beccles – Lowestoft), and similar values for the Glaven (Moorlock et al., 2002a, Moorlock et al., 2000, Moorlock et al., 2002b). Additionally, the coastline during the Devensian glaciation was some 7 km east of its present location. Successive fluctuations in sea level since the Devensian glaciation (18 ka BP) have resulted in a series of estuarine and freshwater peats, clays, silts, sands and gravels in the river valleys and Broads (Moorlock et al., 2002b). The accumulation of the extensive coastal tidal flats and marshes at the coast is caused by the accretion of sediment on an over-deepened river valley. Subsequently, sea-level rise has resulted in a sequence of sands and gravels overlain by peat, which is in turn overlain by estuarine sediments. The marshland deposits have been classified separately, and are described by Moorlock et al. (2000). Details of these, and other, vertically or laterally less significant strata can be found in the memoirs cited above.

3.2 Hydrogeology

The physical hydrogeology of the Chalk is described in the Major Aquifer Properties Manual (Allen et al., 1997) and that of the Crag in the Minor Aquifer Properties Manual (Jones et al., 2000), where more details can be found. Information on the groundwater divides and contours, and regional Cl and total hardness variations, are mapped for both North Norfolk and the Waveney from data obtained in the 1970s (Institute of Geological Sciences, 1976; 1981). Considerable recent advances have been made on conceptualising and modelling the Chalk and Crag aquifer, and their inter-relationships (ENTEC, 2001).

3.2.1 Chalk

The Chalk is a dual-porosity aquifer, with both matrix pores and fracture voids, both of which contribute to the overall permeability of the aquifer. However, the pore throat diameter of average chalk pores is too small to allow significant drainage. Thus the permeability of the aquifer is derived from a continuum from large pores through small fractures up to larger dissolution-enhanced fractures (Price, 1987).

The Upper Chalk of East Anglia has a mean porosity of 38.4% (from 127 measurements) (Allen et al., 1997). The transmissivity is generally lower in east Suffolk and Norfolk than it is in the Great Ouse catchment to the west, which is considered to reflect the greater degree of confinement by low permeability sediments in the eastern area, and the possible occurrence of more marl horizons in the Upper Chalk. In the Norwich area, transmissivity values >2000 $m^2 d^{-1}$ have been recorded in the Bure and Wensum valleys, and high transmissivities have been recorded in other areas of North Norfolk, such as Houghton St Giles (Stiffkey valley) and Glandford (Glaven valley). However, the median transmissivity for the area is much lower, being 277 $m^2 d^{-1}$ (Allen et al., 1997). Whilst transmissivity values are generally higher in the valleys, in keeping with observations through much of the Chalk, some valleys have low transmissivity, such as those of the lower Burn Valley at South Creake (Allen et al., 1997). However, this valley is semi-karstic and has high transmissivity further upstream.

Storage coefficients in the North Norfolk area have a geometric mean of 2.2×10^{-3} (Allen et al., 1997). Significant storage can be contained within the Crag and drift deposits where these overlie the Chalk, and can result in a ten- to hundred-fold increase in storage when they are taken into account (Allen et al., 1997). However, Price (1987) notes that release from elastic storage in the Norfolk Chalk could result in delayed yield from the Chalk itself, which could be misinterpreted as leakage from adjacent formations. In the east Suffolk area, the geometric mean transmissivity value is 255 $m^2 d^{-1}$, and whilst high values frequently lie along valleys, some low values are reported for the Waveney, and for its tributary the Dove (at Eye). Pumping tests in the upper Waveney have revealed low transmissivity zones along the axis of the buried channel, but narrow high transmissivity zones running parallel on either side, which may be a result of dissolution and subsidence in the chalk (Professor RJ West, pers. comm.). Where the rivers have not eroded through overlying sediments to the Chalk, transmissivity values as low as 20 $m^2 d^{-1}$ have been recorded to the south of the present area in the Gipping catchment, near Ipswich (Allen et al., 1997). Where the permeability of the aquifer is lower, this is thought to be reflected in substantially longer residence times for groundwater in the Chalk in these regions, which in turn has implications for the baseline chemistry of groundwaters.

The water table reflects topographical variations. Seasonal variations in water level below the till are generally less than 1 m (Moorlock et al., 2000). Where the Chalk is confined, the potentiometric surface is generally within the overlying deposits, although artesian conditions of up to 2 m above the land surface have been recorded at Halesworth, which is to the east of the Palaeogene boundary (Moorlock et al., 2000). The potentiometric surface of the Chalk and Crag in the lower Waveney catchment are very similar, and where the isobar is over 0 mOD, they are identical (Moorlock et al., 2000).

Where superficial deposits overlie the Chalk aquifer, groundwater heads are often within the superficial sediments. However, the aquifer is generally conceptualised as semi-confined rather than fully confined due to the possibility of recharge via arenaceous lenses within the tills (Allen et al., 1997). An example of this occurs in the Waveney catchment, where the Chalk, Crag and superficial deposits are considered to be in hydraulic continuity in the Waveney valley but not so in that of its tributary, the Dove (Allen et al., 1997). The occurrence of Putty Chalk is expected to restrict recharge from superficial deposits (Jones et al., 2000), such as observed at Rushall (Parker et al., 1987). In the Stradbroke trough, little hydraulic connectivity occurs between the Crag and Chalk (Jones et al., 2000). Overlying strata can affect the groundwater chemistry, such as the greater quantity of SO_4 expected in waters which have percolated through tills compared to recharge which has entered via the Crag (Price, 1987).

Post-glacially infilled buried valleys are widely recognised in the Chalk of East Anglia. It is difficult to ascertain the influence of buried valleys on physical properties – the buried valley at Rushall is thought to have resulted in the erosion of highly permeable chalk resulting in lower transmissivities, whilst in other areas, high transmissivities associated with sand and gravel-infill may occur (Allen et al., 1997).

The Palaeogene clays (London Clay) are an effective aquiclude where they occur at sufficient continuity and thickness, separating the Chalk and Quaternary aquifers (Allen et al., 1997). The feather edge of the clay is often locally incised and generally semi-confined; a thickness of less than 10 m along this boundary leads to some leakage through the clay. The quality of groundwater in the Chalk beneath the Palaeogene boundary shows a rapid and marked change in quality parameters. East of the Palaeogene boundary there is no natural drainage, and only minor abstractions (Moorlock et al., 2000). Chloride concentrations were measured as 4000 mg l^{-1} in 1954 in groundwater at Aldeby [645 293] and an increase in Cl from 50 to 500 mg l^{-1} occurred over a distance of 1.5 km near Peasenhall [635 269] in the river Yox catchment, directly south of the Waveney catchment. Over pumping in the adjacent unconfined zone has to be monitored in order to prevent a reversal of gradient, and westward flow of saline water (of which there are records at Holton [639 277] (Moorlock et al., 2000) and Strumpshaw PS [635 307] (Arthurton et al., 1994). It has been suggested that the salinity originates from connate waters in the Chalk that have never been flushed out (Bath and Edmunds, 1981), although Heathcote and Lloyd suggested that the saline end-member in the Chalk in East Anglia may be Crag seawater which they considered to have flushed the Chalk (Heathcote and Lloyd, 1984).

High groundwater Cl zones (>100 mg l^{-1}) are shown on the regional hydrogeological map for the area between the Waveney and Dove, close to Diss (Institute of Geological Sciences, 1981), and Cl is generally elevated at depth in the Stradbroke depression. Saline intrusions (Cl >300 mg l^{-1}) have been observed in the coastal north Norfolk Chalk aquifer at several locations including Salthouse [607 343], and general areas of moderately high Cl (Cl >50 mg l^{-1}) north-east of North Walsham and between Wells-next-the-Sea and Sheringham (Institute of Geological Sciences, 1976). These may be related to intrusion along fractures as a result of pumping, because there are generally steep seaward hydraulic gradients in the Chalk of this region.

3.2.2 Crag

The Crag is important as an aquifer in its own right, and as a source of significant storage for the Chalk when the two formations are in hydraulic continuity. The aquifer properties of the Crag vary greatly depending upon the grain size of the sediments, degree of sedimentation and presence of semi-confining glacial sediments, although it is largely unconfined (Jones et al., 2000). However, the dominance of intergranular flow means that modelling of the flow in the Crag is generally more robust than that of the Chalk, despite the physical variability of the sediments.

Existing information on the physical properties of the Crag deposits is limited, and may also be compromised by the difficulties in unequivocally differentiating these from younger Quaternary deposits (Jones et al., 2000). In the Minor Aquifer Properties Manual, the only core values of permeability (14.8 m d^{-1}) and porosity (54%) given are derived from the Coralline Crag and considered to be unrepresentative of the aquifer as a whole (Jones et al., 2000). However, Gilvear et al. (1997) in the Ormesby area calculated a mean permeability of 14 m d^{-1} from multiple (12) piezometer measurements. Permeability data calculated from falling-head piezometer tests, and water-balance studies fell in the range 5 - 30 m d^{-1}. Porosity measurements using electrical-resistivity sounding indicate that 25% - 40% may be more appropriate than 54% (Jones et al., 2000). Borehole construction also greatly affects the physical properties data obtained. Median transmissivity is 412 m^2 d^{-1}, with an interquartile range of 238-772 m^2 d^{-1} (obtained from 179 records), whilst the median storage coefficient is 4.0×10^{-3} (from 140 records). A test at an Environment Agency borehole in Hickling, of 50 m depth, indicated a transmissivity of 1000 m^2 d^{-1} and an average permeability of 20 m d^{-1}. Specific yield values have an interquartile range of 0.004 to 0.011 (based on 179 tests) (Jones et al., 2000).

Where the Crag directly overlies the Upper Chalk, the potentiometric surface in the Chalk is generally lower than that of the Crag, indicating that the Crag is a source of recharge to the Chalk (Jones et al., 2000). Where the Crag overlies Palaeogene deposits, the Crag is isolated from the Chalk aquifer, and discharge is generally of a diffuse nature as springs or directly into surface water (e.g. the Broads). Generalised groundwater contours for the Crag were produced by Price and Tuson (1961). Spring and seep discharge is hard to identify due to the problems of accurately distinguishing the (decalcified) Crag from overlying later Quaternary deposits. Seasonal water table fluctuations in the Crag are generally less than 1 m due to the high storage coefficient of the aquifer, and groundwater contours reflect topography where the Crag is underlain by Palaeogene clays (Moorlock et al., 2000). Locally, layered aquifer bodies can occur within the Crag when clay horizons are laterally persistent for some distance (Jones et al., 2000). Where the Crag is overlain by Till, this is thought to increase the residence time of the groundwaters, although not as substantially as those in the Chalk (Moorlock et al., 2000).

The factors other than topography which are expected to control the predominantly intergranular flow of water are (Jones et al., 2000):

- discontinuous layering of sediments with contrasting permeability;
- vertical fractures observed in the Red Crag;
- overlying glacial and inter-glacial sediments affecting recharge rate;
- the low elevation of the ground surface and wide spread land drainage, resulting in saline intrusions at the coast and potential recharge from rivers elevated above the surrounding drained land.

Where argillaceous layers occur within the Crag, there is some evidence that they can be sufficiently laterally and vertically continuous to result in a locally stratified aquifer. Studies of the groundwater at Ludham [638 319] showed that water below a significant clay layer was largely pre-modern (low tritium and nitrate; (Jones et al., 2000), in contrast to water above the clay layer. The importance of recharge 'windows' in the glacial sediments for recharge and discharge of Crag groundwaters was highlighted by the study of Gilvear et al. (1977) who found that an area of the Broads was supported by discharge from such a window. Recharge to the Crag may take place from rain-fed Broads (Gilvear et al., 1997). In some areas, the Crag waters flow up into the peat deposits.

Generally low yields (although improvements are helped by good borehole construction), the construction difficulties (running sands) and high iron concentrations are issues in the use of the groundwater from the Crag aquifer (Jones et al., 2000), although lack of resource is the main limitation on further exploitation. Where construction is carried out to a high standard, yields can be high, as at Ludham PS, where 2600 m^3 d^{-1} was achieved (Jones et al., 2000). There is also hydraulic continuity with deposits offshore. Saline coastal waters occur due to saline ingress arising from land drainage (Holman, 1994) and intermittent but extensive flooding over the last 2000 years (Price and Tuson, 1961).

The main problems restricting the development of the aquifer are (Jones et al., 2000):

- running sands from the poorly-sorted and poorly-cemented sediments;
- variable and unpredictable yields;
- water-quality problems (Fe, Mn, H_2S and NO_3);

The water-quality problems will be discussed further in Section 5.

3.2.3 Quaternary deposits

The hydrogeology of the Quaternary deposits (particularly the tills) are of importance with respect to their impact on recharge and flow in the Chalk and Crag aquifers.

Till is distributed over large areas, with the exception of the valley bottoms where it has often been eroded away. Whilst the argillaceous strata are predominantly stiff grey silty-clays and clays, they may be weathered (oxidised) to a depth of 3 m below the surface, which alters them to a friable rustbrown, decalcified sediment (Arthurton et al., 1994). Field permeability measurements for oxidised till have been found to have a range of 4.47×10^{-7} m d^{-1} to 6.37×10^{-9} m d^{-1}, whilst studies on the unoxidised till indicate a range from 1.17×10^{-11} m d^{-1} to 8.03×10^{-9} m d^{-1}. However, in addition to primary permeability, it has been observed that fractures occur in the tills, and that these are more common in the oxidised layers. These oxidised fractures may be a dominant control on recharge to the underlying aquifer (Klinck et al., 1996, Klinck and Wealthall, 1996). In addition, it has been observed that the Chalk aquifer beneath the till is not always confined by the till, and Feast (1998) observed that relative heads in the till and chalk in the Bure valley indicate egress of water from the chalk to the till.

Where clean sands and gravels are found, permeability will undoubtedly be substantially higher than for the poorly sorted or argillaceous strata.

3.3 Aquifer mineralogy

3.3.1 Chalk

The principal mineralogy of the Chalk is that of complete (1-20 µm) and fragmented (0.5-1 µm) algal coccoliths, with occasional larger skeletal fragments (10-100 µm), deposited as very pure low-Mg (<5 mole percent) calcite (Hancock, 1975). Whilst the Upper Chalk is expected to be >97% $CaCO_3$, and generally >99% $CaCO_3$ (Bath and Edmunds, 1981, Heathcote and Lloyd, 1984), the co-precipitated trace elements within the calcite structure and the accessory minerals within the strata, assume more importance in controlling chalk groundwater chemistry as the residence time of groundwaters increase. Concentrations of trace elements within the calcite phase reported by Heathcote and Lloyd are shown in Table 3.1 and for the Trunch borehole (Bath and Edmunds, 1981) (Figure 3.4).

Table 3.1 Composition of the Chalk

Chemical component	Data	Geographical area	Reference
$CaCO_3$	>98%	Suffolk / Essex	Heathcote and Lloyd 1984
Sr	500 – 800 mg kg^{-1}	Suffolk / Essex	Heathcote and Lloyd 1984
F	200 mg kg^{-1}	Suffolk / Essex	Heathcote and Lloyd 1984
I	2 mg kg^{-1}	Suffolk / Essex	Heathcote and Lloyd 1984
Mn	100 - 200 mg kg^{-1}	Berkshire	Edmunds et al. 1987

The non-carbonate phases are predominantly quartz, montmorillonite and mica (illite, muscovite and some glauconite) (Hancock, 1975, Morgan-Jones, 1977). The clay phases within the aquifer are of low abundance in relation to calcite, but they have a substantially higher surface area, and ion exchange capacity than calcite. Whilst laboratory-scale measurements may thus suggest that the scope for ion exchange within the aquifer is limited (Gillespie et al., 2001), on a regional scale the ubiquitous presence of clay minerals ensures that ion exchange processes can be important (e.g. Shand et al., 2003).

Other mineral phases occurring include pyrite (cubic FeS_2) and marcasite (orthorhombic FeS_2). These sulphide phases are likely to be the major hosts of As, Ni and Cr in the Chalk (Hancock, 1975). The oxidation of these minerals in a calcium-rich aquifer leads to the deposition of gypsum ($CaSO_4.2H_2O$) (Morgan-Jones, 1977). Glauconite is an additional source of Fe in the aquifer (Hancock, 1975). Song and Atkinson found that aqueous Fe^{2+} concentrations in the Bure valley decreased along the groundwater flow paths from the interfluves, which they calculated to be due to the precipitation of siderite ($FeCO_3$), suggesting that this mineral phase could occur within the aquifer. The reaction:

$$FeCO_{3(s)} + Ca^{2+}_{(aq)} \leftrightarrow CaCO_{3(s)} + Fe^{2+}_{(aq)}$$

favours calcite unless $[Fe^{2+}]/[Ca^{2+}] \geq 0.05$ (Song and Atkinson, 1985).

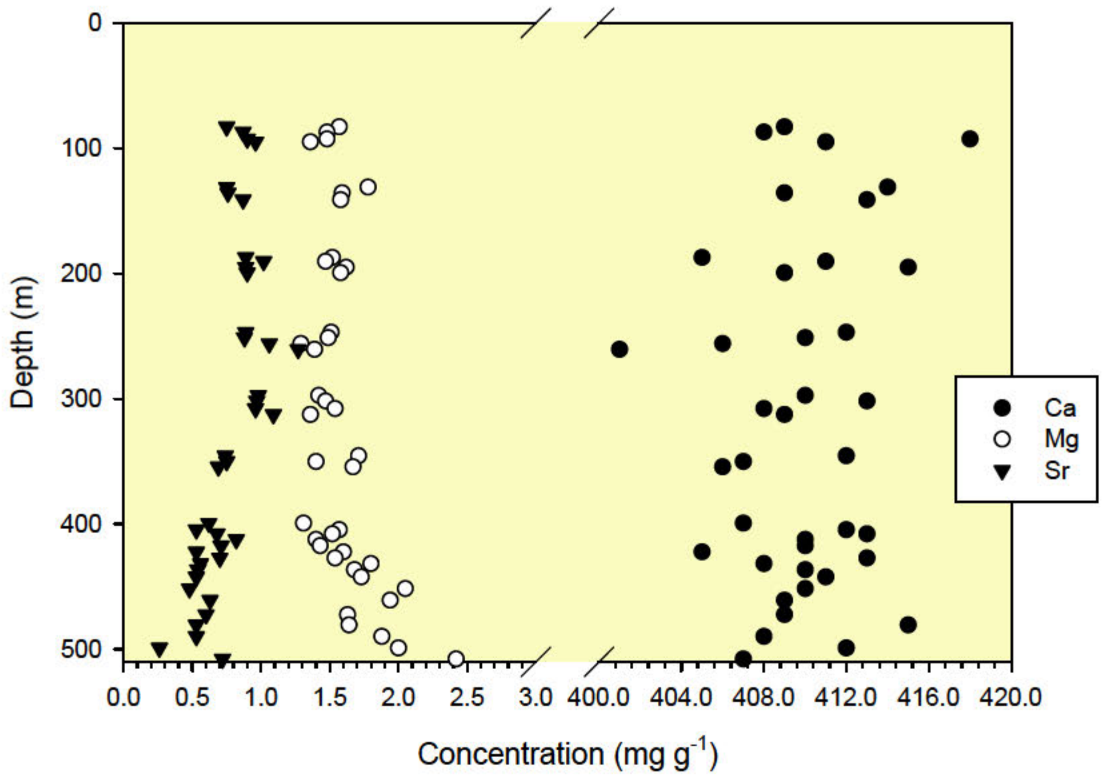


Figure 3.4 Trace-element concentrations in the Chalk of the Trunch borehole (Bath and Edmunds, 1984)

The changes in chemistry as pore and fracture fluids mix may account for the observation of frequent precipitation of Fe and Mn mineral phases on fracture faces (Shand and Bloomfield, 1995). Because the chalk acts as a dual-porosity aquifer, it is likely that these phases are important for both the cycling of trace elements in the aquifer, and may act to isolate the matrix from the fracture flow groundwater.

3.3.2 Crag

As is the case with aquifer properties, very little information exists on the mineralogy of the Crag aquifer. The proportions of clay minerals to sand-size fractions varies considerably both vertically and laterally within the aquifer. Little information exists on the composition of the clay-size fraction, particularly of alumino-silicate phases, apart from that of glauconite (see below). Carbonate, mica and glauconite are the minerals generally identified in the literature, with much phosphate deposition at the base of the Red Crag (which formed the basis of the fertiliser industry).

The sand (and coarser) fractions are frequently carbonate-rich (up to 60% whole and comminuted shells) and micaceous (Balson and Humphreys, 1986, Hamblin et al., 1997). Although considerable loss of $CaCO_3$ from the upper horizons of the sediments has been observed, it is not clear whether this is entirely due to chemical erosion or is a depositional feature (Moorlock et al., 2000). This decalcification process can result in high concentrations of Ca and HCO_3 in the groundwaters, and involves the dissolution of metastable aragonite and re-precipitation of the $CaCO_3$ as calcite.

The sediments are always observed to be dark-green at depth, as a result of the high concentrations of glauconite, up to 3% by volume in the Red Crag (Humphreys and Balson, 1985, Moorlock et al., 2002b). Glauconite is a term used to cover material from smectite to mica compositions. Strictly the composition is as follows:

$$(K,Na,Ca)_{1\ 2\text{-}2\ 0}(Fe^{3+},Al,Fe^{2+},Mg)_{4\ 0}[Si_{7\text{-}7\ 6}Al_{1\text{-}0\ 4}O_{20}](OH)_{4}.n(H_{2}O)$$

Glauconite contains mixed-valency iron, suggesting precipitation in a moderately reducing environment. It has been disputed whether this is authigenic or allogenic in origin (Humphreys and Balson, 1985, Merriman, 1983). The glauconitic material includes discrete grains (200-500 µm), coatings on flints and infilling of pore spaces (Humphreys and Balson, 1985). Generally the glaucony is as glauconitic smectite (Humphreys and Balson, 1985). Oxidation of the glauconite greatly contributes to the near ubiquitous reddening of the Crag in surface or coastal exposures; on a microscopic scale the oxidation products can occur as a rim on the glauconite or penetrate the whole grain, or can result in the irregular cementation of the sediments away from the original source of the Fe^{2+}. It has been suggested that the onset of oxidation of the Fe in the sediments was during the periods of hiatus within the overall deposition of the sediments. The glauconite also results in the Crag generally having a significant ion-exchange capacity (Heathcote and Lloyd, 1984), in the order of 5-40 meq/100g for glauconite (Appelo and Postma, 1994), although this is substantially higher than the value of 3.5 meq 100 g^{-1} recorded for the clean sands of the Chillesford Sand Member (Norwich Crag) [6383 2523] (Gillespie et al., 2001).

3.3.3 Quaternary superficial deposits

The mineralogy of these deposits is important as they affect the quality of recharge to underlying aquifers. The tills in south Suffolk have pyritic Jurassic and Tertiary clays as their major source rocks, oxidation of which leads to high SO_4 concentrations in porewaters (Heathcote and Lloyd, 1984). The reduced species may also be oxidised by the reduction of NO_3 in recharge waters, which provides an additional protective function to the underlying aquifer (Parker et al., 1987). It is suggested that gypsum in the till is a source of Ca and SO_4. The marine nature of the source rocks may also contribute Na, Mg and Cl (Heathcote and Lloyd, 1984).

The clays of the Lowestoft Till are dominated by mica and kaolinite, with subordinate and variable smectite and chlorite (Moorlock et al., 2000). Chalk and flints are the dominant clasts in the till with a mean of 40% carbonate (up to 70%) and a matrix texture of a sand or silty-clay. The unweathered clay is blue-grey and weathers to a yellow-brown, as a result of the oxidation of Fe^{2+} bearing mineral phases.

3.4 Rainfall chemistry

Rainfall provides the recharge for the Chalk and most of the Crag under study, and its composition is thus the minimum baseline condition. The coastal location of much of the Chalk and Crag aquifers studied here plays a role in the recharge chemistry, with greater concentrations of marine derived Na and Cl than would be observed further inland. The composition of rainfall is also illustrated (Table 3.2) with a threefold multiplication to approximate for the effects of evapotranspiration.

Table 3.2 Representative rainfall chemistry for the study region, measured at Stoke Ferry, Norfolk [5700 2988] for 1998, to the west of the present study area (retrieved from The UK National Air Quality Information Archive at http://www.aeat.co.uk/netcen/airqual/ on 18 April 2002).

Parameter (annual mean value)	Rainfall composition	Rainfall composition × 3
pH	5.1	
Na ($mg\ l^{-1}$)	1.26	3.79
K ($mg\ l^{-1}$)	0.12	0.35
Ca ($mg\ l^{-1}$)	0.78	2.34
Mg ($mg\ l^{-1}$)	0.27	0.80
Cl ($mg\ l^{-1}$)	2.20	6.59
SO_4 ($mg\ l^{-1}$)	2.26	6.77
NO_3 ($mg\ l^{-1}$)	2.48	7.44
NH_4 ($mg\ l^{-1}$)	0.90	7.21
Total N ($mg\ l^{-1}$)	1.26	3.78
SEC ($\mu S\ cm^{-1}$)	27.2	81.80
Rainfall amount (mm)	435	

3.5 Landuse

North Norfolk is a predominantly arable farming area, with wheat, barley, potatoes and sugar beet as the most important crops. There are some areas of woodland and heathland particularly along the sand soils of the Cromer ridge and to the north of Taverham (Figure 3.5). The artificially drained areas of the Broads are largely used for livestock farming, with some areas (e.g. around Horning) managed as semi-natural woodlands. Market gardening and horticultural landuses also occur in this area. A decline in industry using the groundwater resources of the area has taken place, which used to include mushroom growing and packaging. Brewing is still a user of the groundwater from the Chalk.

The landuse in the river Waveney catchment is dominated by arable farming, with similar crops as north Norfolk (Figure 3.5) in the valley sides. The drained soils of the floodplain are often used for cattle grazing, particularly in the summer. Tourism is an important source of revenue for the area, particularly centred on the coast and Broads. This has consequences for development in the coastal areas in particular, and seasonal changes in road use intensity. Industrial uses in the Lowestoft area for the Crag aquifer include commercial amenity lands and industrial units.

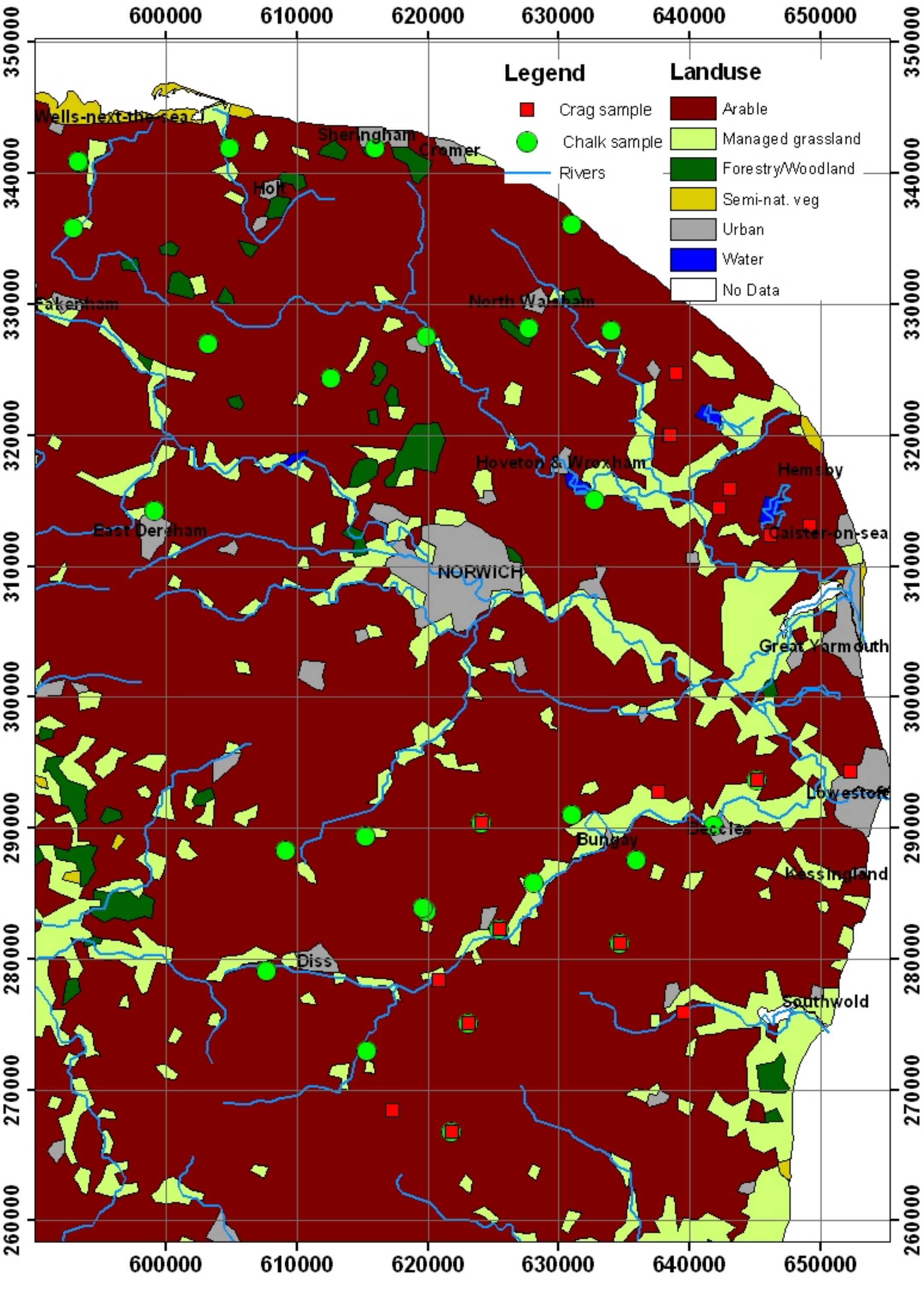


Figure 3.5 **Landuse in the study areas**

4. DATA AND INTERPRETATION

4.1 Project sampling programme

A total of 56 samples were collected from two regions of East Anglia during June 2003 in order to characterise the nature of groundwater within the Crag and Chalk aquifer systems. The sampling was undertaken in two aquifers, the Crag and the Chalk, from two distinct geographical areas, the Waveney valley and North Norfolk. Within the Waveney valley, samples were collected predominantly from Environment Agency piezometers installed during 2002, with some public water supply sites also being sampled. The samples in North Norfolk were from public water supply sources in the Chalk aquifer and private water supply sources in the Crag aquifer. A summary of the samples collected from each aquifer and each area is shown in Table 4.1. No springs were sampled in either field area, due to the difficulty in ascertaining whether surface springs are associated with the Crag, or whether they are derived largely from glacial and post-glacial sediments.

For the Environment Agency piezometers, sampling was carried out simultaneously with that for the Environment Agency groundwater network sampling programme. At each site, the piezometers were purged for three borehole volumes prior to sampling. Several samples were also collected from piezometers in the superficial deposits of the area installed at locations where chalk or Crag piezometers were present.

Table 4.1 Summary of the samples collected

Aquifer	Waveney catchment	North Norfolk	Total
Chalk	17	13	30
Crag	11	7	18
Glacial / alluvial sands & gravels	6	0	6
Boulder Clay / till	2	0	2
Total	36	20	56

The physico-chemical parameters of pH, redox potential (Eh), and dissolved oxygen (DO) were measured on-site whenever possible by connecting an air-tight flow-through cell to the rising pipe. At four sites (CC53-CC56), measurements are those taken using the Environment Agency flow-through cell (which had previously shown good agreement with data collected using the BGS flow-through cell). At two sites (CC07 and CC37) it was not possible to connect the pump outlet to the flow-through cell, so measurements were made as quickly as possible within a large container. At another site (CC15), pumping from the Wortwell boulder clay piezometer, pumping had to be undertaken at a slow rate due to the high draw down encountered, so the flow-through cell was not used. The temperature is, therefore, likely to be artificially high due. Measurements of temperature (T), specific electrical conductance (SEC), and alkalinity (by titration) were also made whilst on site. Water samples were filtered (<0.45 µm) into Nalgene polyethylene bottles for major and trace cation and SO_4 analyses (acidified to 1% v/v HNO_3). Filtered (<0.45 µm), unacidified, water samples were also collected into Nalgene bottles for anion analysis. Samples were collected in glass bottles for dissolved organic carbon (DOC) (filtered through a 0.45 µm Ag-membrane filter), and stable isotopes (δ^2H, $\delta^{18}O$ and $\delta^{13}C$).

Analysis of the major cations and sulphate was undertaken by inductively coupled plasma atomic emission spectrometry (ICP-AES). Trace elements were determined using inductively coupled plasma mass spectrometry (ICP-MS). Nitrogen species, Cl, Br, F and I were determined by automated colorimetry (SKALAR). Stable isotopes were measured by mass spectrometry and values reported relative to VSMOW for δ^2H and $\delta^{18}O$, and VPDB for $\delta^{13}C$.

In addition to the new data measured as part of this study, data from the Environment Agency (Anglian region) WIMS database and national network monitoring scheme were incorporated where the samples had been filtered and had good charge balances.

Data has also been incorporated where appropriate from the scientific literature, for which major element data are available for the North Norfolk Chalk, through the publications summarised in Table 4.2.

Table 4.2 Literature data sources for the Chalk and Crag aquifers.

Aquifer	Number of sample points used	Region	Source
Crag	5	North Norfolk	Hudson et al. (2003)
Crag	15	North Norfolk	ENTEC (2001)
Crag	17	North Norfolk	Cook
Crag	7	North Norfolk	Hiscock (1987)
Crag	20	North Norfolk	Holman (1994)
Chalk	52	North Norfolk	Feast et al. (1998)
Chalk	2	North Norfolk	Bath and Edmunds (1981)

4.2 Historical data

A few reference sources provided historical comparative information for the aquifers (e.g. Whittaker, 1906, Whittaker, 1921). From such sources it can be recognised that some 'modern' problems with establishing baseline may have comparisons stretching back over 100 years. For instance the high nitrate concentrations which are found in the Crag are not necessarily recent in origin e.g. a concentration of 93 mg l^{-1} as NO_3 was found in Southwold in 1888 (this area has light soils which would readily leach any agricultural NO_3 applications). Few datasets are available over a very long period (>50 years) for a single source, and no information could be found for a complete suite of major elements or trace elements collected over such a period of time although some information provided is summarised in Section 6.

4.3 Processes affecting the composition of pumped groundwater

The chemical composition of a groundwater sample will be a function of many factors and the very act of drilling and pumping water from a borehole will cause deviations in the chemistry from that characteristic of the undisturbed aquifer. These variations may arise as a result of:

- differences in borehole design and construction (depth, depth of casing);
- different stratigraphic horizons present in the borehole (including fractures intersected);
- different pumping histories of a borehole and differences in pumping regimes at different boreholes otherwise very similar in design and geological setting.

4.3.1 Different borehole designs

The occurrence of different flow regimes within the Chalk (Section 3.3) means that differences between fracture and pore water chemistry are likely, as well as lateral and vertical stratification. Where a borehole intersects these chemically stratified groundwaters, mixing will be expected to occur in the borehole column. Thus the borehole depth and length of casing will all have the potential to affect water chemistry simply by differences in the nature and quantity of groundwater drawn into the borehole.

Wells and boreholes in the Crag generally require screening because the sediments are prone to problems with running sands. Running sands can locally alter the flow of groundwater to the borehole. It is also likely that vertical stratification of groundwaters within the Crag occurs where contiguous clays act as effective barriers to groundwater flow. If two bodies of water are intersected by a borehole, then mixing may be expected whilst pumping takes place.

4.3.2 Differences in stratigraphy

The natural variability of the structure, mineralogy and geochemistry of the Chalk will result in variations in the groundwater chemistry. The dual-porosity nature of the aquifer may result in porewater chemistry (where diffusion may be important) being different to fracture water chemistry (dominated by advection and dispersion). The aqueous composition sampled by pumped boreholes will be overwhelmingly dominated by fracture water. Whilst the Crag is a heterogeneous aquifer matrix, its overall physical properties have been found to be more consistent and predictable than the Chalk.

The in-situ composition of Chalk porewaters has been studied in this region by Bath and Edmunds (1981), using material from the 472 m Trunch borehole in north-east Norfolk. Data from their study of the Chalk porewater compositions, and comparison with pumped (fracture flow dominated) waters are reproduced in Figure 4.1. The porewater profile is interpreted as a diffusion controlled mixing between older (saline) waters at depth and younger, fresher waters towards the top of the profile (Bath and Edmunds, 1981). The data for the White House PWS (1 km from the Trunch borehole) cited by Bath and Edmunds is also plotted on the figure for comparison (at an arbitrary depth for plotting purposes), and shows that the composition of elements associated with increasing residence time (particularly Sr) are much lower (note the log scale) than those observed in the porewaters. Celestite ($SrSO_4$) was observed in fracture fill material at depth in the borehole, limiting further increases in Sr concentration above c.30 mg l^{-1} (Bath and Edmunds, 1981).

A significant issue in the representative sampling of Chalk groundwaters is due to a biasing in the distribution of boreholes to the higher transmissivity zones in the valleys, in order to maximise the probability of intersecting fractures, and thus greatly increasing yields. Where boreholes are sited in the interfluve areas elsewhere in the East Anglian Chalk, the aggressive nature of the reducing waters to the pumping equipment increases the costs of running such boreholes, reinforcing the economic desirability of siting boreholes and pumping from valley locations. This makes the even distribution of the sampling sites across the groundwater catchment extremely difficult. The distribution vastly increases the proportion of samples from valleys, at the expense of those from the interfluves. The design of the Waveney network has been specifically to avoid these issues, but it is not clear whether these piezometers have been pumped sufficiently to remove any perturbations to the local hydrochemical regime caused by installation. No data on porewater analysis of core from the Crag has been located during this study.

4.3.3 Differences in pumping history

The dual porosity nature of the Chalk means that variations in the rate and quantity of water abstracted may have a significant effect on the lateral extent from which water is drawn. Considerations of sediment heterogeneity suggest that flow paths within the Crag may be locally complex and thus affected by pumping regimes employed. When the Chalk groundwater is abstracted from depth, or from beneath the Crag or confining Quaternary sediments, this may affect the redox status and composition of the waters due to drawdown of overlying water. The effect of pumping history has been shown in the long records of nitrate data for some Cambridgeshire public water supply sources, where sharp steps in the data are artefacts attributable to pumping history, rather than changing fluxes of nitrate into the aquifer (Carey and Lloyd, 1985). Horizontal flow components may be replaced over time by vertical flow after the commencement of pumping from a borehole, and that this effect will accentuate the ingress of nitrate into the supply.

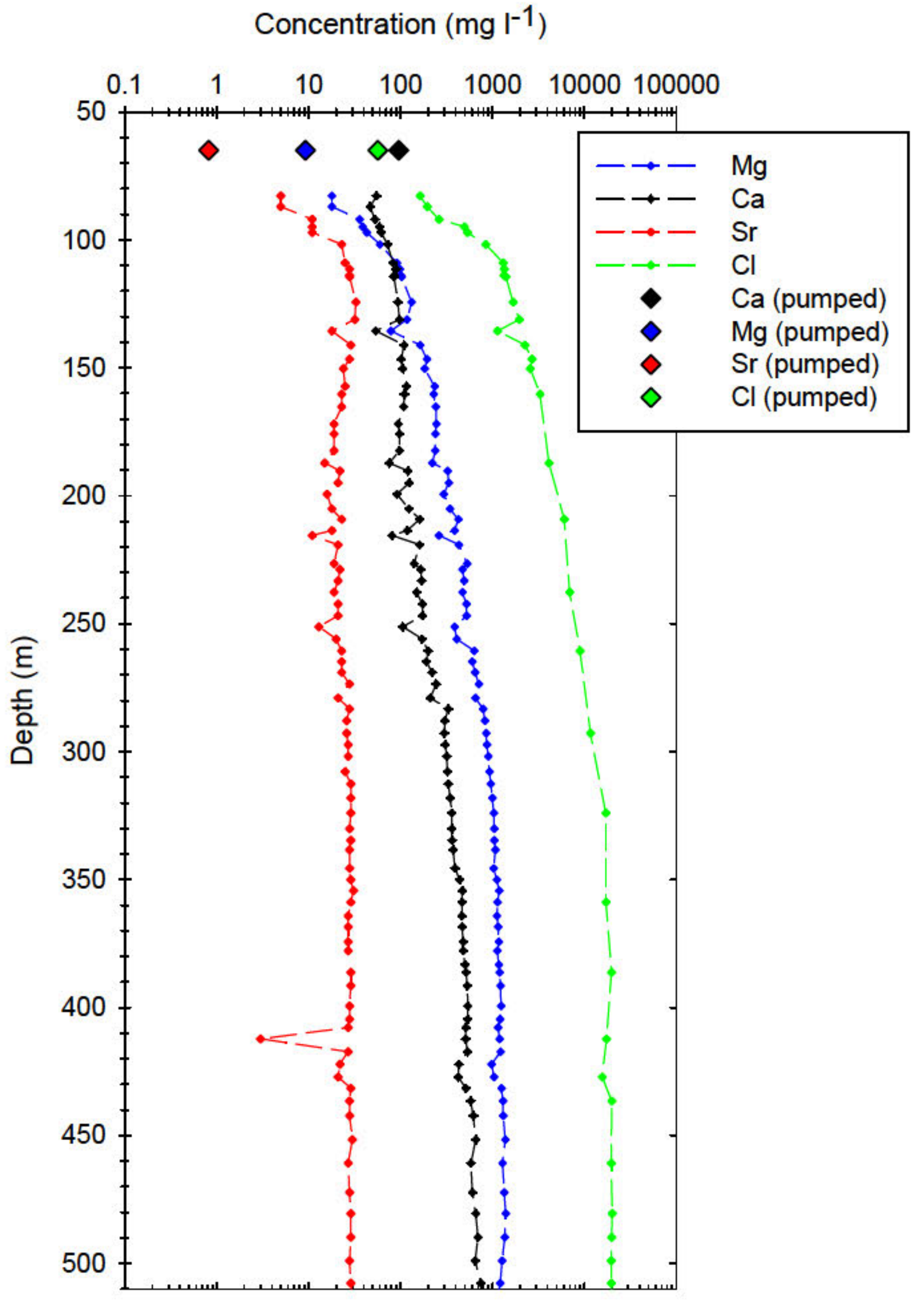


Figure 4.1 Pore-water profile of the Trunch borehole (Bath & Edmunds, 1981). The samples marked 'pumped' are plotted at an arbitrary depth for comparative purposes only.

This report presents a broad assessment of the water-quality variations observed across the aquifers studied and the controlling geochemical processes. Chemical reactions are both time- and space-dependent and the data presented simply represent a snapshot of the water quality, which is in a constant state of change.

4.4 Data handling

Sample site selection was undertaken in the Waveney valley with a view to augmenting the samples collected from the Environment Agency piezometers. Samples in the North Norfolk area were also selected to give a good coverage of the aquifer through the designated region; for the Chalk this was achieved by additional sampling of public supply sources. Locating private supplies which are unequivocally from the Crag, rather than a combination of Crag and overlying Superficial deposits, was difficult in the North Norfolk area. Thus the samples were selected by this criterion rather than purely that of geographical distribution. Known areas of point-source pollution were avoided.

The data from this study, and pre-existing data, are described in Section 5. Where analytical results were below the detection limit of the method used, a value of half of that detection limit has been applied to the data for statistical purposes. For consistency, the same value has been applied to historical data, irrespective of the actual detection limit quoted. Such variations in detection limit are an inevitable consequence of variations in, and improvements to, analytical methodologies.

Pre-existing data were rejected when charge balance errors were greater than 10%. Those collected for the present study had charge balance values better than ±5%, with the exception of one sample which was +6%.

5. HYDROCHEMICAL CHARACTERISTICS

5.1 Introduction

This section describes the hydrochemical characteristics of the aquifers studied in this report. Because the Chalk and Crag are so different in their groundwater characteristics, they are described in separate sections below. Chapter 6 presents interpretation of the data in a regional hydrogeochemical framework to understand the processes controlling the observed baseline geochemistry.

A distinction in the composition within each aquifer is only described when differences in the baseline chemistry make such an approach appropriate.

5.2 The Chalk Aquifer

5.2.1 Introduction

A summary of major and minor element data of the Chalk groundwaters from north Norfolk and the river Waveney catchment areas are presented in Table 5.1 and for trace elements in Table 5.2. The tables show the data range, median, mean and 97.7 percentile values for each parameter. The 97.7 percentile represents the mean + 2σ (where σ is standard deviation), and is used simply to remove outlying data.

Table 5.1 Summary of major and minor ion data for the Chalk groundwaters.

Parameter	units	min.	max.	median	mean	97.7th percentile	N
T	°C	10.4	17.3	11.9	11.6	15.5	30
pH		6.73	8.90	7.18	7.10	7.89	41
Eh	mV	-128	467	67	32	333	28
DO	$mg\ l^{-1}$	<0.05	5.02	0.85	<0.05	3.98	30
SEC	$\mu S\ cm^{-1}$	380	12420	1325	809	4772	42
δ^2H	‰	-51.50	-44.00	-47.03	-47.15	-44.00	12
$\delta^{18}O$	‰	-7.98	-7.01	-7.55	-7.55	-7.16	56
$\delta^{13}C$	‰	-17.26	-4.91	-10.15	-10.02	-5.21	10
Ca	$mg\ l^{-1}$	48	301	124	126	231	96
Mg	$mg\ l^{-1}$	2.00	212	13	8.20	41	96
Na	$mg\ l^{-1}$	11	2010	63	27	238	96
K	$mg\ l^{-1}$	0.60	91	6.06	3.20	31	92
Cl	$mg\ l^{-1}$	18	3650	110	55	385	96
SO_4	$mg\ l^{-1}$	6.41	1180	93	71	369	96
HCO_3	$mg\ l^{-1}$	110	561	295	287	464	96
NO_3 as N	$mg\ l^{-1}$	0.001	21.8	3.6	0.09	17.3	87
NO_2 as N	$mg\ l^{-1}$	0.0015	4.07	0.34	0.09	1.99	33
NH_4 as N	$mg\ l^{-1}$	0.0005	0.01	0.00	0.0005	0.01	30
P	$\mu g\ l^{-1}$	10	120	52.6	45	104	30
DOC	$mg\ l^{-1}$	0.74	23.2	3.221	1.840	13.09	29
F	$mg\ l^{-1}$	0.05	1.94	0.462	0.280	1.85	43
Br	$mg\ l^{-1}$	0.015	11	0.694	0.184	4.51	34
I	$mg\ l^{-1}$	0.0027	0.114	0.020	0.011	0.082	30
Si	$mg\ l^{-1}$	4.4	15.1	8.878	9.130	14.85	37

Table 5.2 Summary of trace element data for the Chalk groundwaters

Parameter	units	min.	max.	median	mean	97.7th percentile	N
Ag	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
Al	µg l^{-1}	0.5	8	1.867	1	5.999	30
As	µg l^{-1}	0.25	18.1	2.375	0.85	12.1637	30
Au	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
B	µg l^{-1}	10	1000	96.5	33	639	30
Ba	µg l^{-1}	11.0	156	50.2	48.9	101	30
Be	µg l^{-1}	0.025	0.16	0.037	0.025	0.133	30
Bi	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
Cd	µg l^{-1}	<0.025	3.93	0.386	0.1	3.54	30
Ce	µg l^{-1}	0.005	0.02	0.0075	0.005	0.02	30
Co	µg l^{-1}	0.01	2.24	0.315	0.08	1.893	30
Cr	µg l^{-1}	0.25	2	0.618	0.425	1.933	30
Cs	µg l^{-1}	0.005	0.25	0.020	0.005	0.150	30
Cu	µg l^{-1}	0.1	20	2.817	0.9	15.66	30
Dy	µg l^{-1}	<0.005	0.01	0.0053	<0.005	0.01	30
Er	µg l^{-1}	0.005	0.01	0.0052	0.005	0.0067	30
Eu	µg l^{-1}	<0.005	<0.005	<0.005	<0.005	<0.005	30
Fe	mg l^{-1}	5	16600	1490	402	7875	94
Ga	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
Gd	µg l^{-1}	0.005	0.06	0.0085	0.005	0.033	30
Ge	µg l^{-1}	<0.025	0.61	0.0928	0.065	0.450	30
Hf	µg l^{-1}	0.01	0.03	0.0107	0.01	0.017	30
Hg	µg l^{-1}	0.05	0.05	0.05	0.05	0.05	30
Ho	µg l^{-1}	0.005	0.005	0.005	0.005	0.005	30
In	µg l^{-1}	0.005	0.005	0.005	0.005	0.005	30
Ir	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
La	µg l^{-1}	<0.005	0.02	0.007	<0.005	0.02	30
Li	µg l^{-1}	2.3	466	33.5	10.8	221	32
Lu	µg l^{-1}	<0.005	<0.005	<0.005	<0.005	<0.005	30
Mn	µg l^{-1}	0.005	520	97.4	70.7	365	42
Mo	µg l^{-1}	0.1	2.7	0.6933	0.45	2.633	30
Nb	µg l^{-1}	<0.005	0.01	0.0052	<0.005	0.007	30
Nd	µg l^{-1}	0.005	0.02	0.0073	0.005	0.020	30
Ni	µg l^{-1}	0.1	9.3	0.8467	0.1	5.965	30
Os	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
Pb	µg l^{-1}	0.05	4.1	0.298	0.075	1.899	30
Pd	µg l^{-1}	0.1	0.1	0.1	0.1	0.1	30
Pr	µg l^{-1}	0.005	0.005	0.005	0.005	0.005	30
Pt	µg l^{-1}	0.005	0.005	0.005	0.005	0.005	30
Rb	µg l^{-1}	0.46	37.55	5.007	1.62	33.11	30
Re	µg l^{-1}	<0.005	0.02	0.008	<0.005	0.02	30
Rh	µg l^{-1}	0.005	0.005	0.005	0.005	0.005	30
Ru	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30
Sb	µg l^{-1}	0.025	0.87	0.081	0.025	0.563	30
Sc	µg l^{-1}	1	4	2.7	3	4	30
Se	µg l^{-1}	<0.025	15.5	1.51	0.6	11.23	30
Sm	µg l^{-1}	0.01	0.01	0.01	0.01	0.01	30
Sn	µg l^{-1}	<0.025	0.17	0.04	<0.025	0.117	30
Sr	µg l^{-1}	262	25121	3082	1201	14190	34
Ta	µg l^{-1}	0.01	0.01	0.01	0.01	0.01	30
Tb	µg l^{-1}	0.005	0.005	0.005	0.005	0.005	30
Te	µg l^{-1}	0.025	0.07	0.027	0.025	0.040	30
Th	µg l^{-1}	0.025	0.025	0.025	0.025	0.025	30

Parameter	units	min.	max.	median	mean	97.7th percentile	N
Ti	$\mu g\ l^{-1}$	5	5	5	5	5	30
Tl	$\mu g\ l^{-1}$	0.005	0.05	0.009	0.005	0.037	30
Tm	$\mu g\ l^{-1}$	0.005	0.005	0.005	0.005	0.005	30
U	$\mu g\ l^{-1}$	0.01	4.21	0.472	0.015	2.863	30
V	$\mu g\ l^{-1}$	0.1	20.3	1.147	0.1	9.495	30
W	$\mu g\ l^{-1}$	<0.01	0.44	0.040	<0.01	0.280	30
Y	$\mu g\ l^{-1}$	0.005	0.07	0.017	0.01	0.063	30
Yb	$\mu g\ l^{-1}$	0.005	<0.01	0.006	0.005	<0.010	30
Zn	$\mu g\ l^{-1}$	0.25	114	19.3	14.6	63	30
Zr	$\mu g\ l^{-1}$	0.01	1.17	0.053	0.01	0.430	30

Summary presentations of the data are shown as a Piper Plot (Figure 5.1), box-and-whisker plots (Figure 5.2) and cumulative frequency plots (Figure 5.3).

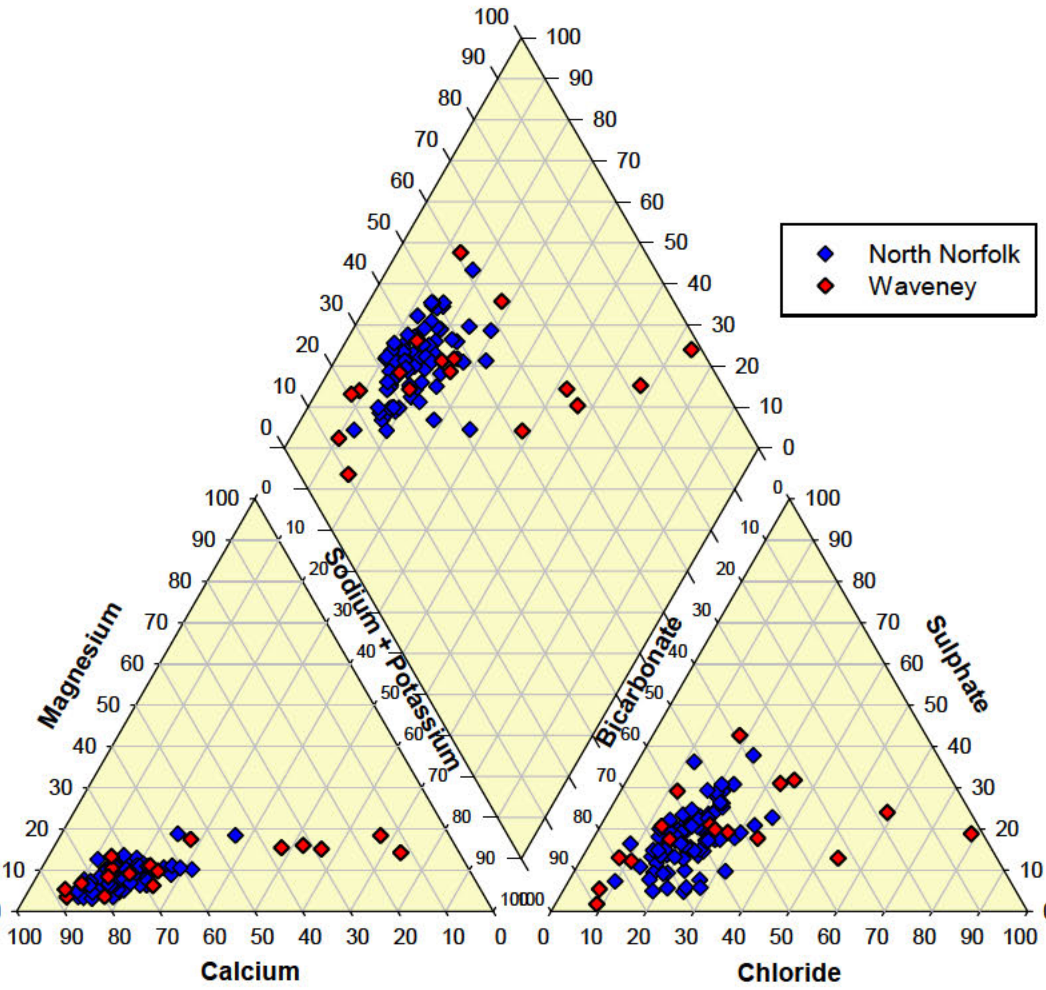


Figure 5.1 Piper diagram for the North Norfolk and Waveney Chalk groundwaters

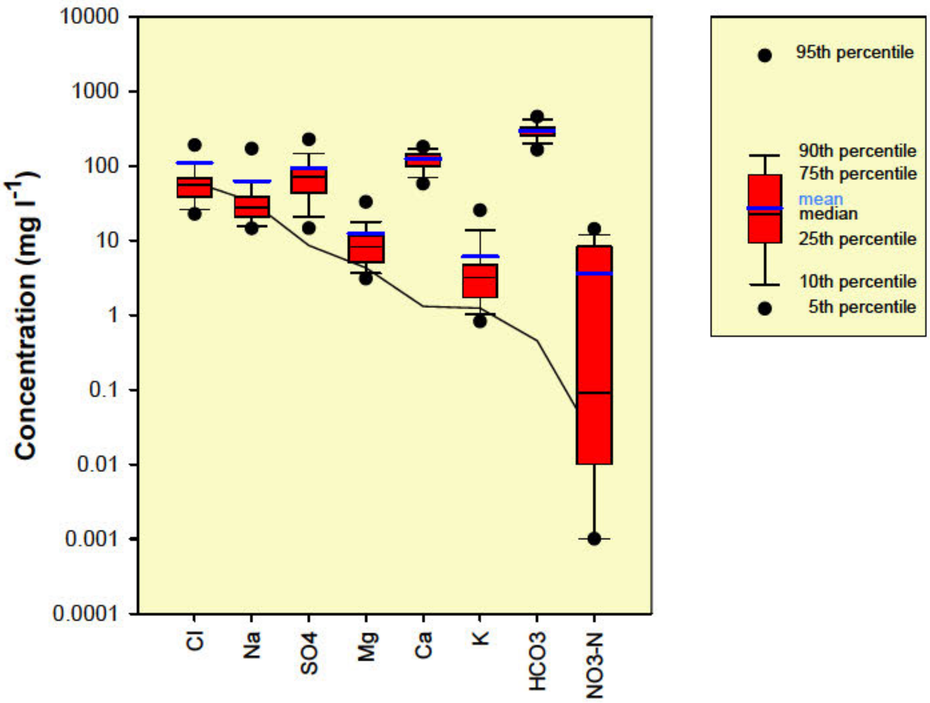


Figure 5.2 Box-plot of major elements in the Chalk groundwaters

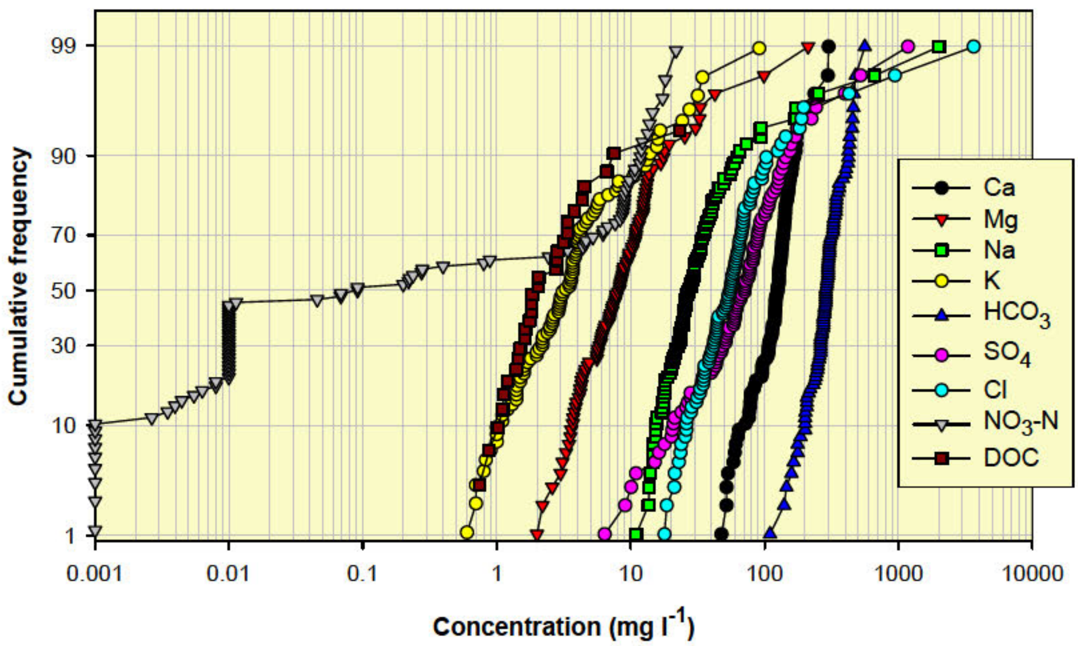
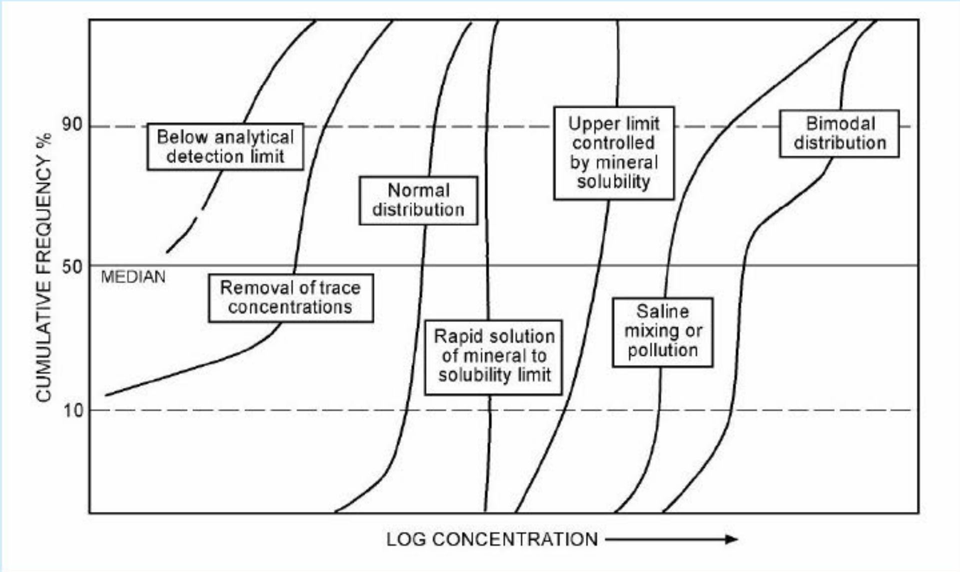


Figure 5.3 Cumulative probability plot of major elements in the Chalk groundwaters

Cumulative frequency plots (Figure 5.3) are useful tools in visualising the distribution of data and for determining different data populations, including outlying data or pollution affected samples. Time and space dependant geochemical processes may be expected to affect data distributions, and thus baseline, throughout an aquifer (Box 5.1).

Box 5.1 Use of cumulative frequency diagrams to indicate baseline characteristics in groundwaters



i) The median and upper and lower percentile concentrations are used as a reference for the element baseline which can be compared regionally or in relation to other elements.
ii) Normal to multi -modal distributions are to be expected for many elements reflecting the range in recharge conditions, water-rock interaction and residence times under natural aquifer conditions.
iii) Narrow ranges of concentratio n may indicate rapid attainment of saturation with minerals (e.g. Si with silica, Ca with calcite).
iv) A strong negative skew may indicate selective removal of an element by some geochemical process (e.g. NO_3 by *in situ* denitrification).
v) A narrow range in concentration at the upper limit may indicate a mineral solubility control (e.g. F by fluorite)
vi) A positive skew most probably indicates a contaminant source for a small number of the groundwaters and this gives one simple way of separating those wa ters above the baseline. Alternatively the highest concentrations may indicate waters of natural higher salinity.

5.2.2 Water types and physico-chemical characteristics

The statistical summary of the data for the Chalk in both North Norfolk and the Waveney catchment is shown in Table 5.1, which shows that the range in concentrations of many of the major elements ranges over two orders of magnitude.

The physico-chemical parameters, including dissolved oxygen (DO) and redox potential (Eh), were measured on site where possible using a flow-through cell (Section 4); these parameters are generally only available for the samples collected during this study.

Specific electrical conductivity measurements show that the waters range from weakly to highly mineralised (maximum SEC >12,000 $\mu S\ cm^{-1}$). There is a general trend of higher values in the Waveney catchment than in the North Norfolk area, with the maximum conductivity in North Norfolk being 873 $\mu S\ cm^{-1}$, whilst only four sites in the Waveney region have a conductivity below 873 $\mu S\ cm^{-1}$. The temperature of the waters sampled ranged from 10.4 to 17.3 °C, but was generally between 10 and 12 °C. Dissolved oxygen (DO) was below the detection limit in some samples, but ranged up to 5 $mg\ l^{-1}$. Despite the well established difficulties in measuring Eh, the range of values (-128 to 467 mV) reflect the variable redox status suggested by the DO data.

The major element chemistry of groundwater from the two aquifer areas is presented on a Piper diagram in Figure 5.1. This shows the major ions (Ca, Mg, Na, K, HCO_3, SO_4 and Cl) plotted as relative proportions calculated from their concentration in milli-equivalents, and demonstrates the major element dominance of a given sample, rather than absolute concentrations. The two study areas have been distinguished as they show differing overall characteristics. In North Norfolk, all the waters sampled are of a Ca-HCO_3 type, with two samples showing a moderate trend towards Na-Cl. Within the Waveney catchment, a range of water types was found, from Ca-HCO_3 to Na-Cl. In a general sense, these follow a relationship from the upper catchment to the confined coastal aquifer, but the varying depth of the boreholes in the chalk at different localities may also be important in determining these variations.

5.2.3 Major elements

The major element chemistry of the Chalk groundwaters is summarised in Table 5.1. The box-plots shown in Figure 5.2 are arranged in order of abundance in seawater, using a logarithmic scale. The seawater concentrations, normalised to the median Cl of the dataset, are shown for comparison. The relationship between the seawater concentration and the measured concentrations provides an indicator of the extent of water-rock interaction over and above the marine- derived input (rainwater, seawater, connate water).

The box-plots show that, apart from the normalised Cl data, the rest of the major elements are enhanced relative to the concentration expected from a dilute seawater (or rainfall) source. The range of Na data is very close to that of Cl, although the median concentration is slightly elevated. There is a large range in NO_3-N concentrations, from below the detection limit to above the present EC drinking water limit of 11.3 mg l^{-1} NO_3-N.

The cumulative frequency plots (Figure 5.3) illustrate the population distribution, range and relative concentrations of selected parameters in the Chalk groundwaters. The population distribution can be discerned from the shape of the curve, which can indicate controlling processes on the hydrochemical environment (Box 5.1). The curves for the major elements and DOC indicate multimodal populations in most cases (e.g. for NO_3). However, Ca and HCO_3 concentrations show a narrow range, suggesting rapid equilibrium with respect to a carbonate mineral phase. The groundwaters are all at saturation with respect to calcite and many are saturated with respect to dolomite and siderite.

5.2.4 Minor and trace elements

The minor and trace element data which are summarised in Table 5.2, are also plotted as box-plots (relative to seawater) and cumulative probability plots on Figures 5.4 and 5.5 respectively. Where the trace elements were below the detection limit of the method used, vertical lines will appear at the low end of the concentration range for the elements in Figure 5.5 (e.g. Ni and U). This is consistent with the low mobility of many elements in neutral pH, moderately oxidising chalk groundwaters. The data shown here are largely those collected for this study, as the trace elements were rarely measured in other studies.

The probability plot for trace elements also shows some multi-modal population distributions. Redox sensitive elements such as As, Fe and Mn show large variations in concentrations. The variation of Fe and Mn, by three orders of magnitude, reflects their ubiquitous occurrence through the aquifer, allowing relatively high concentrations to be reached when sufficiently reducing conditions become prevalent. The box-plots show the relative abundance of the elements in comparison to a dilute seawater line, with all elements showing enrichment. With some this may be as a result of variations in the ratio in rainfall recharging the aquifer (e.g. I/Cl is commonly higher in rainfall than seawater), whilst for other elements (e.g. Fe, Sr) it clearly indicates water-mineral interaction in the soil, unsaturated or saturated zones as water flows into and through the aquifer.

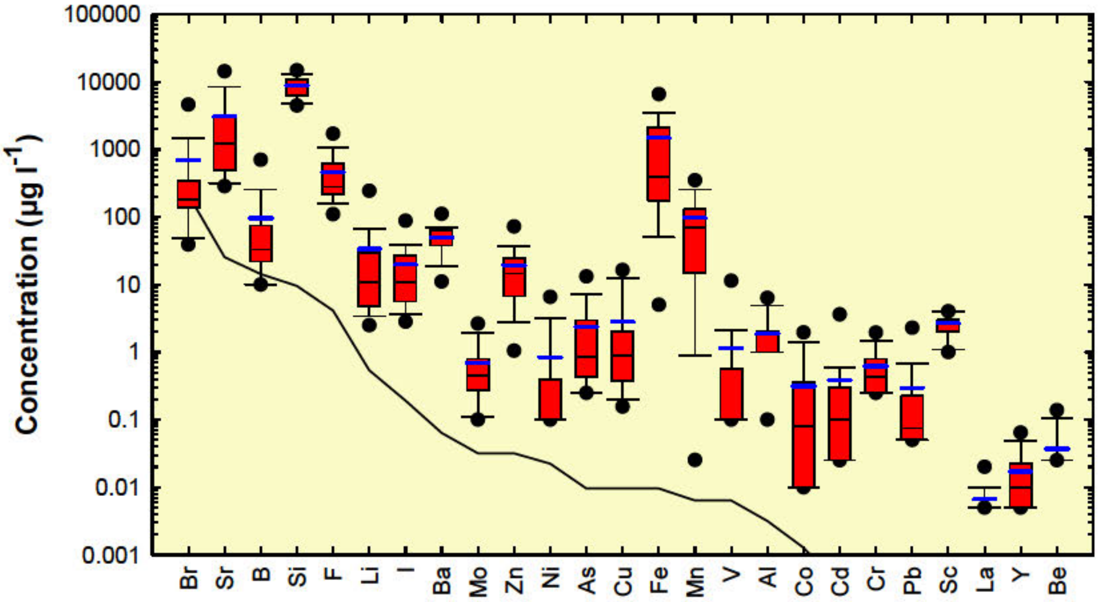


Figure 5.4 Box-plot of minor and trace elements in the Chalk groundwaters

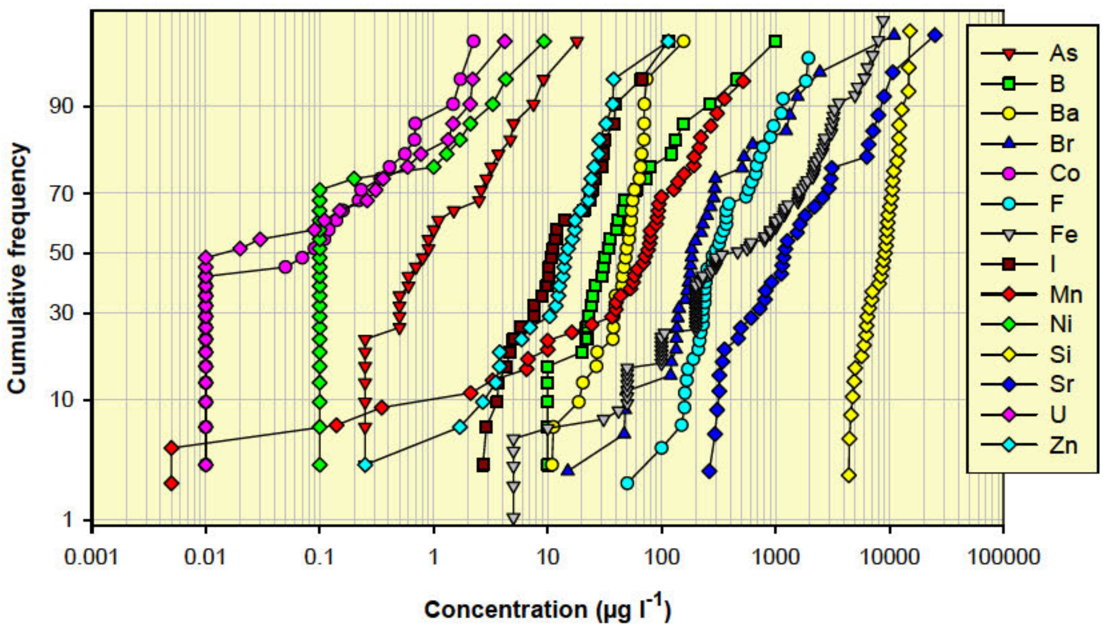


Figure 5.5 Cumulative probability plot of minor and trace elements in the Chalk groundwaters

Other trace elements, which are insensitive to redox conditions, have multi-modal population distributions reflecting residence time within the aquifer. Strontium concentrations in groundwaters are usually not limited by the solubility of a Sr bearing mineral, but saturation is approached in some of the waters where Sr concentrations are high (up to 25 mg l^{-1}).

Uranium displays a bimodal distribution, which may in part be due to increased mobility in oxidising carbonate waters. Silicon concentrations would be expected to be controlled by the solubility of Si bearing minerals within the aquifer, and Figure 5.5 suggests that equilibrium is rapidly attained to a Si phase (probably chalcedony).

Nickel varies up to 10 g l^{-1}, but with 70% of the samples being below the detection limit. The remainder of the samples vary with concentrations up to 10 µg l^{-1} (Figure 5.5).

5.2.5 Pollution indicators

The concept of baseline ideally requires that samples used for its numerical characterisation are free of anthropogenic influence. Pollution can directly alter the baseline either by the addition of solutes, or indirectly by promoting chemical reactions within the aquifer (Box 5.2). The almost ubiquitous nature of diffuse pollution within some aquifers makes diffuse sources very hard to avoid when sampling.

Box 5.2 How can we distinguish pristine waters from polluted groundwater?

Groundwater prior to the industrial era (before c. 1800) emerged as springs or was taken from shallow wells, whilst the deeper reserves were in a pristine condition. The water first encountered using modern drilling practices would have had compositions reflecting true baseline determined only by geological and geochemical processes. Only rarely is it possible to find such waters because the majority of groundwaters sampled in the present study are derived from aquifers which have been developed for decades. The problem in baseline is to recognise the impact of any of human activities over and above the natural baseline in the data sets used.

The approach adopted is threefold:

(i) to have evidence of groundwater age

(ii) to extrapolate data series back to an initial time

(iii) to use indicator elements in the groundwater, known to result from human activities. The most probable indicators of human activities are enhanced TOC and N species – especially NO_3 – the presence of foreign substances such as agro-chemicals or industrial chemicals. The sets of data are examined for these substances as a clue to the presence of "contamination", although it is stressed that it is impossible to quantify this. However, traces of contamination may have little impact on the overall chemistry of the groundwater.

Boreholes known to be affected by point source pollution were avoided in this study at the site selection phase. The high nitrate concentrations observed in some groundwater sources indicates that diffuse pollution has occurred, for instance, through fertilisation application. Other elements, such as K, SO_4 or Cl, may be affected by urban or agricultural diffuse pollution, but can be harder to delineate due to the relative natural abundance of these ions, and their occurrence in formation waters within parts of the Chalk aquifer.

5.3 The Crag aquifer

5.3.1 Introduction

A summary of the major and minor ion data is provided in Table 5.3. This shows the range, mean, median and 97.7th percentile. The 97.7th percentile (mean + 2σ) represents an upper concentration used to exclude outliers. As a description of the central tendency of the data population, the median is preferred as being more robust against outlying data.

The data are shown on a Piper plot (Figure 5.6) and the ranges displayed using box-plots (Figure 5.7). The boxplots summarise the data, and a comparison with normalised seawater concentrations is included: where concentrations are normalised to the median Cl concentration of the dataset. Cumulative probability plots (Figure 5.8) are used to study the distribution of the data population, the shape of the curve when plotted on a probability scale being indicative of different distributions which may, in turn, reflect geochemical processes in the aquifer (Box 5.1).

Table 5.3 Summary of major and minor trace element data for the Crag groundwaters

Parameter	units	min.	max.	median	mean	97.7th percentile	N
T	°C	6.7	15.4	11.6	11.6	15.1	25
pH		4.23	8.40	7.29	7.31	8.17	62
Eh	mV	-76	410	107	25	391	19
DO	mg l^{-1}	<0.05	6.64	1.60	0.08	5.95	18
SEC	µS cm^{-1}	291	9200	1234	960	6118	63
δ^2H	**‰**	-49.70	-43.30	-45.75	-45.80	-43.34	10
$\delta^{18}O$	‰	-7.66	-7.05	-7.30	-7.25	-7.05	10
$\delta^{13}C$	‰	-15.77	-11.82	-14.19	-14.31	-12.04	10
Ca	mg l^{-1}	29	350	125	110	275	81
Mg	mg l^{-1}	2.3	290	21	13	77	81
Na	mg l^{-1}	19	1140	75	41	353	81
K	mg l^{-1}	<0.3	220	16	4.8	92	81
Cl	mg l^{-1}	13	2680	141	77	660	81
SO_4	mg l^{-1}	8	1480	155	115	596	80
HCO_3	mg l^{-1}	11	610	265	248	466	80
NO_3 as N	mg l^{-1}	0.001	49	9.7	6.8	35	78
NO_2 as N	mg l^{-1}	0.0015	2.6	0.207	0.008	1.7	21
NH_4 as N	mg l^{-1}	0.0005	0.016	0.003	0.0005	0.014	18
P	µg l^{-1}	10	922	163	99	723	18
DOC	mg l^{-1}	0.82	6.66	2.01	1.69	5.39	17
F	mg l^{-1}	0.01	11.2	0.54	0.22	1.44	43
Br	mg l^{-1}	0.015	0.316	0.20	0.20	0.31	18
I	mg l^{-1}	0.004	20.8	1.85	0.01	15.1	23
Si	mg l^{-1}	2.60	11.4	7.46	7.48	11.0	23

5.3.2 Water types and physico-chemical characteristics

The Crag groundwaters are generally moderately mineralised, with only one sample having SEC less than 700 µS cm^{-1}, and 50% of the samples being greater than1000 µS cm^{-1}. Temperatures were generally between 10 and 12 °C, higher values being unrepresentative, as they are associated with non-ideal sampling points (for these unstable parameters). The pH is well buffered to circum-neutral values (Table 5.3), with the interquartile range being between 6.9 and 7.3. Half of the samples collected did not contain detectable dissolved oxygen, largely those from the Waveney Crag groundwaters, with those from North Norfolk private supplies having moderate concentrations (3 – 7 mg l^{-1}). The Eh has a broadly positive correlation with the DO concentrations, but well-established limitations on the measurement of the redox potential limit the interpretation of Eh data.

The water-type varied across the aquifer, from Ca-HCO_3 dominated to mixed cation-SO_4 and Na-Cl type waters, as shown on the Piper diagram (Figure 5.6). The North Norfolk samples appear to show more of an influence of Na and Cl, which are from published data sources.

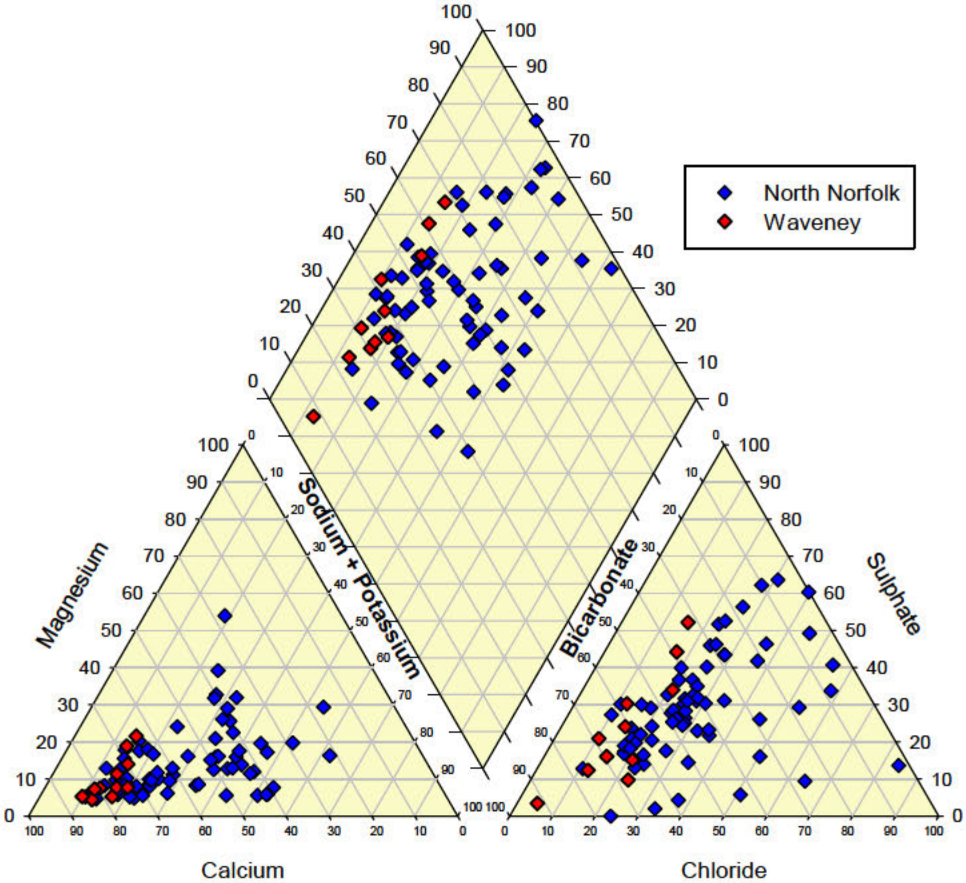


Figure 5.6 Piper diagram for the (a) North Norfolk and (b) Waveney Crag groundwaters

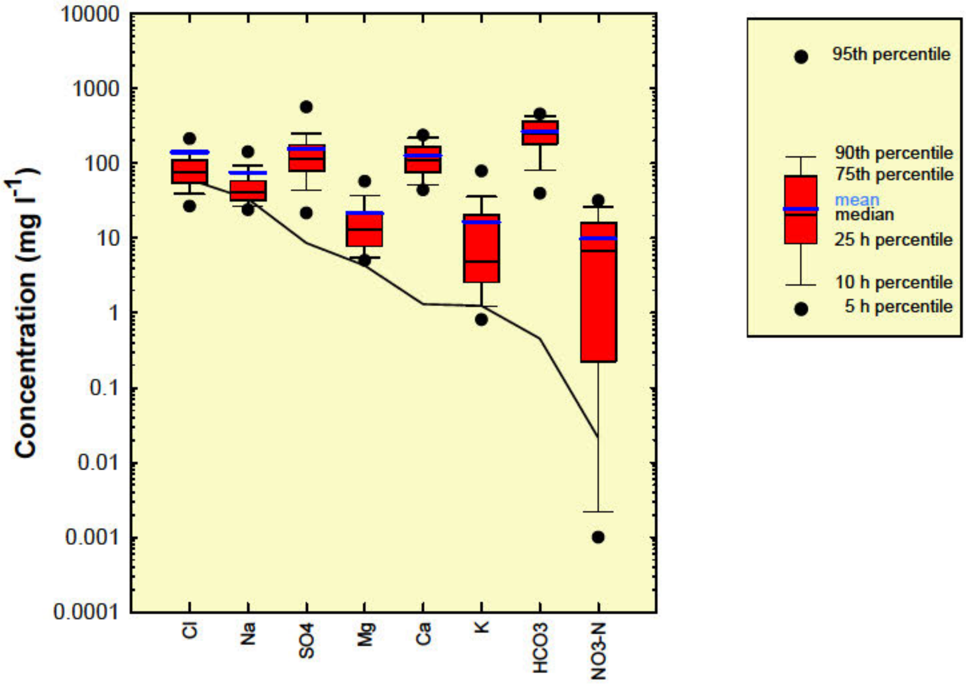


Figure 5.7 Boxplot of major elements in the Crag groundwaters

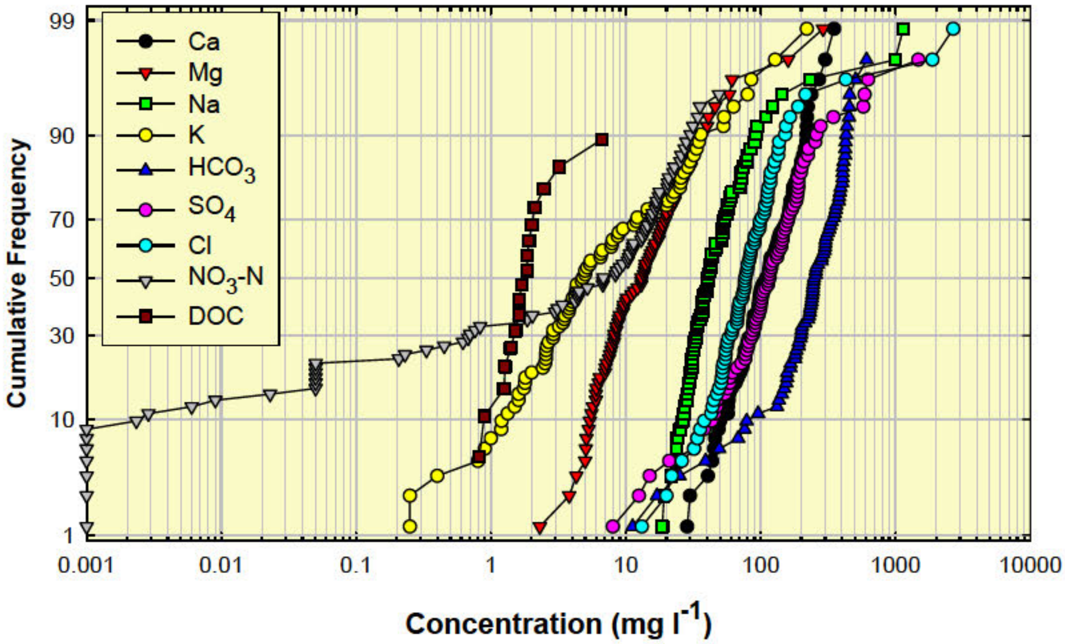


Figure 5.8 **Cumulative probability plot of major elements in the Crag groundwater**

5.3.3 Major elements

The composition of the Crag groundwaters with respect to the major ions is summarised in Table 5.3 and Figures 5.7 and 5.8. Average Cl concentrations were significantly higher than in the underlying Chalk groundwaters (c.f. Figure 5.2), and the median Na showed little enhancement over the normalised seawater signature. The enhanced Cl concentrations are largely as a result of the inclusion of literature data, which included studies of seawater ingress into Broadland groundwater, where surface elevations are at or below sea level (Holman et al., 1999). Most of the other major elements are enhanced relative to the seawater curve. Those elements which are enhanced have been introduced via water-rock interaction or extraneous sources (such as diffuse pollution for NO_3). The probability plots (Figure 5.8) show the population distributions of these ions. The dominant major elements are Ca, HCO_3 and SO_4 which show a skew at low concentrations. The highest sulphate concentrations appear to represent a different population, associated with an increase in SEC, Na and Cl. The Mg and NO_3 data also indicate several potential populations.

5.3.4 Minor and trace elements

These data are summarised in Table 5.4 and Figures 5.9 and 5.10. As is the case for major ions, the box-plots compare the data summary to the normalised seawater curve. The Br concentrations can be seen to lie close to this curve, but most other elements show enrichment relative to a marine source. Relatively high concentrations of the redox sensitive elements, Fe and Mn, were present, reaching maxima of 8.7 mg l^{-1} and 0.5 mg l^{-1} respectively.

Silicon concentrations show a near normal distribution, which suggests rapid equilibrium with a solubility limiting phase (Box 5.1). For all samples where Si was measured the groundwaters are close to equilibrium with chalcedony. The waters are undersaturated with respect to F, with concentrations in general being lower than those in the Chalk.

Table 5.4 Summary of trace element data for the Chalk groundwaters

Parameter	units	min.	max.	median	mean	97.7th percentile	N
Ag	µg l-1	0.025	0.025	0.025	0.025	0.025	18
Al	µg l-1	1.0	23	3.0	1.0	17.5	18
As	µg l-1	0.25	23	3.4	1.2	18.5	18
Au	µg l-1	0.025	0.025	0.025	0.025	0.025	18
B	µg l-1	20	331	67	34	274	18
Ba	µg l-1	3	79	47	47	77	18
Be	µg l-1	0.025	0.080	0.028	0.025	0.058	18
Bi	µg l-1	0.025	0.025	0.025	0.025	0.025	18
Cd	µg l-1	<0.03	0.43	0.17	0.10	0.43	18
Ce	µg l-1	0.01	0.12	0.024	0.008	0.11	18
Co	µg l-1	0.01	3.01	0.41	0.06	2.30	18
Cr	µg l-1	0.25	1.50	0.74	0.80	1.46	18
Cs	µg l-1	0.005	0.020	0.006	0.005	0.016	18
Cu	µg l-1	0.2	37.3	4.39	0.8	30.8	18
Dy	µg l-1	<0.005	0.02	0.0069	<0.005	0.016	18
Er	µg l-1	0.005	0.01	0.0061	0.005	0.01	18
Eu	µg l-1	<0.005	<0.005	<0.005	<0.005	<0.005	18
Fe	mg l-1	5	41700	2226	375	19440	60
Ga	µg l-1	0.025	0.025	0.025	0.025	0.025	18
Gd	µg l-1	0.005	0.010	0.007	0.005	0.010	18
Ge	µg l-1	<0.025	0.130	0.039	<0.025	0.118	18
Hf	µg l-1	0.01	0.01	0.01	0.01	0.01	18
Hg	µg l-1	0.05	0.05	0.05	0.05	0.05	18
Ho	µg l-1	0.005	0.005	0.005	0.005	0.005	18
In	µg l-1	0.005	0.100	0.010	0.005	0.063	18
Ir	µg l-1	0.025	0.025	0.025	0.025	0.025	18
La	µg l-1	<0.01	0.06	0.02	0.01	0.05	18
Li	µg l-1	1.30	49.20	13.83	10.00	43.61	19
Lu	µg l-1	<0.005	<0.005	<0.005	<0.005	<0.005	18
Mn	µg l-1	2	1970	296	135	1381	43
Mo	µg l-1	0.05	1	0.361	0.25	0.961	18
Nb	µg l-1	<0.005	0.01	0.006	<0.005	0.01	18
Nd	µg l-1	0.005	0.06	0.017	0.01	0.056	18
Ni	µg l-1	0.1	8.1	0.744	0.1	5.52	18
Os	µg l-1	0.025	0.025	0.025	0.025	0.025	18
Pb	µg l-1	0.05	5.8	0.49	<0.1	3.8	18
Pd	µg l-1	0.1	0.1	0.1	0.1	0.1	18
Pr	µg l-1	0.005	0.01	0.006	0.005	0.01	18
Pt	µg l-1	0.005	0.005	0.005	0.005	0.005	18
Rb	µg l-1	0.05	9.45	2.02	1.725	7.63	18
Re	µg l-1	<0.005	0.03	0.008	<0.005	0.022	18
Rh	µg l-1	0.005	0.005	0.005	0.005	0.005	18
Ru	µg l-1	0.025	0.025	0.025	0.025	0.025	18
Sb	µg l-1	0.025	0.29	0.048	0.025	0.224	18
Sc	µg l-1	1	4	2.33	2	3.61	18
Se	µg l-1	<0.025	3.9	0.70	<0.025	3.67	18
Sm	µg l-1	0.01	0.01	0.01	0.01	0.01	18
Sn	µg l-1	<0.025	2.29	0.15	<0.025	1.40	18
Sr	µg l-1	280	3835	801	465	3162	23
Ta	µg l-1	0.01	0.01	0.01	0.01	0.01	18
Tb	µg l-1	0.005	0.005	0.005	0.005	0.005	18
Te	µg l-1	0.025	0.06	0.027	0.025	0.046	18
Th	µg l-1	0.025	0.025	0.025	0.025	0.025	18
Ti	µg l-1	5	5	5	5	5	18
Tl	µg l-1	0.005	0.01	0.005	0.005	0.008	18
Tm	µg l-1	0.005	0.005	0.005	0.005	0.005	18
U	µg l-1	0.010	0.370	0.120	0.045	0.354	18

Parameter	units	min.	max.	median	mean	97.7th percentile	N
V	μg l^{-1}	0.1	1.2	0.417	0.3	1.16	18
W	μg l^{-1}	<0.01	0.1	0.034	0.035	0.092	18
Y	μg l^{-1}	0.005	0.12	0.046	0.025	0.112	18
Yb	μg l^{-1}	0.005	<0.01	0.006	0.005	<0.01	18
Zn	μg l^{-1}	3.0	3997	255	18	2519	18
Zr	μg l^{-1}	0.01	0.13	0.031	0.015	0.118	18

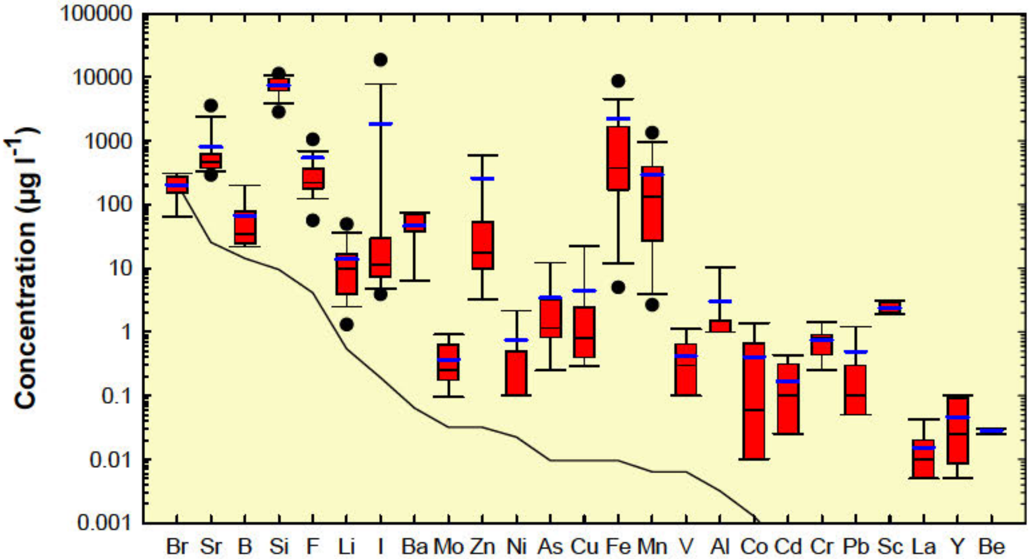


Figure 5.9 Boxplot of minor and trace elements in the Crag groundwaters

5.3.5 Pollution indicators

As discussed previously (Section 5.2.5), a baseline survey should ideally sample from areas of the aquifer which are unaffected by both diffuse and point source pollution. Due to widespread diffuse pollution in the region, it is impossible to achieve this. Whilst NO_3 is widely recognised as being elevated, diffuse pollution may also increase the concentrations of Na, K and Cl. Such increases may be more difficult to unequivocally identify in the context of the natural variability of the aquifer groundwater composition. A determination of the baseline for areas of aquifer which may be so affected requires a good historical record with which to compare the data (Box 5.2). Such data are limited from the Crag aquifer in this area.

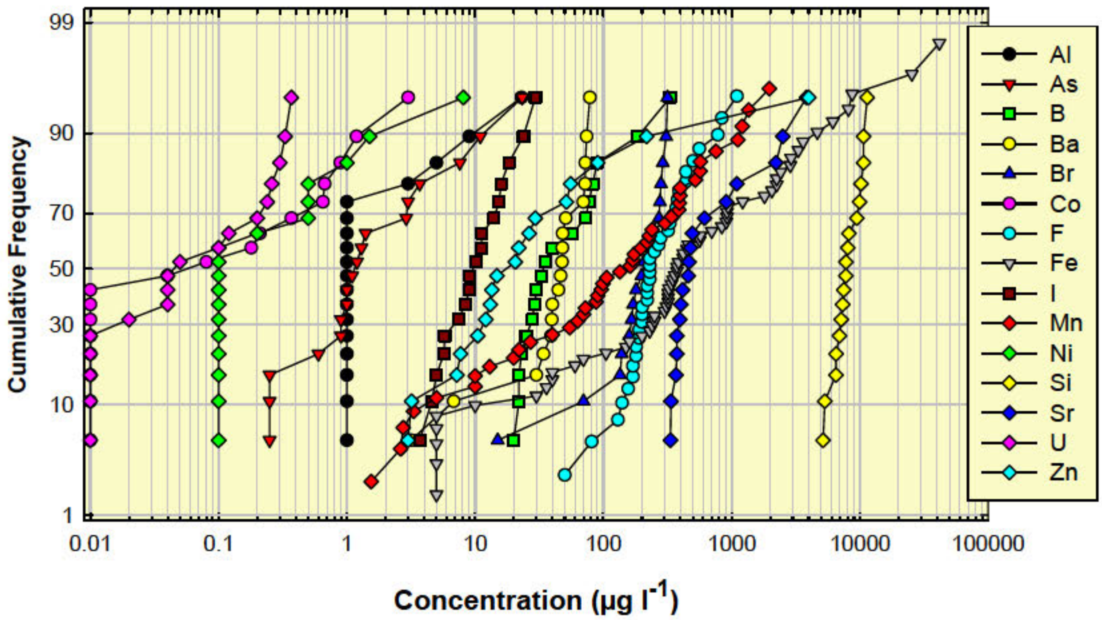


Figure 5.10 **Cumulative probability plot of minor and trace elements in the Crag groundwaters**

6. GEOCHEMICAL CONTROLS AND REGIONAL CHARACTERISTICS

6.1 Introduction

The primary source of recharge to the aquifers is rainfall, a dilute solution with a slightly acidic pH (Table 3.2). This acidic recharge will dissolve carbonate minerals in the soil and unsaturated zone, if they are present, and may result in the chemistry of water entering the saturated aquifer having already acquired its dominant hydrochemical characteristics. The increased partial pressure of carbon dioxide in the soil zone (due to microbial respiration) may also increase the dissolution of carbonate minerals. Until the waters reach equilibrium with calcite, the initial dissolution will be congruent. With increasing residence time incongruent dissolution of calcite, dissolution of silicate minerals, redox reactions, ion exchange and mixing all contribute to modify the groundwater composition. Where soils are very sandy and have little or sparse carbonate mineral phases, these reactions will take place rapidly upon reaching the Chalk unsaturated zone or calcareous Crag sediments.

Baseline conditions vary spatially and temporally due to different recharge history and flow paths, aquifer composition and groundwater residence time. The geochemical variations observed during this study are evaluated below and placed in their regional context. The limited temporal data available are also evaluated.

The aquifers studied do not conform to the ideal of 'flow-line' as used to present and interpret the geochemical evolution of groundwater in other chalk aquifers (e.g. Shand et al., 2003). Thus the primary interpretation of the data is undertaken in the section on spatial relationships, and incorporates the understanding of the evolution of the hydrochemistry.

6.2 The Chalk aquifer

6.2.1 Introduction

The primary source of recharge to the aquifer is rainfall, a dilute solution with a slightly acidic pH (Table 3.2), which will dissolve carbonate minerals in the soil and unsaturated zone. Thus, the chemistry of water entering the saturated aquifer has generally already acquired its dominant hydrochemical characteristics. The increased partial pressure of carbon dioxide in the soil zone may also increase the dissolution of carbonate minerals. Until the waters reach equilibrium with calcite, the initial dissolution will be congruent. With increasing residence time incongruent dissolution of calcite, dissolution of silicate minerals, redox reactions, ion exchange and mixing all contribute to modify the groundwater composition.

Baseline conditions vary spatially and temporally due to different recharge and flow paths, aquifer composition and groundwater residence time. Differences between the Waveney and North Norfolk catchment areas are discussed separately where pertinent. The limited temporal data available are also evaluated. Through much of this discussion, importance is placed on the use of minor and trace ion data in understanding the geochemical processes. Where this is the case, the data used is that collected during the BGS sampling, rather than the full set of major ion data presented in Table 5.1 and Figure 5.1.

6.2.2 Depth variations

A detailed study of the major-ion concentrations in porewaters from a deep borehole in the North Norfolk area was carried out by Bath and Edmunds (1981), which has been summarised in Figure 4.1, and demonstrates the vertical variation in porewaters in the Chalk. The systematic variations observed have been related to the mixing (by diffusion and advection along micro-fractures) of connate

Cretaceous porewater and post-Tertiary meteoric waters, with an increasing influence of connate water with increasing depth, although this origin of the saline water has been disputed by Hiscock (1993). The interpretation of these data also indicated that the pumped samples from two local PWS boreholes are part of the mixing series, which is inferred from a Cl concentration which is greater than that which can be accounted for by local rainfall and the concentration effect of evapo-transpiration. It should be noted, however, that other studies have attributed the additional source of Cl to be of diffuse origin, from agricultural application (Hiscock et al., 1996).

Analysis of data from the Bure catchment of Norfolk, led Hiscock et al. (1996) to conclude that the vertical extent of the effective Chalk aquifer is a maximum of 60 m, and as little as 25 m deep, and mixing with a more saline, Pleistocene recharge end-member takes places below the effective aquifer depth.

The highly detailed information on the installation of the EA piezometers in the Waveney catchment has allowed the plotting of the depth of the piezometers against various measured parameters. These are particularly suitable for this process as only a small part of the length of the piezometer is open to the aquifer, providing more control over the sampling depth than is generally the case with large commercial wells. Figure 6.1 shows selected determinands plotted against depth of these piezometers (12 samples), and suggests that there is little direct relationship between depth and hydrochemical composition, including for redox sensitive elements such as NO_3-N. This is largely controlled by the depth and nature of the overlying drift and/ or Crag deposits determining the degree of confinement of the aquifer, which is described further in Section 6.2.5.

6.2.3 Temporal variations

The most marked temporal variations which may be expected to have affected the determination of baseline in this aquifer are those associated with agricultural and waste-water additions of NO_3 to the aquifer. Monitoring data for the period 1990-2000 are shown in Figure 6.2 for 5 PWS boreholes in the North Norfolk area. These show little variation in most cases for Fe and NO_3, with the exception of Wighton No 2 which appears to have a trend of increasing NO_3, and the large variation in Fe concentrations in the two boreholes with reducing compositions (Mundsley and East Ruston No 2). Further interpretation, including whether step-changes and outliers are representative or not, is not appropriate without more information on pumping regimes.

The relatively short timescale of these data, and the lower concentrations of NO_3 reported using much older data (from the 1940s) in the adjacent area of Cambridgeshire (Carey and Lloyd, 1985), suggests that NO_3 concentrations could have been lower than those reported here (in oxidising environment boreholes), if regionally increasing concentration trends have been repeated in this aquifer area. The long-term trends identified by Carey and Lloyd clearly illustrate how the present concentrations of a parameter in groundwater may not truly represent baseline, and the importance of such data with which to compare modern measurements.

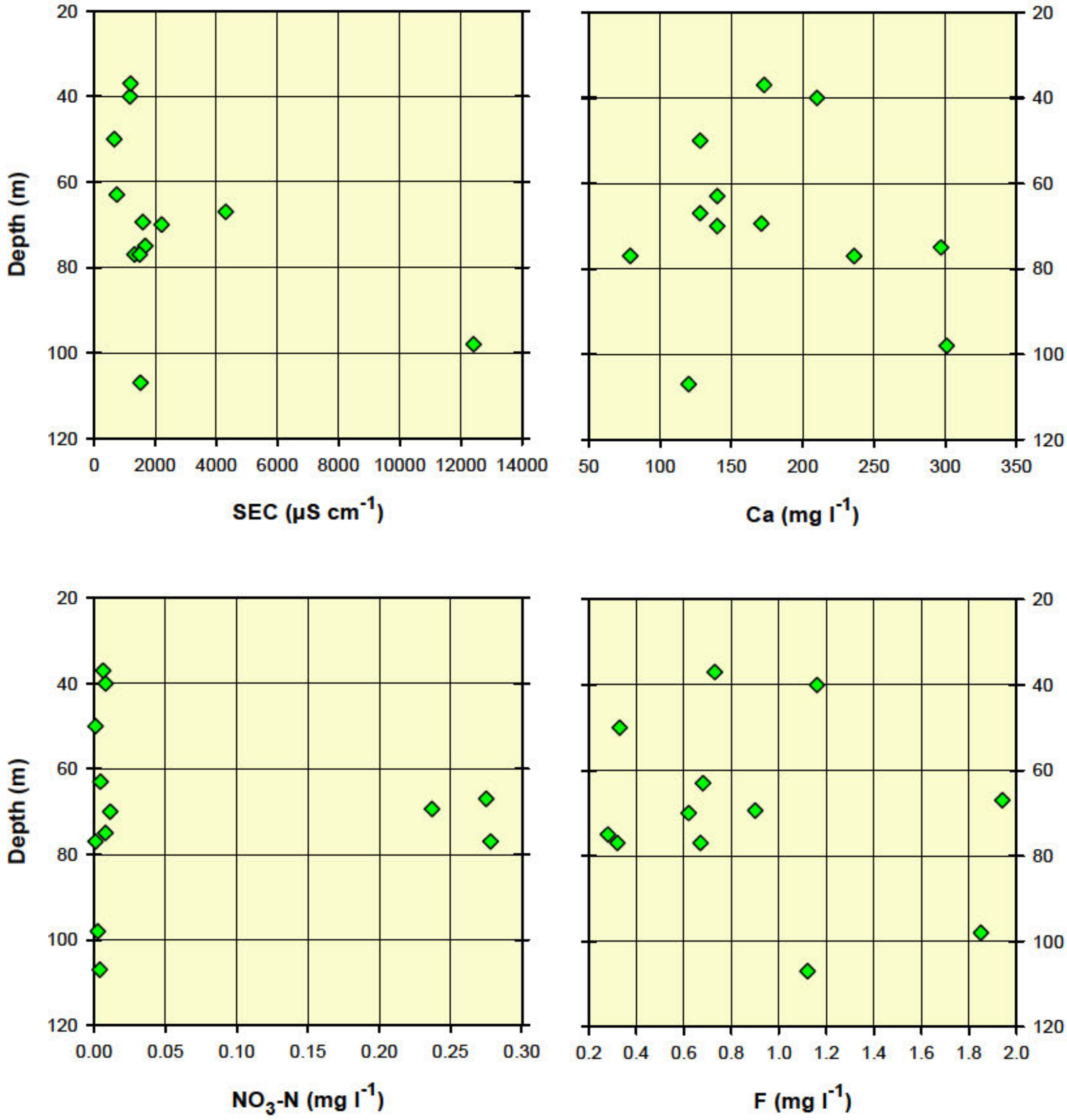


Figure 6.1 Comparison of analytes with depth for the chalk aquifer

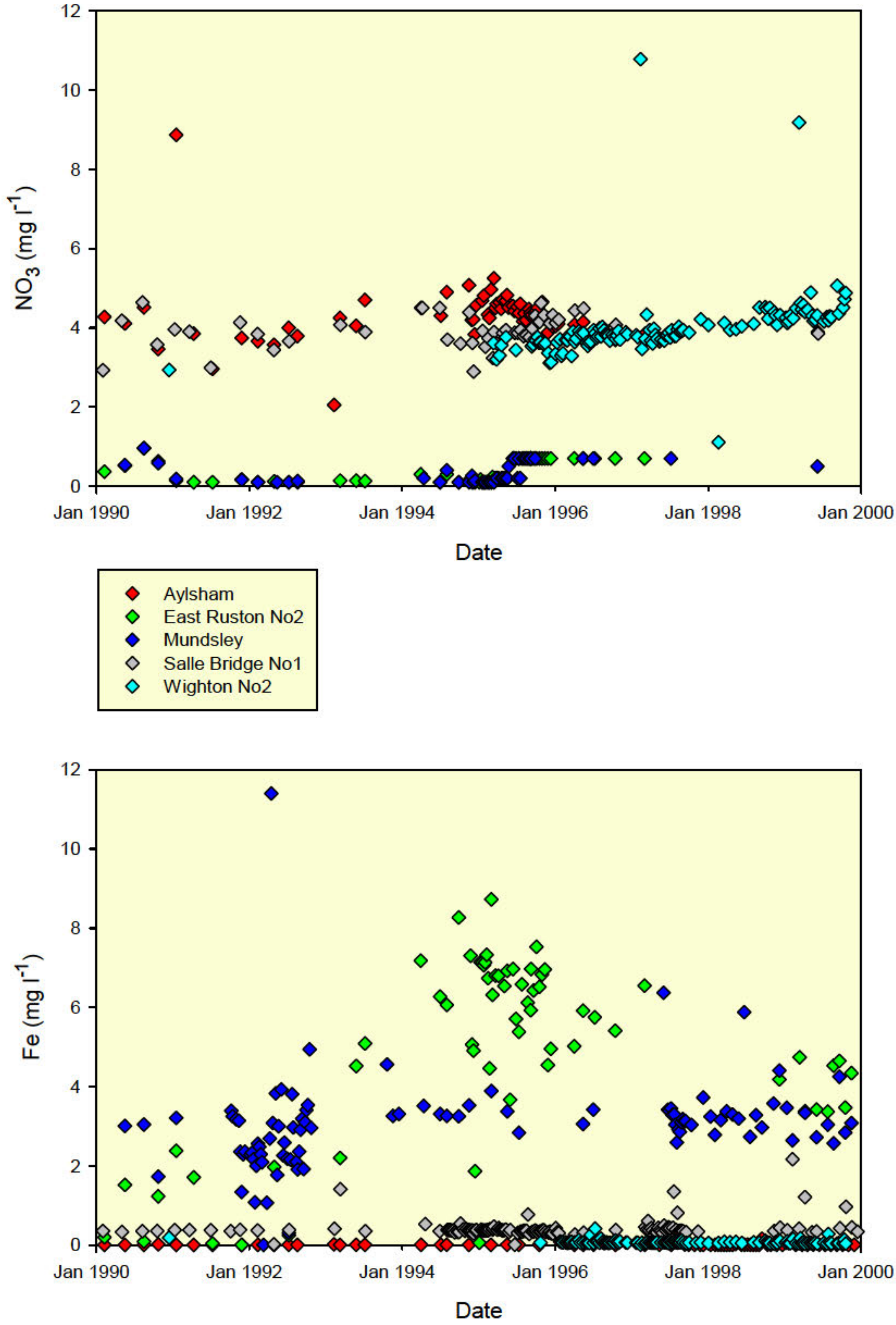


Figure 6.2 **Temporal trends in selected AWS bores for Fe and NO3.**

6.2.4 Regional variations

Changes in the baseline composition of groundwater are expected to occur naturally as it flows from the recharge area through the aquifer. Many reports in the baseline series have studied these processes along flow-lines (e.g. Shand et al., 2003), however, such a concept is difficult to illustrate for the current study areas. The North Norfolk aquifer has been sampled over a wide spatial area, but not along the length of a particular catchment, whilst the Waveney catchment has been sampled extensively, but lateral variations in the nature of the overlying sediments and variations in the depths of the boreholes used preclude presentation of data from a single flow-line. Thus the data is presented here on a spatial basis.

Spatial variations in the data are presented for both catchments in Figure 6.3. Figure 6.3a shows that that the variation in SEC is greatest within the Waveney catchment, but that North Norfolk generally has fresher waters with lower overall dissolved solids. This may reflect a lesser degree of water-rock interaction, resulting in mineral dissolution, and an absence of saline waters in the boreholes sampled, which were biased towards high transmissivity valley zones, discussed further below.

MINERAL DISSOLUTION REACTIONS

The most reactive minerals in the aquifer will determine the composition of the young groundwaters. Chalk groundwater is thus dominated by the dissolution of calcite

$$Ca_x(Mg_{1-x})CO_3 + H_2O + CO_2 \leftrightarrow xCa^{2+} + (1-x)Mg^{2+} + 2HCO_3^-$$

The dissolution kinetics of calcite are rapid (Appelo and Postma, 1994), such that equilibrium should be attained in the unsaturated zone, even where the soil zone is depleted in carbonate minerals. Figure 6.3b shows that Ca concentrations are generally lower in the North Norfolk area than the Waveney catchment. This is also reflected in the other major ions, as shown for Mg and HCO_3 (Figure 6.3c and d). The difference between the two aquifer regions is likely to reflect the increased residence time of the groundwater in many of the Waveney catchment piezometers due to the thickness of the overlying Crag and/ or till sediments. These concentrations are comparable with those of the Great Ouse catchment (Ander et al., 2004) in North Norfolk, but the higher concentrations measured in the Waveney catchment exceed those in the area of aquifer to the west of the regional groundwater divide.

Carbonate reactions are dominant in this aquifer, but despite the high purity of the calcite phase occurring in this aquifer (Section 3) the congruent and incongruent dissolution and re-precipitation of the calcite will lead to an increase in the concentration of ions originally incorporated into the calcite matrix in trace amounts, such as Sr and F. Increases in other trace elements will arise from the dissolution of accessory phases, such the release of Si, Li and NH_4^+ from silicates (Edmunds et al., 1992). Where the concentrations of ions is not limited by solubility controls, such as for Sr and Li, these may serve as indicators for residence time.

Silicon is released into solution primarily from the weathering of the alumino-silicate phases found in the aquifer. Concentrations of Si are in the range 4–15 mg l^{-1}, which indicates a considerable variation in the degree of clay mineral weathering. These concentrations can be seen to be highest (10-15 mg l^{-1}) in the upper Waveney catchment (Figure 6.4a), reflecting ingress of recharge from the Boulder Clay cover, and concentrations are generally lower on the North Norfolk coast (4-6 mg l^{-1}), where glacial sediments are more sandy, and flow through the aquifer appears to be more shallow and rapid. This regional distribution of concentrations reflects that observed in the Great Ouse region, where similar concentrations were seen in the upper catchments (partially confined by till), and low concentrations of Si in the lower catchment where a greater flux of groundwater occurs.

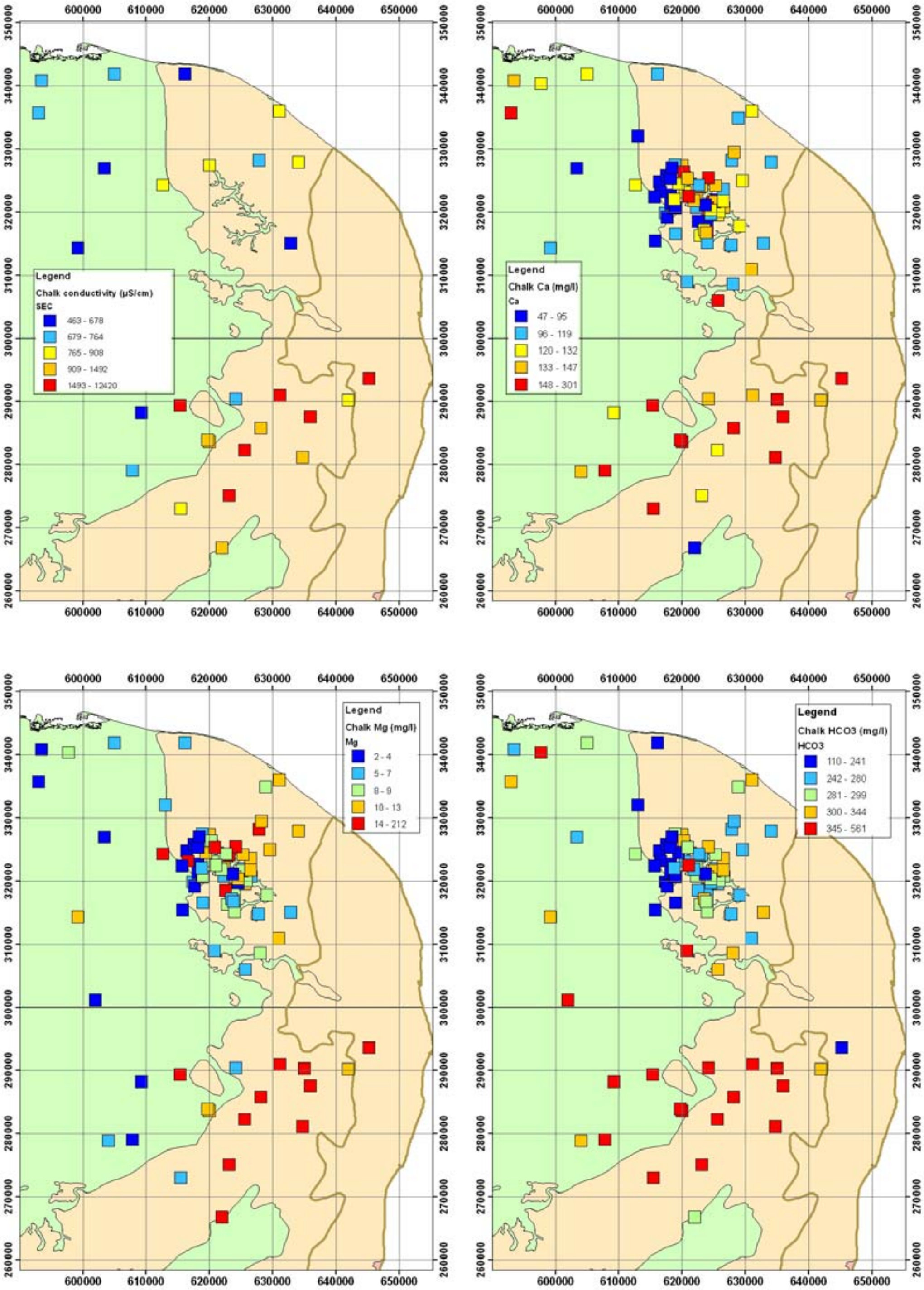


Figure 6.3 **Spatial distribution of analyte concentrations in the Chalk aquifer (a) SEC (b) Ca (c) Mg (d) HCO_3**

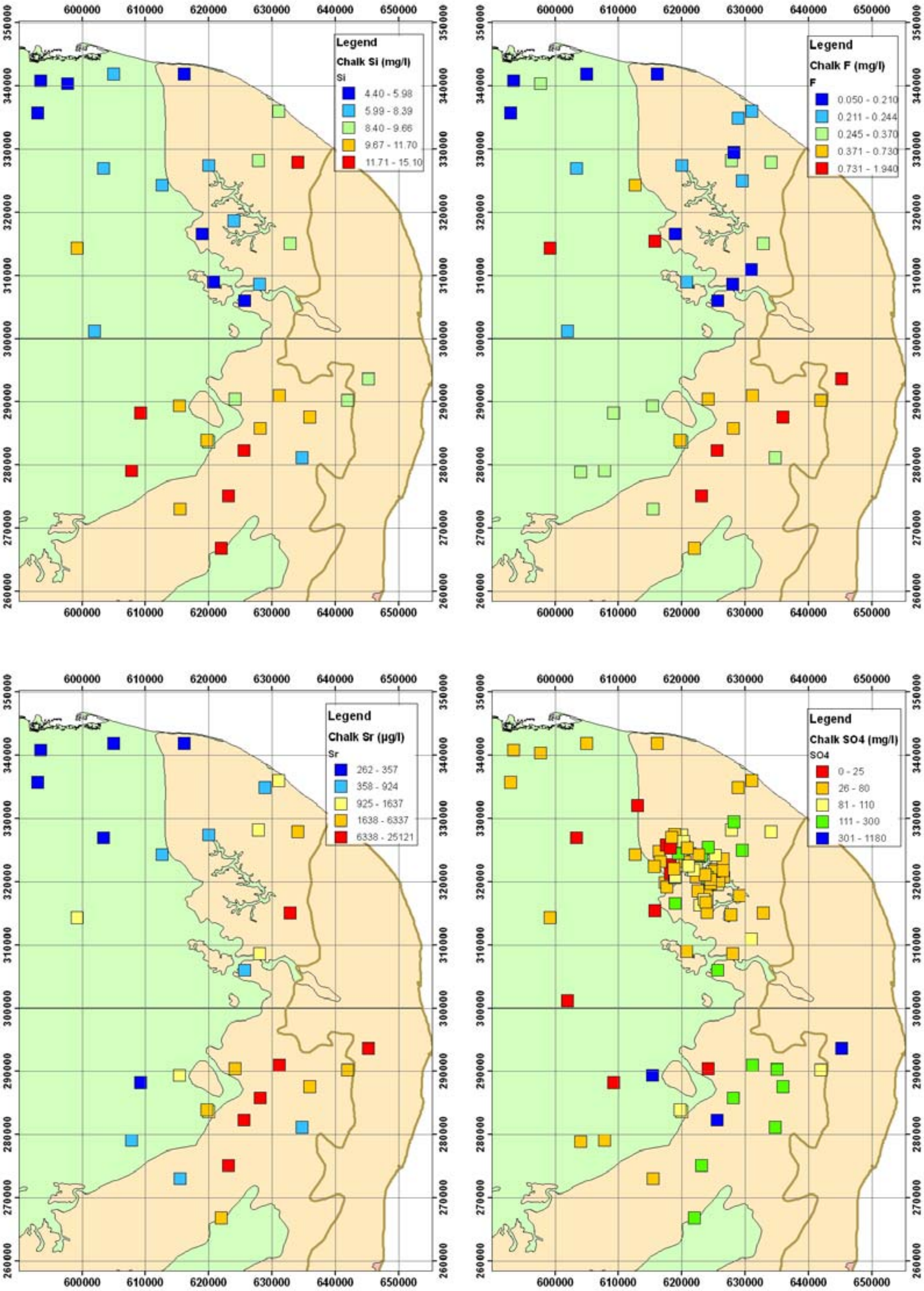


Figure 6.4 Spatial distribution of ion concentrations in the Chalk aquifer (a) Si (b) F (c) Sr (d) SO_4

Fluoride concentrations are regionally lowest (Figure 6.4b) in the sampling areas of North Norfolk, and the upper Waveney catchment, generally below 0.5 mg l^{-1}, and increase substantially in the central and lower Waveney catchment to a maximum of 1.9 mg l^{-1} at Needham, compatible with regional variations of other indicators of increased groundwater residence time, and likely recharge components from (semi)-confining overlying sediments. Strontium concentrations show a systematic variation (Figure 6.4c) in keeping with observations from other major and minor ions in solution, with low concentrations for the aquifer (*ca*.300 μg l^{-1}) in North Norfolk, rising to >1000 μg l^{-1} in samples where the Chalk is confined by the Palaeogene. The maximum concentration recorded (25 mg l^{-1}) occurs in the Bungay piezometer of the Waveney catchment, which is an extremely high concentration of Sr, in relation to both this aquifer, and other Chalk aquifers in the Baseline report series (e.g. Ander et al., 2004, Shand et al., 2003).

Sulphate concentrations may increase as a result of weathering of overlying tills, or of pyrite within the aquifer. Concentrations are moderate (40-70 mg l^{-1}) in the coastal area of North Norfolk, by with much higher concentrations (90-522 mg l^{-1}) in the area around the river Ant and the majority of the samples beneath Palaeogene cover in the Waveney catchment (Figure 6.4d). The concentrations along the coast are elevated in comparison to those found in unconfined Chalk catchments in the Colne and Lee valleys of Hertfordshire (Shand et al., 2003), which reflects the greater concentration of SO_4 arising from locally derived marine influenced recharge. The highest concentrations observed in the Waveney catchment are comparable with concentrations observed in the confined aquifer of Hertfordshire (Shand et al., 2003) and in the Great Ouse region (Ander et al., 2004). The highest concentration (1180 mg l^{-1}) at Aldeby is likely to be related to mixing with saline water (see below).

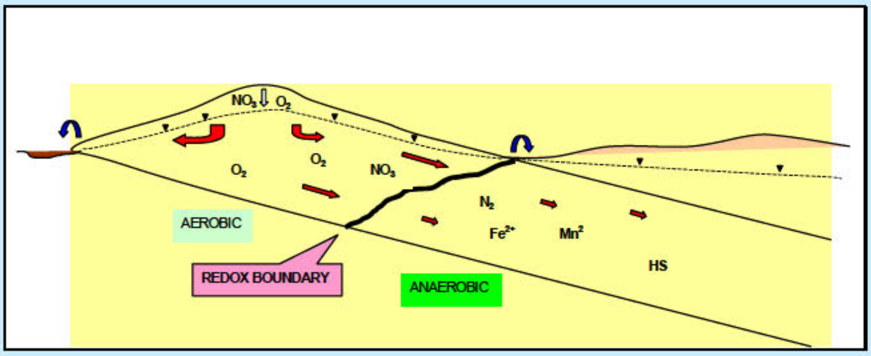
REDOX REACTIONS

The primary indicators of the redox status of groundwaters are the redox potential (Eh) and dissolved oxygen (DO) (Figure 6.6a). These parameters are very unstable and can only be measured using a flow-through cell at the time of sampling. The analysis of redox-sensitive elements also provides information on the redox status of the aquifer (Box 6.1), and can be a useful check on Eh measurements, which are well recognised to have limitations (Appelo and Postma, 1994), as noted in Section 5, it is unlikely that the Eh measurement for the sample at Shelton (467 mV) is accurate, as it compares poorly with all other redox sensitive indicators.

Nitrate is stable in the presence of oxygen, but once the oxygen contained in recharge is consumed, nitrate becomes unstable, the resulting denitrification resulting in negligible concentrations (Box 6.1). It should be noted that the dominant product of denitrification is $N_{2(g)}$ rather than ammonia ($NH_4^+{}_{(aq)}$) (Appelo and Postma, 1994). Figure 6.5b shows that NO_3-N concentrations vary across the aquifer, with lowest concentrations in boreholes beneath the Palaeogene cover and highest in the North Norfolk coastal, unconfined, samples, where concentrations approach the present EC MAC of 11.3 mg l^{-1} in several boreholes.

Variation in redox conditions in the aquifer can clearly be seen to take place with Figure 6.5b, with the hydrochemical spatial variation found in the NO_3-N data being broadly the expected inverse relationship with the Fe data (Figure 6.5c), confirming the interpretation of the spatial variation in redox conditions. Comparison of results of various redox sensitive species can be used to illustrate positive and negative relationships between parameters. Iron measurements are available on all samples collected during the BGS sampling, unlike Eh and DO which can only be measured using the flow-through cell, and are thus used to plot against other potentially redox sensitive elements in Figure 6.6. It can be seen that the (corrected) values of Eh have the expected positive and inverse relationships with DO and Fe respectively (Figure 6.6). Both Fe and Mn would be expected to be ubiquitous in the aquifer, with the Mn being released from the calcite phase during re-precipitation, although in oxidising conditions this can be seen to re-precipitate as Mn-oxide coatings on fracture surfaces on the chalk (Shand and Bloomfield, 1995). Whilst both would be expected to be more soluble in reducing conditions, it would seem that there is a lack of correlation between boreholes where Mn is elevated and those where Fe is elevated (Figure 6.6). Arsenic is known to be redox sensitive and Figure 6.6 shows the relationship with Fe, as a proxy for redox status. Concentrations were found to be highest (18 µg l^{-1}) at Aldeby (Figure 6.5d) and are clearly associated with elevated Fe, and thus low redox potential. Ammonium (NH_4^+) concentrations are elevated in several of the samples (Figure 6.6), associated with reducing conditions, and are probably derived from clays (see ion exchange, below).

BOX 6.1 REDOX BOUNDARY



Water at recharge is generally saturated with dissolved oxygen at the partial pressure of the atmosphere (10-12 mg l^{-1} depending upon barometric conditions). Passing through the soil and the unsaturated zone some of this O_2 will react as a result of microbiological processes and oxidation-reduction reactions. However, almost all water reaching the water table still contains several mg l^{-1} O_2. Geochemical reactions (oxidation of traces of pyrite, organic matter and Fe^{2+} present in minerals) progressively remove the O_2 along flow lines. Once all the oxygen has reacted an abrupt change of water chemistry takes place (redox boundary). Other changes may occur at and down-gradient of the redox boundary, especially denitrification and the probability that total dissolved iron (Fe^{2+}) concentrations will increase. Sulphate reduction and the production of sulphide (H_2S as HS^- in solution) may also occur at greater depths.

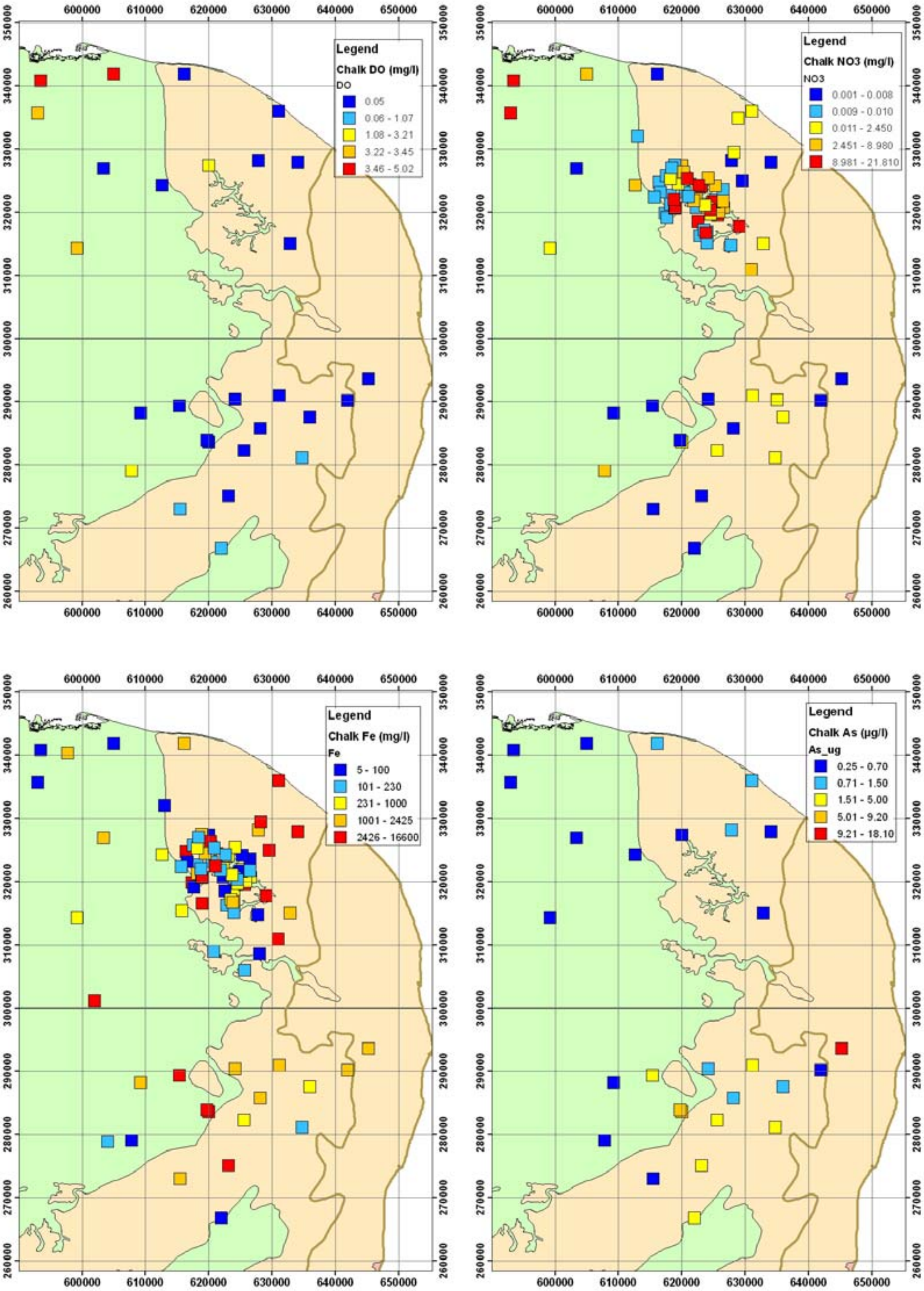


Figure 6.5 Spatial distribution of selected redox indicators over the Chalk outcrop (a) DO (b) NO_3 (c) Fe (d) As

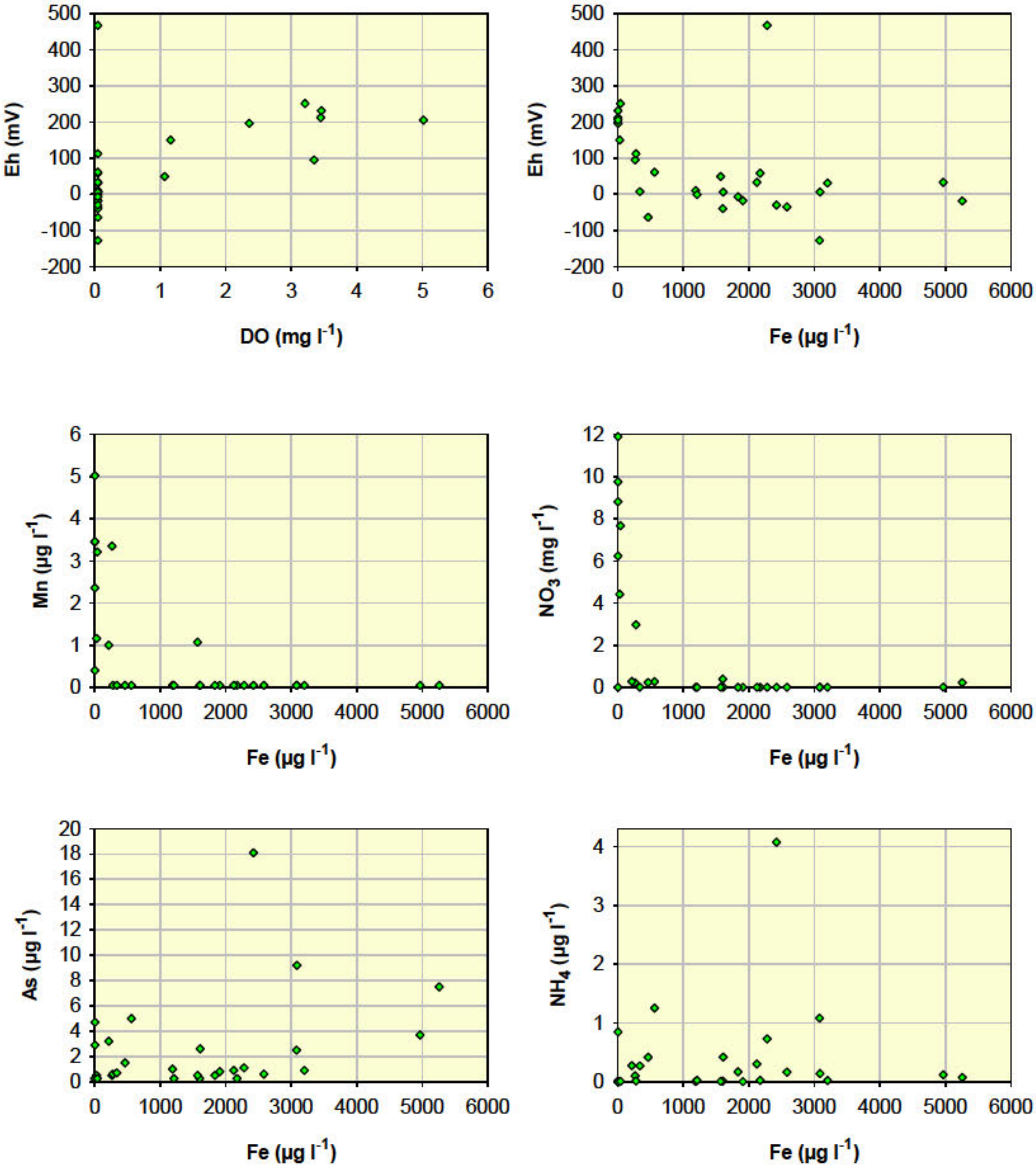


Figure 6.6 Redox indicator species

ION EXCHANGE

Ion exchange is an important chemical process in many aquifer systems, and manifests itself when there is a change in the composition of water flushing the aquifer from that which it had been in equilibrium with (Appelo and Postma, 1994). Studies of Chalk aquifers along flow-lines from recharge areas to confinement have shown that 'freshening', which typically causes the exchange of dissolved Ca for adsorbed Na, is generally only important in older confined parts of Chalk aquifers which have not been sufficiently flushed of formation waters (e.g. Shand et al., 2003). Such a change will be indicated on the Piper Plot by a change in water type from the Ca-HCO_3 of recharge areas, to that of Na-HCO_3 from ion exchange (Appelo and Postma, 1994):

$$\tfrac{1}{2}Ca^{2+} + Na\text{–}X \rightarrow \tfrac{1}{2}Ca^{2+}\text{-}X_2 + Na^{+}$$

Where Na-rich seawater enters an aquifer ('salinisation'), it is possible that the reverse of this process will take place, and Na will be adsorbed onto clay minerals, releasing Ca to solution and producing a Ca-Cl water type from the Na-Cl seawater (Appelo and Postma, 1994):

$$Na^{+} + \tfrac{1}{2}\,Ca\text{–}X_2 \rightarrow Na\text{-}X + \tfrac{1}{2}Ca^{2+}$$

(where X represents the exchange site on the mineral phase)

In the Waveney catchment there is a considerable variation in water types (see Figure 5.1), however, there is little indication on the Piper Plot of evolution due to ion exchange, with the possible exception of the samples from Stradbroke, Needham and Bedfield. The use of Cl as a conservative tracer suggests that any perturbation to the Na/Cl ratio from that expected from recharge water mixing with sea water could result from ion exchange. If Na is being released from the aquifer minerals then the Na/Cl ratio would be expected to increase. Figure 6.7 shows the comparison of Na/Cl molar ratio with the measured concentration of Cl. This shows that of the two most saline samples, Needham has a slight excess of Na which may be from ion exchange, whilst Aldeby appears to be represented by simple mixing towards a seawater end-member (see below).

At the lower concentration range samples from both the North Norfolk and Waveney catchments have ratios which vary above and below the expected equilibrium, particularly that of Winfarthing. Some of these may be affected by surficial inputs, such as road salts and fertilisers, as they are not considered to have undergone significant evolution based on other hydrochemical parameters.

MIXING WITH OLDER FORMATION WATERS

An increase in element concentration may be related to groundwater residence time ('groundwater age'), in Chalk aquifers and results from mineral dissolution, ion exchange or mixing with formation waters. Geochemical indicators of mixing with older saline waters are most useful when they have greatly differing concentrations in recharge waters, in comparison with saline waters, and are largely unmodified by reactions within the aquifer. The Na-Cl nature of the most saline waters found in the study area (Aldeby), confined by the Palaeogene clays, demonstrate mixing of a recharge water with saline waters using these major ions, and by examination of minor and trace element data such as Br and B (where neither are affected by contaminant sources). Thus the Figure 6.7 shows the Na/Cl ratio and the Br/Cl ratio, which can be used to study the dilution of a saline solution irrespective of total Cl concentration. These data would appear to indicate that the samples at Aldeby and some of the other deep samples in the Waveney catchment (with high Cl) represent part of a dilution series with a saline solution (in contrast with those possibly modified by ion-exchange). Similar results are obtained for B, which reaches a maximum concentration of 1 mg l^{-1} in the Aldeby piezometer. This would is also supported by the stable isotope data (see below). The age of such saline waters has been postulated as both connate water (Bath and Edmunds, 1981), and remnant Neogene-Quaternary Crag seawater (Hiscock et al., 1996) in the Chalk of North Norfolk.

6.2.5 Age of the groundwater

Groundwater age measurement is difficult without specific age dating measurements (e.g. ^{14}C or CFCs), and assessment using geochemical variations between different bodies of water may only be able to lead to the assessment of relative ages. Stable isotopes can be used to discriminate older Pleistocene (>10,000 years old) and Holocene (<10,000 years old) waters with lighter (more negative) δ^2H and $\delta^{18}O$ values being expected from Pleistocene recharge. It has been suggested, from radiocarbon data and hydrogeological considerations, that values of $\delta^{18}O$ more negative than –8.0 ‰ are indicative of such recharge (Hiscock et al., 1996). Stable isotopes (δ^2H and $\delta^{18}O$) have been used by Hiscock (1993) and Feast et al. (1997) in the area of North Norfolk. Hiscocks work estimated groundwater ages of ca.10,000 years underneath thick Boulder Clay on interfluves, to 1,000-2,000 years where the Chalk is overlain by more permeable sediments, whilst Feast et al. found $\delta^{18}O$ values as light as –8.25 ‰. No measurements of stable isotopes were made on the samples from North Norfolk in this study, as much data has already been published by Hiscock and colleagues, but stable isotope analysis was undertaken on selected samples from the Waveney catchment, where there was no existing published information.

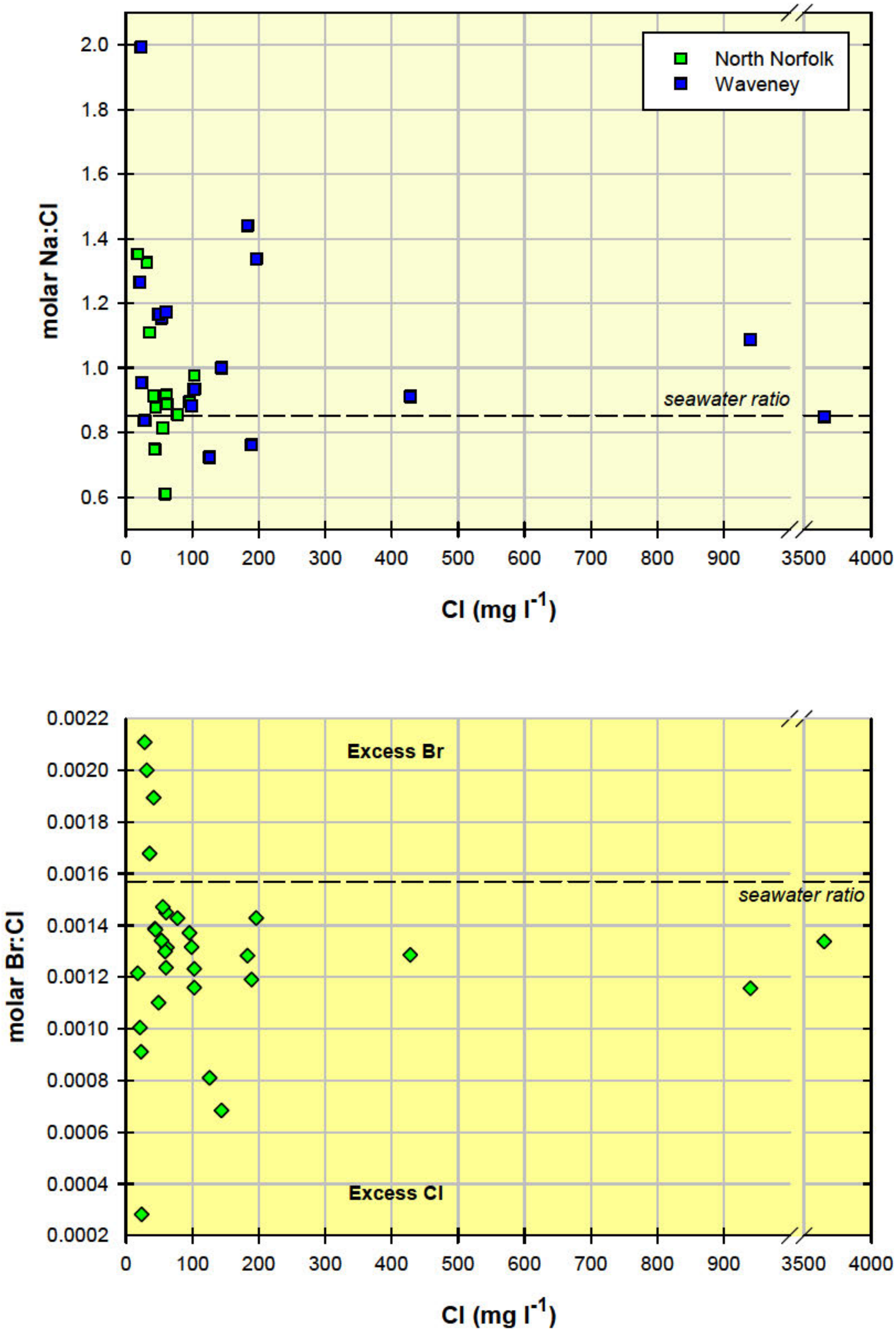


Figure 6.7 Chloride ratios compared to seawater dilution

Figure 6.3 shows that the data for the Waveney chalk plot with a generally less negative $\delta^{18}O$ value than the data from the adjacent Great Ouse Chalk (Ander et al., 2004). These data all fall within the values expected for those dominated by modern day groundwaters of -7.5 ±0.5 (Edmunds et al., 1992), although the sample from Needham in particular appears to show possible mixing with older water as it has a value of -7.98 ‰ and -51.5 ‰ for $\delta^{18}O$ and $\delta^{2}H$ respectively (Figure 6.8). This sample is of Na-Cl type, with high SEC (4310 µS cm^{-1}) and it is possible that it shows a trend towards mixing with an older saline groundwater (Figure 5.1).

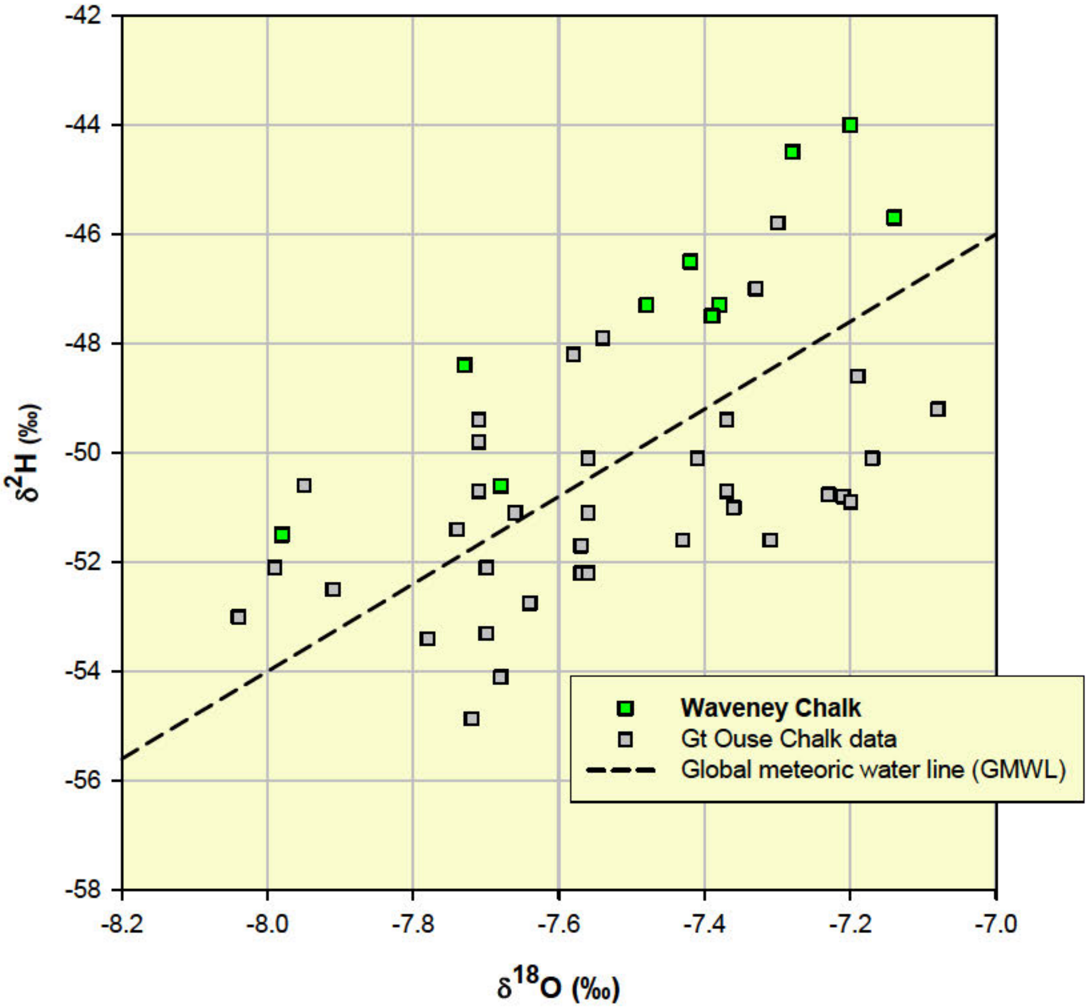


Figure 6.8 Stable isotope composition of the Waveney chalk groundwaters

The evolution of the groundwater through increased water-rock interaction can also be studied using the stable isotope $\delta^{13}C$ values, which are shown in Figure 6.9 related to the Sr/Ca ratio. The $\delta^{13}C$ value for the Chalk matrix is approximately +2.4 ‰, whilst that associated with soil and unsaturated zone microbial activity is generally of the order of –25 ‰ (Edmunds et al., 1992), thus recharge waters will be expected to have a $\delta^{13}C$ of the order of –14 ‰ (Shand et al., 2003), thus the $\delta^{13}C$ of groundwater may be expected to evolve towards the Chalk matrix value with increasing water-rock interaction time. The Sr/Ca ratio is a useful measure of residence time because Sr is released during the equilibrium dissolution-recrystallisation of calcite, but is not incorporated into the newly formed calcite. Thus, the ratio should increase with increase residence time, whilst the Ca concentrations are limited by calcite equilibria (Edmunds et al., 1992) or ion-exchange (Edmunds et al., 1992). This often results in an increase in the Sr/Ca value with increasing recrystallisation, and hence loosely residence time. These parameters very clearly show a positive relationship, most likely indicating variations in residence time of the groundwaters.

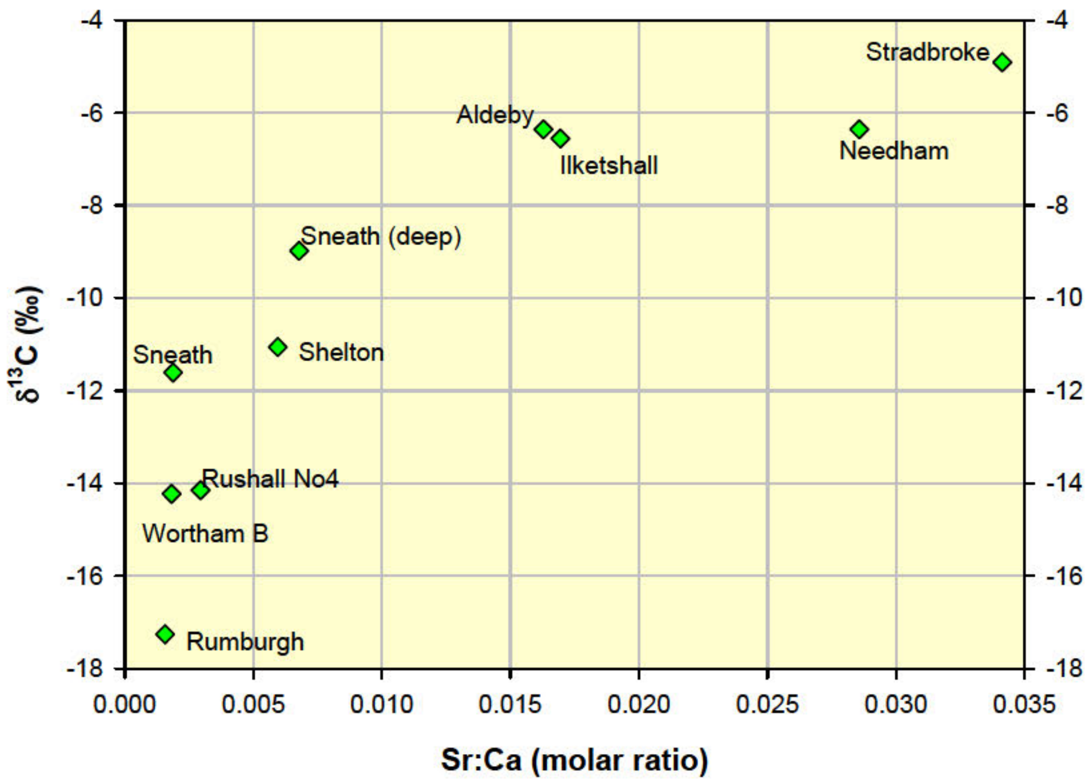


Figure 6.9 Comparison of Sr/Ca with $\delta^{13}C$ in the Waveney Chalk aquifer

6.3 The Crag aquifer

6.3.1 Introduction

The primary source of recharge to the aquifer is rainfall, a dilute solution with a slightly acidic pH (Table 3.2), which will dissolve carbonate minerals in the soil and unsaturated zone. These reactions are rapid in comparison to those of the alumino-silicates, and the chemistry of water entering the saturated aquifer has generally already reached equilibrium with calcite. The continued reaction with both carbonate and silicate phases will result in the continued evolution of the hydrochemical characteristics of the groundwater, and these changes can be used to understand the flow paths and residence time of the groundwater.

Flow in the Crag aquifer is conceptualised as being inter-granular, with lateral and vertical permeability contrasts likely to be more influential over local flow directions than any minor fractures. Factors which control the variations observed in groundwater chemistry are studied in this section, with importance placed on the use of minor and trace ion data in understanding the geochemical processes. Where this is the case, the data used is that collected during the BGS sampling, rather than the full set of major ion data presented in Table 5.2 and Figures 5.7 and 5.8.

6.3.2 Depth variations

The interpretation of aqueous chemistry in relation to vertical and lateral differences within aquifers is complicated by the mixture of water when boreholes are pumped (see Section 4.3). Techniques such as packer tests, specific depth sampling and comparison of adjacent, but different depth boreholes can all help to provide additional information on this process. The sampling and analysis of porewater may also provide detail of vertical variations within the matrix. In contrast to the more intensively studied Chalk aquifer, very little information is available for the Crag.

The Ludham PWS boreholes are sited to differing depths within the Ludham Trough. The interval between the uncased termini includes a laterally contiguous clay horizon which has previously been invoked as acting as an effective aquiclude (Holman et al., 1999), and protecting the abstracted groundwaters from (near)-surface sources of NO_3 (Jones et al., 2000), resulting in minimal NO_3-N concentrations in the PWS. In this study Ludham no 1 was found to have 0.21 mg l^{-1} NO_3-N, whilst that of Ludham no 2 was below the detection limit (0.01 mg l^{-1}). Shallow private supplies in the area of the Broads were associated with the highest NO_3-N concentrations found in this study (13-18 mg l^{-1}).

In the Waveney catchment, far greater control exists on understanding of the depth interval from which pumping took place, although the piezometers were sited widely across the aquifer outcrop. Examples of the comparison of the piezometer depth with analytical determinands are shown in Figure 6.10. It can be seen that there is little systematic relationship between solute concentration and depth, with the exception of NO_3, which is higher in the more shallow piezometers. This may be a result of interactions between the overlying tills and underlying Chalk, as well as lateral variations within the Crag. These data appear to indicate that the depth and age relationships are not linearly related within the aquifer (see Section 6.3.3).

6.3.3 *Temporal variations*

Little time-series data exists with which to study temporal variations in the composition of the groundwater chemistry. The records compiled by Whittaker (1906) suggest that locally high concentrations of NO_3 were found in the Crag aquifer in the 1870s (e.g. *ca.*80 mg l^{-1} in a Crag borehole in Lowestoft), but no very long term records for wells sampled during this study could be found. The importance of having long-term data from areas which represent baseline conditions, with which to set data into context, are emphasised by the limited and relatively short-term nature of the data available during this study.

The data available from the Ludham boreholes in the North Norfolk area show little variation in Fe and Mn concentrations over a 5 year period (Figure 6.11). The data is indicative however, of the water quality problems, for potable supply, routinely associated with the natural composition of the Crag groundwaters (Section 3) with Fe and Mn systematically exceeding the MAC concentrations (0.2 mg l^{-1} and 0.05 mg l^{-1} respectively).

6.3.4 *Spatial variations*

The baseline chemistry of an aquifer naturally varies as water moves from the recharge area to the discharge zone. Different areas of the aquifer may be characterised by longer residence times, and thus increased time available for reaction with the aquifer minerals. Identification of these zones is complicated by the aquifer heterogeneity, the influence of overlying tills and the low lying topography of the area (especially in North Norfolk). Thus the concept of sampling along a ‘flowline’ cannot be regarded as appropriate for this area, and the spatial variations in water chemistry have been examined. The major control on the hydrochemistry is the interaction between the waters and the aquifer minerals.

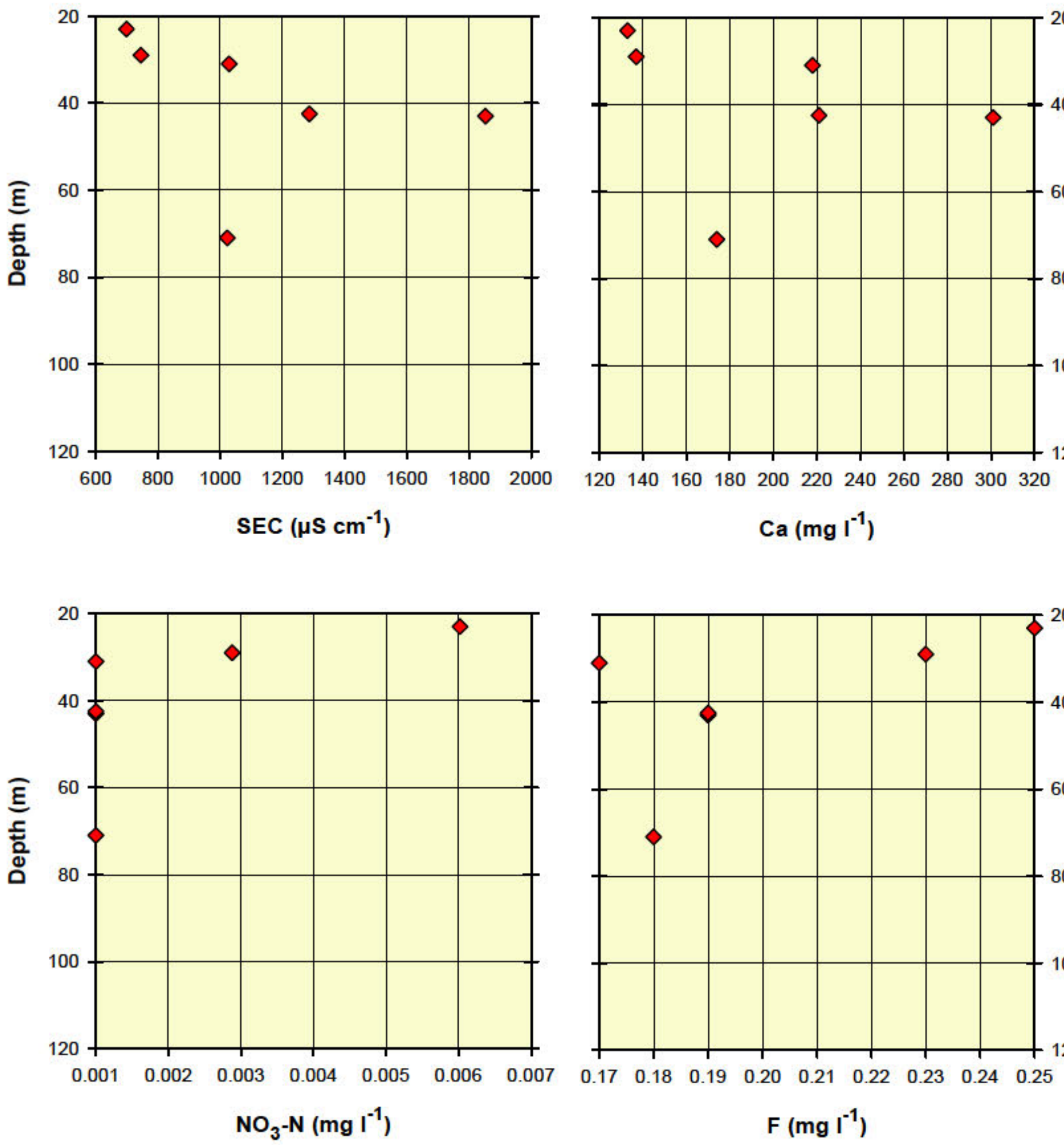


Figure 6.10 Comparison of selected determinands with borehole depth for the Waveney Crag aquifer.

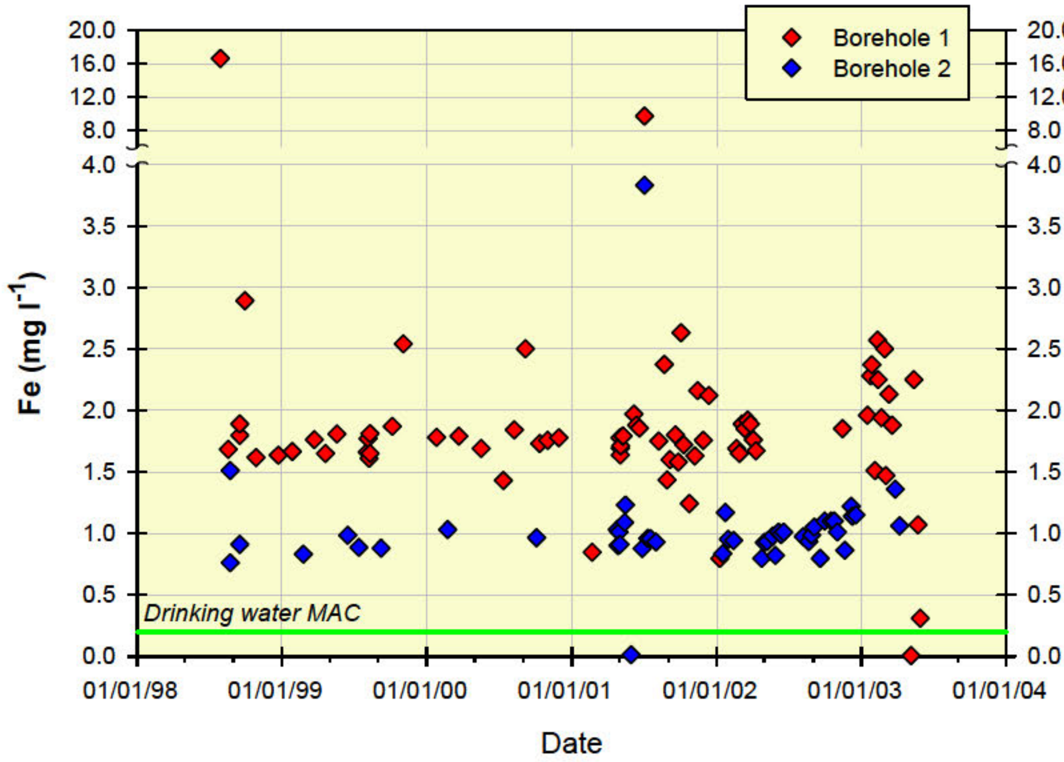
MINERAL DISSOLUTION REACTIONS

The most chemically reactive minerals within the Crag are key for determining the chemical evolution of groundwater in the aquifer. Thus, the generally abundant, and reactive, carbonate and alumino-silicate minerals are likely to be the principal controlling reactions.

The re-crystallisation of the $CaCO_3$ polymorph aragonite (orthorhombic $CaCO_3$) to calcite, or the incongruent dissolution of calcite, results in the release to solution of associated trace elements which do not tend to be accepted into the freshwater calcite structure, particularly Mg and Sr^{2+} (Deer et al., 1966). Thus with increasing residence time, Sr concentrations may be expected to increase in the aquifer.

The dissolution of calcite in the presence of dissolved $CO_{2(g)}$ results in the release of bicarbonate ions and Ca to solution:

$$CaCO_3 + H_2O + CO_2 \leftrightarrow Ca^{2+} + 2HCO_3^-$$



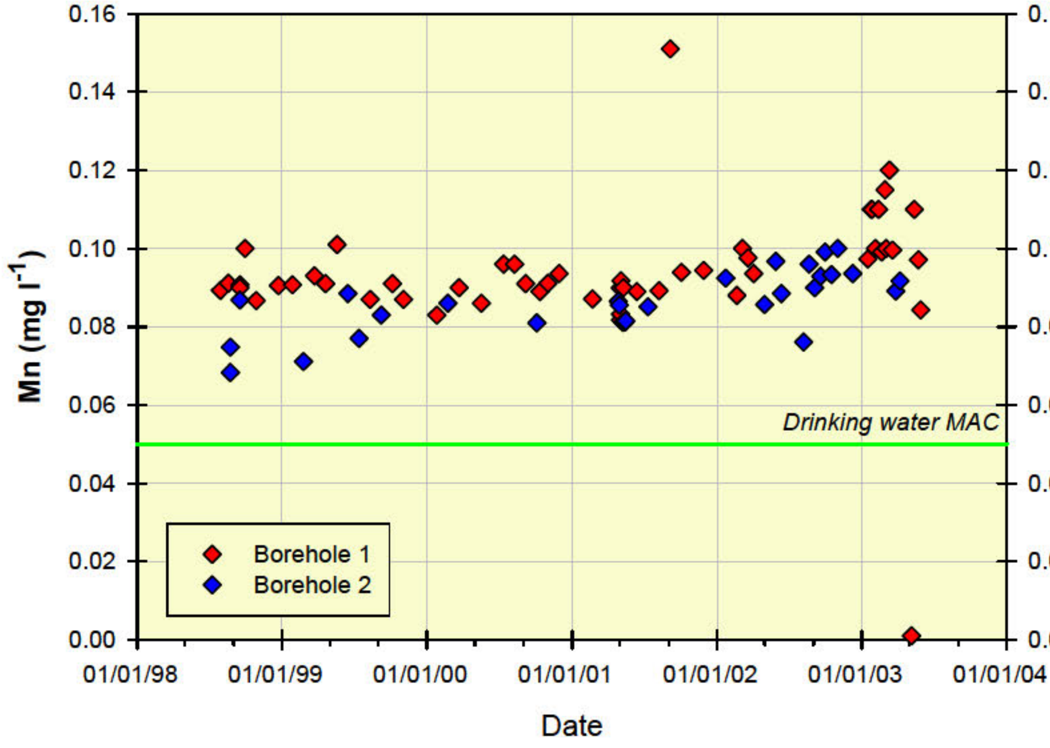


Figure 6.11 Time series data for the Ludham PWS boreholes in the Crag.

The dissolution of calcite is also an important pH buffering reaction (related to multiple dissociation constants), and typically buffers pH to neutral to slightly alkaline pH. pH values in the Crag samples collected during this study range between 6.8 – 7.8, with the exception of one samples (Landseer) with a pH of 5.9, suggesting that the aquifer is carbonate depleted in the capture zone of that private supply. The distribution of Ca across the aquifer outcrop (Figure 6.12a) can be seen to have little systematic variation, in contrast to the HCO_3 concentrations which are generally higher in the Waveney than in North Norfolk (Figure 6.12b), and appear to be solubility controlled (Figure 5.8) at similar concentration to the samples from the Chalk (cf. Figure 5.3). As would be expected, the low pH sample has the lowest HCO_3 concentration (68 mg l^{-1}). It is not clear whether sources of Mg into solution in the Crag aquifer are dominated by release from a carbonate phase, or whether silicate weathering is influential. Concentrations are largely low (≤16 mg l^{-1}), of the order of those observed in the Chalk in modern, less evolved waters. Where Mg concentrations in the Waveney catchment are higher (Figure 6.12c), these are generally associated with deeper waters, which may be inferred to have had a longer residence time.

The reaction of carbonate phases in the aquifer matrix may be expected to release into solution ions originally incorporated into the matrix during the dissolution of aragonite or calcite, and recrystallisation of calcite. Such ions typically include Sr and F in a very pure calcite aquifer such as the Chalk, although other mineral sources of these ions cannot be ruled out in this mineralogically heterogeneous aquifer. Concentrations of F (Figure 6.13a) vary little across the aquifer, and these variations do not appear to show any systematic pattern. Strontium concentrations vary substantially; those associated with the boreholes in the Broads area are generally moderate (<460 μg^{-1}), as are some of the samples in the Waveney area (Figure 6.13b). However, concentrations in deeper piezometers into the Crag in the Waveney catchment are substantially higher (maximum of 3835 $\mu g\ l^{-1}$), and may indicate (with other parameters, see below) an increased residence time and, thus, water-rock interaction in these samples.

Silicon is released into solution primarily from the weathering of alumino-silicate phases, which are expected to be abundant in this aquifer. Concentrations are systematically higher in the Waveney catchment than observed in the North Norfolk field area, but do not exceed 11.4 mg l^{-1} in any sample (6.13c). The exception to this distribution pattern is Ludham where concentrations reach 10.8 mg l^{-1}. In addition to Si, an indication of the other elements which may be released into solution from silicate weathering can be gained from consideration of the typical composition of glauconite $[(K,Na,Ca)_{2\ 0}(Fe^{3+},Al,Fe^{2+},Mg)_{4\ 0}[Si_7Al_1O_{20}](OH)_4.n(H_2O)]$ a locally abundant reactive mineral in the aquifer, which is potentially a major source of dissolved Fe (see below). Trace elements frequently associated with alumino-silicate lattices include Li, Rb, NH_4^+ and B; concentrations of these generally follow the relative abundance of Si, as exemplified in Figure 6.14d for Rb. Concentrations of Rb are low (<1 $\mu g\ l^{-1}$) in samples with lower concentrations of Si, and reach a high concentration (9.45 $\mu g\ l^{-1}$) in the sample from Rumburgh.

Dissolved SO_4 may be derived from the weathering of any sulphide minerals in the aquifer (although these are not widely recorded (Section 3)), and in overlying tills (where pyrite is known to occur), or the dissolution of sulphate minerals in the aquifer matrix. Concentrations across the aquifer are largely moderate (<100 mg l^{-1}) (Figure 6.12d) although these are higher concentrations than would be found in an aquifer further inland where the recharge is more distal with respect to seawater.

The highest concentration is found in the sample from Rumburgh (576 mg l^{-1}), which is one of two samples from the Waveney catchment where the water type is Ca-SO_4, and a further sample is Ca-HCO_3-SO_4. These groundwaters have a considerable excess of SO_4, compared to Cl, than would be expected from seawater mixing. These three samples have SO_4 concentrations from 260-576 mg l^{-1}, which are the highest concentrations measured in the Waveney Crag groundwater samples, the remainder of which are all <150 mg l^{-1}.

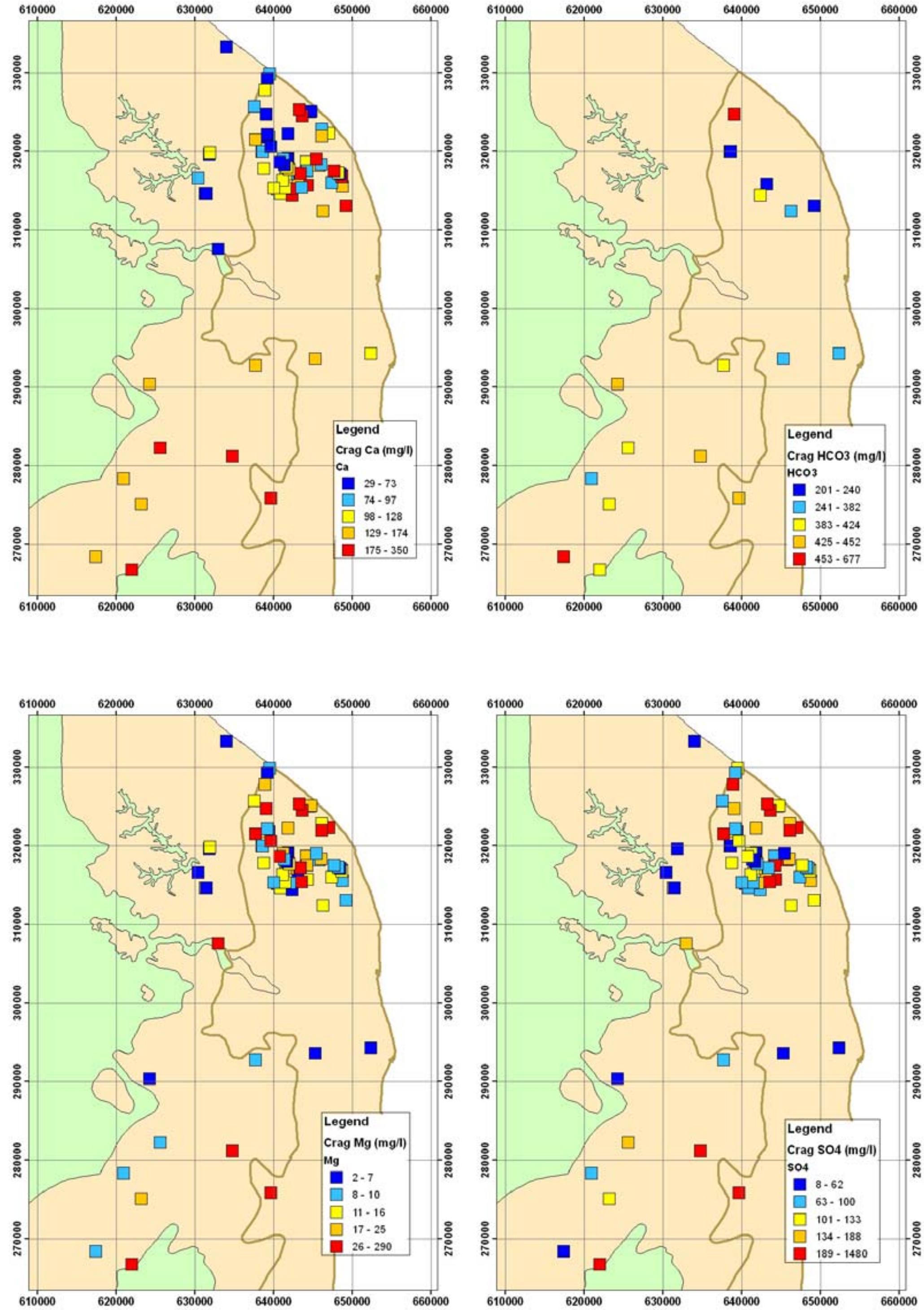


Figure 6.12 Spatial distribution of concentrations in the Crag aquifer (a) Ca (b) HCO3 (c) Mg (d) SO4

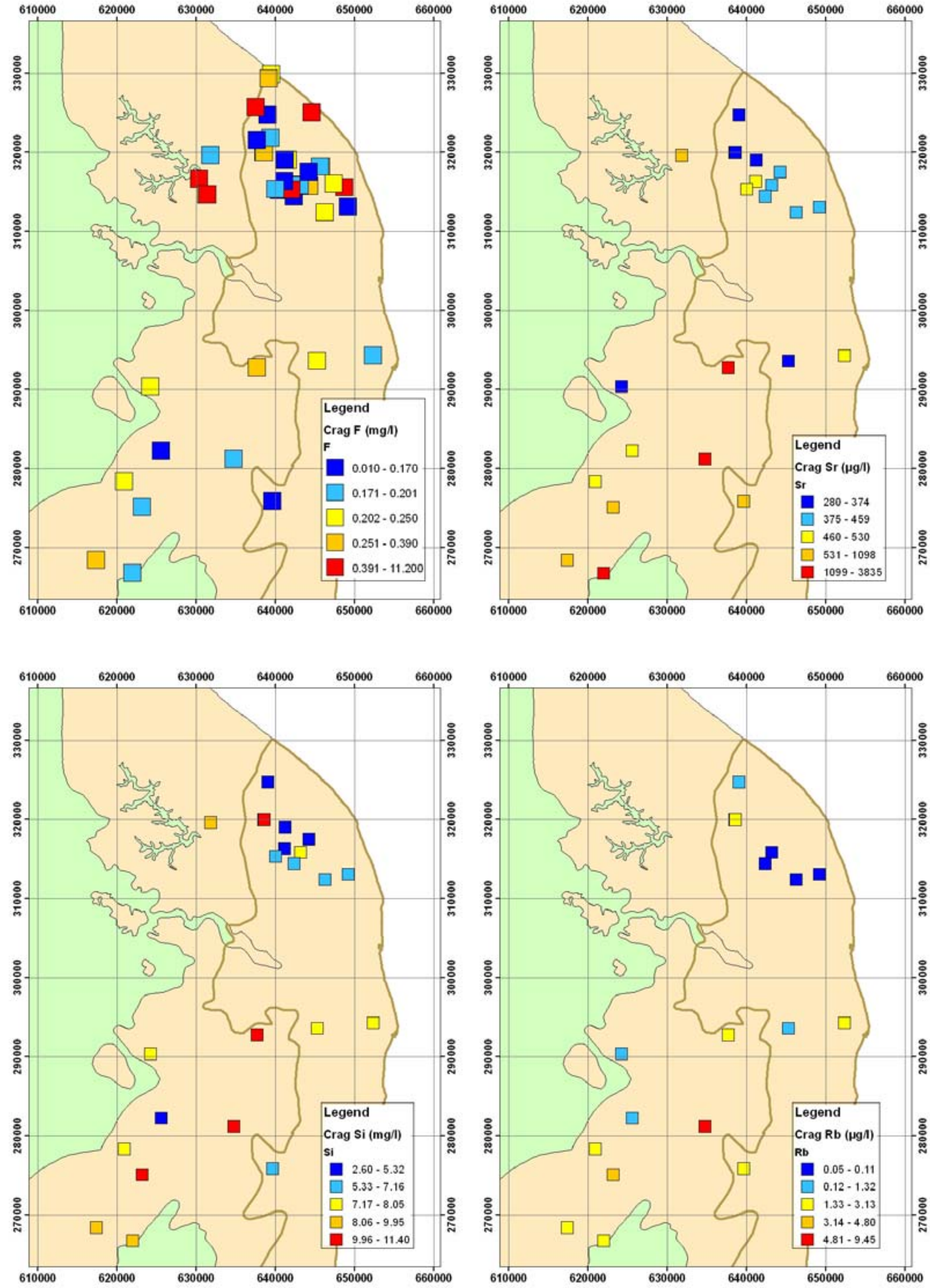


Figure 6.13 Spatial distribution of selected trace elements over the outcrop of the Crag aquifer (a) F (b) Sr (c) Si (d) Rb

Possible geological sources are the dissolution of sulphate minerals, such as gypsum salts. These can either be primary mineral phases, or can occur as secondary mineralisation from the oxidation of pyrite, liberating sulphide ions into solution which are then oxidised to sulphate ions. Observations of pyrite in the aquifer sediments have not been reported in the literature cited in this report. It is, however, possible that disseminated pyrite is under-recorded where lithological studies are carried out primarily for stratigraphical correlation purposes rather than hydrogeological investigations. An additional source of SO_4 to the aquifer could be via leakage from overlying till deposits (Section 3.3.3). The Chalky Boulder Clay is derived from the early Cretaceous and Jurassic strata to the west of the Chalk outcrop, and as such tends to contain appreciable concentrations of pyrite. It is also plausible that excess SO_4 could be sourced from anthropogenic contamination. Landuses immediately around these sites varied from a golf course to cereal production at the time of sampling, which may supply SO_4 from fertiliser applications. Alternatively contamination could come from the borehole itself, but these boreholes varied from commercial to EA installations, and similar SO_4 concentrations were not observed at other sites, which would seem to rule out such a problem.

REDOX REACTIONS

The primary indicators of the redox status of groundwaters are the redox potential (Eh) and dissolved oxygen (DO) (Figure 6.14a). These parameters are very unstable and can only be measured using a flow-through cell at the time of sampling. The analysis of redox sensitive elements also provides information on the redox status of the aquifer (Box 6.1), and can be a useful check on Eh measurements, which are well recognised to have limitations (Appelo and Postma, 1994).

The groundwaters of the Crag have varying redox status across the outcrop. The direct measurements of Eh and DO compare well, despite the well documented difficulties in measuring Eh (e.g. Appelo and Postma, 1994). These indicate that the groundwaters sampled in the Waveney catchment are generally poorly oxidising or reducing in nature, with no detectable DO in any of the samples where it was possible to use the flow-through cell. In North Norfolk, with the exception of the Ludham PWS boreholes, the groundwaters can be seen to be generally oxidising, with detectable DO. It is likely that this systematic variation reflects the deeper installation of the EA piezometers in the Wavney catchment than the private wells sampled in North Norfolk. These data and other hydrochemical indicators described in this section suggest a longer residence time for the Waveney Crag groundwater than observed in North Norfolk. The solubility of Fe and Mn is greatly affected by variations in aquifer redox status, with concentrations greatest in reducing environments, as the soluble divalent forms of the elements are prevalent. These data correspond to those of the physico-chemical measurements, with concentrations of Fe generally exceeding 2 mg l^{-1} in the Waveney catchment (Figure 6.14b). Concentrations of Mn and Fe are low in the North Norfolk region, with the exception of Ludham.

Iron(II) is unstable in oxidising waters and rapidly oxidises to Fe(III). The solubility of Fe(III) is very low, and the precipitation of iron oxyhydroxides is greatly favoured.

$$Fe^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3(s)} + 3H^+$$

These Fe phases are responsible for the ubiquitous reddening of Crag strata exposed to the atmosphere (and reduced Fe for the grey-green colour of the unoxidised sediments). Whilst this reaction series liberates H^+, the frequent observation of calcite (and aragonitic) shell debris and secondary calcite precipitates suggests that the aquifer should have sufficient pH buffering capacity to minimise any effects on pH. The mineralogical source of Fe to groundwaters is likely to be the glauconitic minerals which are found through the aquifer (Section 4) (Cook, 1979).

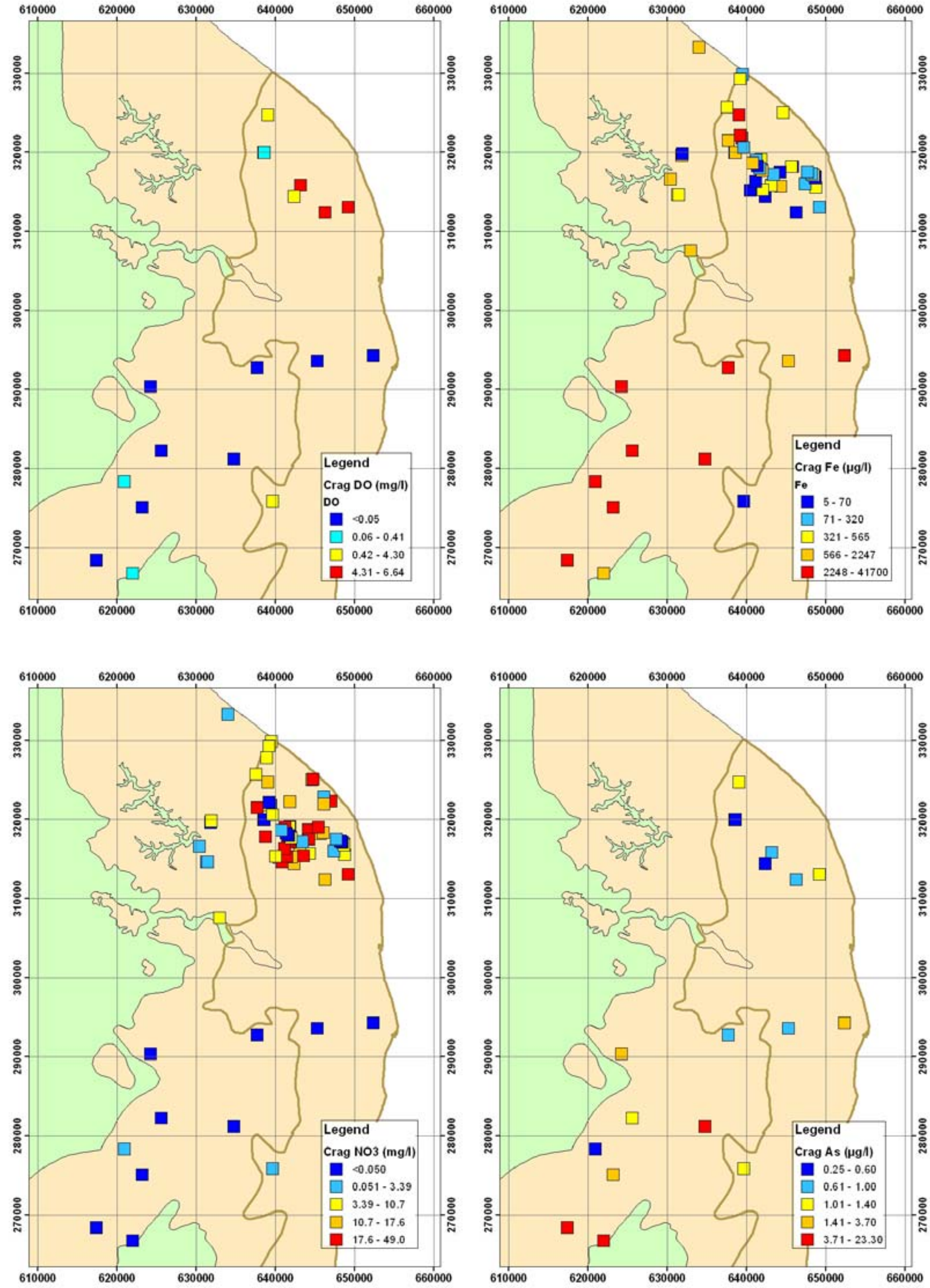


Figure 6.14 Spatial distribution of redox indicators in the Crag aquifer (a) DO (b) Fe (c) NO3 (d) As

Nitrate is largely unaffected by solubility or sorption controls of its mobility within aquifers, and is thus liable to reach high concentrations if leaching takes place from land where fertiliser has been applied, or from inadvertent release of organic waste leachate. However, a natural restriction on the transport of NO_3 occurs in reducing conditions, when NO_3 is reduced (ultimately) to N_2 (Appelo and Postma, 1994). The electron donor sources within the aquifer which can reduce nitrate and are common are organic carbon, pyrite and Fe(II)-silicates. Pyrite is not recorded from this aquifer, and little information can be found on the organic carbon content, the concentration of dissolved organic carbon (DOC) in this study varied between 0.8-6.7 mg l^{-1}). Glauconite is abundant in some parts of the aquifer and may lead to increased NO_3 reduction potential. Indicative overall reactions for these processes are shown below (Appelo and Postma, 1994).

$$5CH_2O + 4NO_3^- \rightarrow 2N_2 + 4HCO_3^- + CO_2 + 3H_2O$$

$$10Fe^{2+} + 2NO_3^- + 14H_2O \rightarrow 10FeOOH + N_2 + 18H^+$$

The NO_3 data (Figure 6.14c) correspond well to the other indicators of the redox status of the waters already described (above), with high concentrations in the oxidising waters of North Norfolk (17.6 – 36.7 mg l^{-1} NO_3-N), exceeding the present drinking water MAC (11.3 mg l^{-1} NO_3-N). The low redox potential, and thus NO_3-N concentrations found in the Waveney catchment may reflect the protective function of the more argillaceous nature of the till (Chalk Boulder Clay) that is dominant in this area, compared to North Norfolk (Corton Formation) and the more argillaceous and glauconitic nature of the aquifer materials. The occurrence of reduced Fe in the till and the glauconite minerals both represent a considerable reducing potential within the Crag, although this reaction is considered to be required to be bacterially mediated to proceed at rates sufficiently fast to be significant (Appelo and Postma, 1994).

Trace elements which are redox sensitive may reach high concentrations as a result of variations in the groundwater physico-chemistry. An example of this is As, which is shown in Figure 6.14d and Figure 6.15, where the oxidised waters of North Norfolk can be seen to have low concentrations of As (<1.2 µg l^{-1}), whilst concentrations rise to 23 µg l^{-1} in one sample of the Waveney catchment, in the expected inverse concentration relationship with DO. Uranium chemistry is different to that of many other trace elements of concern, and has its greatest solubility in oxidising, HCO_3 rich waters, which would appear to largely restrict U concentrations in the Crag aquifer (all data <0.27 µg l^{-1}). Whilst many other trace elements are low in these waters, reflecting a low mobility, some probable contamination is observed in the Landseer sample, specifically in the concentrations of Zn (4.0 mg l^{-1}) and Ni (8 µg l^{-1}).

ION EXCHANGE REACTIONS

The process of ion exchange has been described in Section 6.2.4. There is no evidence from the data itself, and in the visualisation of the data (Figure 5.6), that ion exchange is a dominant process in the groundwaters collected during this study. Where saline ingress is occurring in areas of the Broads (Holman and Hiscock, 1998), it is possible that water types of Ca-Cl composition could occur (Appelo and Postma, 1994), which has been invoked to explain complex Na/Cl in the coastal Crag groundwaters (ENTEC, 2001).

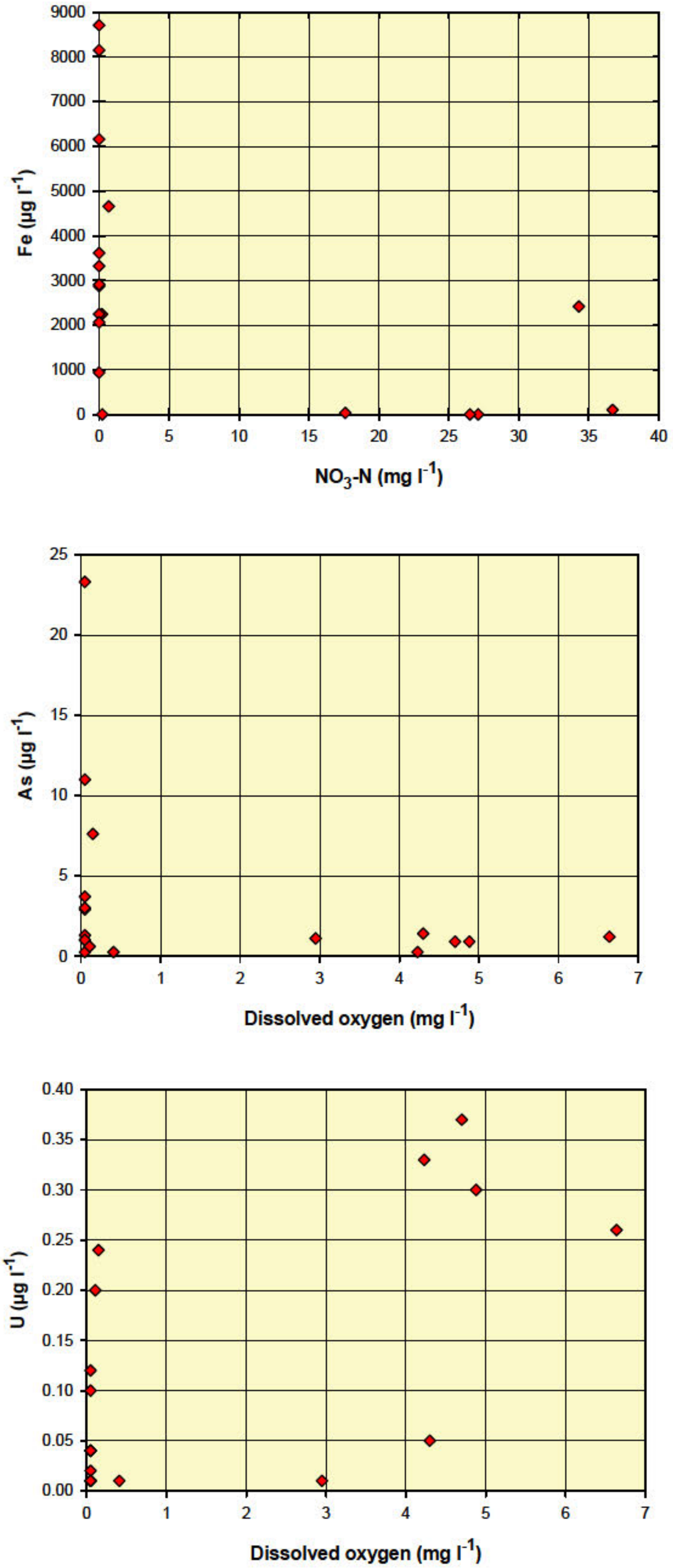


Figure 6.15 Redox indicator species in the Crag aquifer (a) NO_3-N and Fe (b) As and DO (c) U and DO

MIXING WITH OLDER FORMATION WATERS

The evidence for mixing with saline waters is conflicting in the Waveney catchment, with the sample from Rumburgh having the highest SEC (1853 µS cm^{-1}), and high concentrations of trace element indicators such Li, Rb and B and generally high concentrations of major ions (in the context of this aquifer). The same is also true, to a slightly lesser extent, for Stradbroke. However, these samples show an overall water composition of Ca-SO_4 and Ca-HCO_3 types respectively, with no evolution towards cation-exchange (towards Na-HCO_3) or saline mixing (with a presumed Na-Cl end-member) on the Piper Plot. Additional information suggesting that these groundwaters may not have a significant connate water component comes from stable isotope analysis (see below). These waters are very reducing, with high Fe concentrations (6.2 and 4.7 mg l^{-1} respectively), and it may be that these conditions have accelerated the processes of carbonate and silicate weathering, to give an apparently greater residence time based on trace element indicators alone. An alternative hypothesis is that the Crag has been completely flushed of Tertiary and early-Quaternary seawaters, due to the intergrannular nature of the flow, and thus the oldest waters will not reflect a seawater component. There is, thus, no evidence for mixing with older formation waters in any of these samples.

6.3.5 Age of the groundwater

There are no published data on the residence time (age) of the Crag groundwater in the North Norfolk or Waveney areas. The presence of a Pleistocene palaeowater component (> 10000 yrs BP) can be indicated from the variation in $\delta^{18}O$ and $\delta^{2}H$, which was isotopically lighter (more negative) during colder recharge periods of the last glaciation. Stable isotope analyses were undertaken on a subset of the samples collected, in order to obtain some indication of residence time in the aquifer.

It can be seen from Figure 6.16, that the data plot along the GMWL similar to that expected from modern or Holocene recharge. There is no clear trend of salinity with stable isotope signature. The sample with the heaviest isotope composition ($\delta^{18}O$ of –7.66 ‰, $\delta^{2}H$ of –49.7 ‰) located in the north of the North Norfolk Crag sampling area, is only moderately saline (888 µS cm^{-1}), and does not otherwise have a chemical composition different to the other private supplies in the area (e.g. oxygenated with a DO of 3 mg l^{-1} and NO_3-N of 16.6 mg l^{-1}), although the pH is unusually low in comparison to other samples (5.91), and elevated trace elements are suggestive of local contamination of the sample. The sample analysed from the Ludham borehole has an isotope signature indicative of modern recharge, $\delta^{18}O$ of –7.23 ‰, $\delta^{2}H$ of –45 ‰. All the samples analysed from the Waveney catchment had a stable isotope composition indicating modern recharge (Figure 6.16).

The stable isotope $\delta^{13}C$ can be indicative of the interaction with carbonate in the aquifer matrix, particularly under closed system conditions. As the Crag is frequently a very shelly sediment, it is assumed that the reservoir of carbonate C is not limited within the bulk aquifer, and thus interaction will be as for the Chalk. Although no information could be found on the stable isotope composition of the Crag carbonate where it is of marine origin it is likely to be representative of marine carbonate (i.e. similar to that of the Chalk, *ca.*–25 ‰).

The value of $\delta^{13}C$ can be seen to vary positively with Sr/Ca (Figure 6.17), both of which may be used as indicators of increasing water-mineral reaction and more loosely as indicator of residence time. The shelly deposits of the Crag may be expected to be originally dominated by aragonite, and thus subject to the same slow recrystallisation to calcite process that the Chalk aquifer undergoes. In this recrystallisation process, the Sr co-precipitated into the aragonite lattice is preferentially retained in solution rather than being incorporated into the calcite mineral. A good correlation exists for these parameters (Figure 6.17) indicating that incongruent dissolution dominates the carbonate evolution of the groundwaters. The sample which is apparently most evolved ($\delta^{13}C$ of –11.82 ‰), at Rumburgh, is one of the deepest of the Crag boreholes, at 43 m, lending support to the hydrochemical evidence of an increased residence time at this site. Whilst artefacts arising from any systematic variations in the mineralogical and isotopic composition of the Crag aquifer cannot be accounted for in this study, the correlations observed broadly support the model of assessing groundwater residence used.

6.4 Comparison of hydrochemical data from the Waveney piezometer samples

A brief comparison of the hydrochemical environments in the Waveney presented here. The major ions are presented as a Piper Plot (Figure 6.18) containing data for the Chalk, Crag and Superficial aquifers of the Waveney catchment (Section 4 for details of sample numbers). These data include all the samples collected during this study in the Waveney catchment. These data illustrate the mixing of recent Chalk groundwaters with a more saline end-member, as described above (Section 6.2); where this occurs to the east of the Palaeogene subcrop then the Chalk groundwater is expected to be isolated from that of the Crag and superficial strata. To the west of the Palaeogene subcrop the Quaternary, Crag and Chalk are considered to be in hydraulic continuity (Allen et al., 1997). The Crag groundwaters have also already been discussed (Section 6.3), and the trend from a Ca-HCO_3 type towards a Ca-SO_4 type in some samples is clearly shown in Figure 6.18. The superficial groundwater samples appear to follow a very similar trend to that of the Crag. Whilst the small sample size (8) prevents definitive conclusions being drawn, this would seem to support the possibility that the SO_4 excess in the Crag samples is derived from a source in the overlying glacial sands and gravels or till deposits.

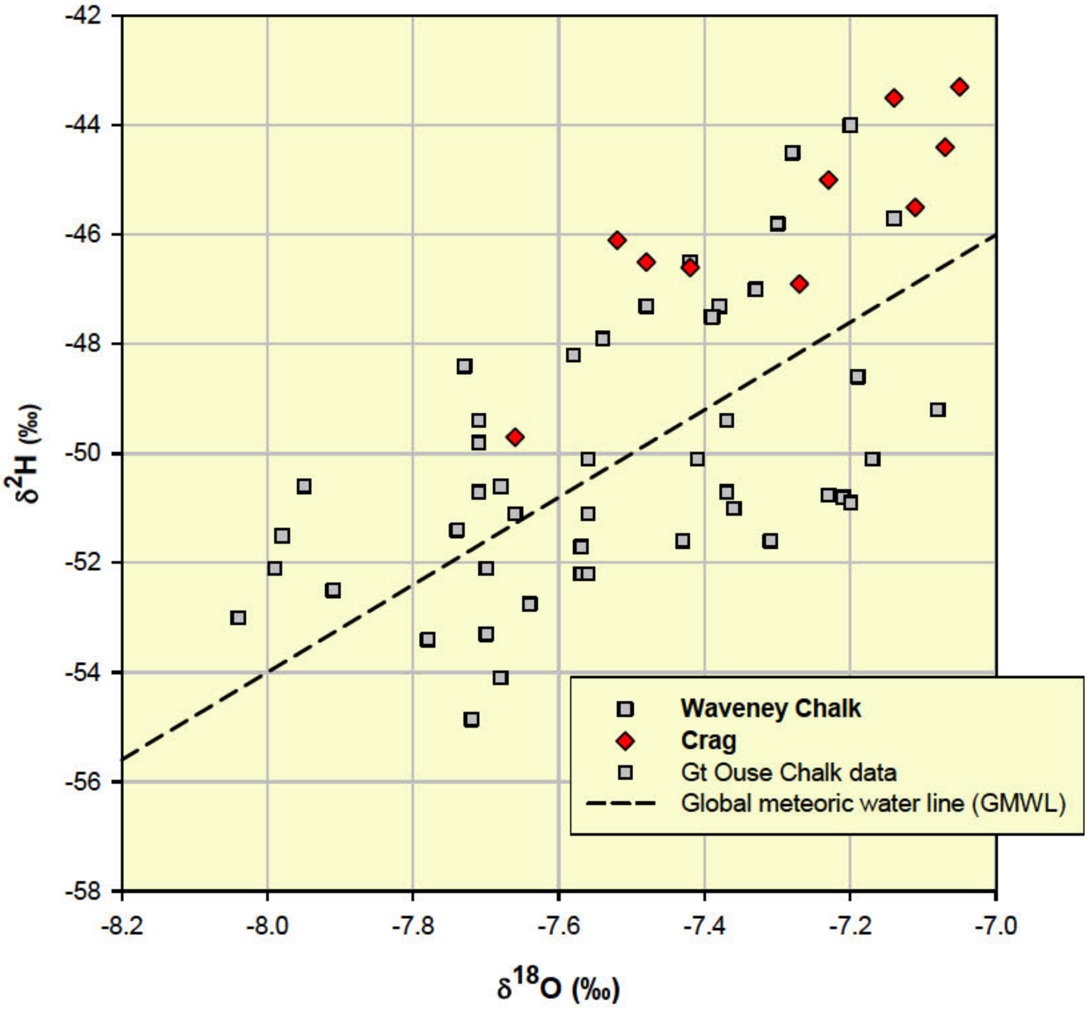


Figure 6.16 δ^2H-$\delta^{18}O$ plot for Crag groundwaters

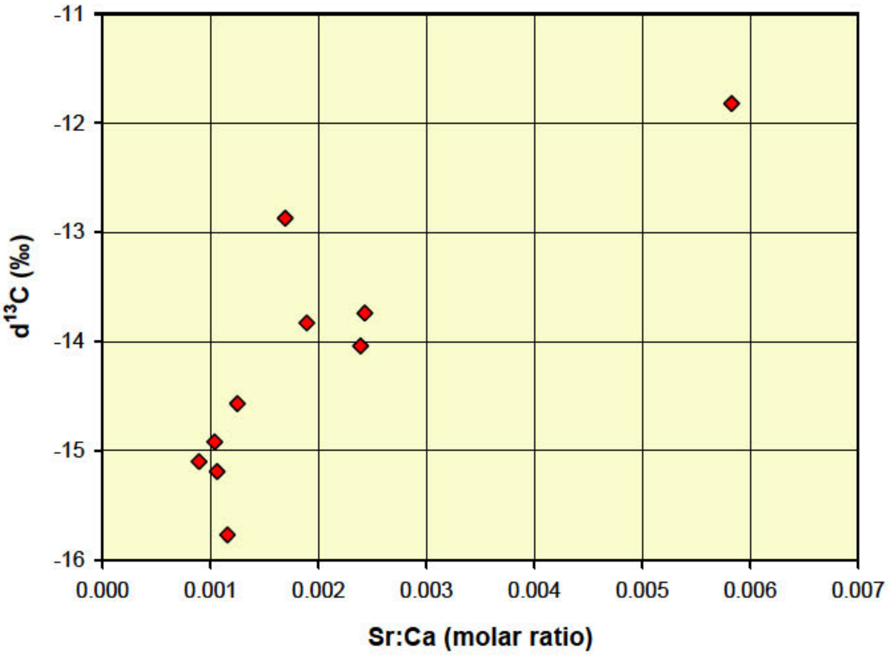


Figure 6.17 Comparison of Sr/Ca with $\delta^{13}C$ in the Crag aquifer

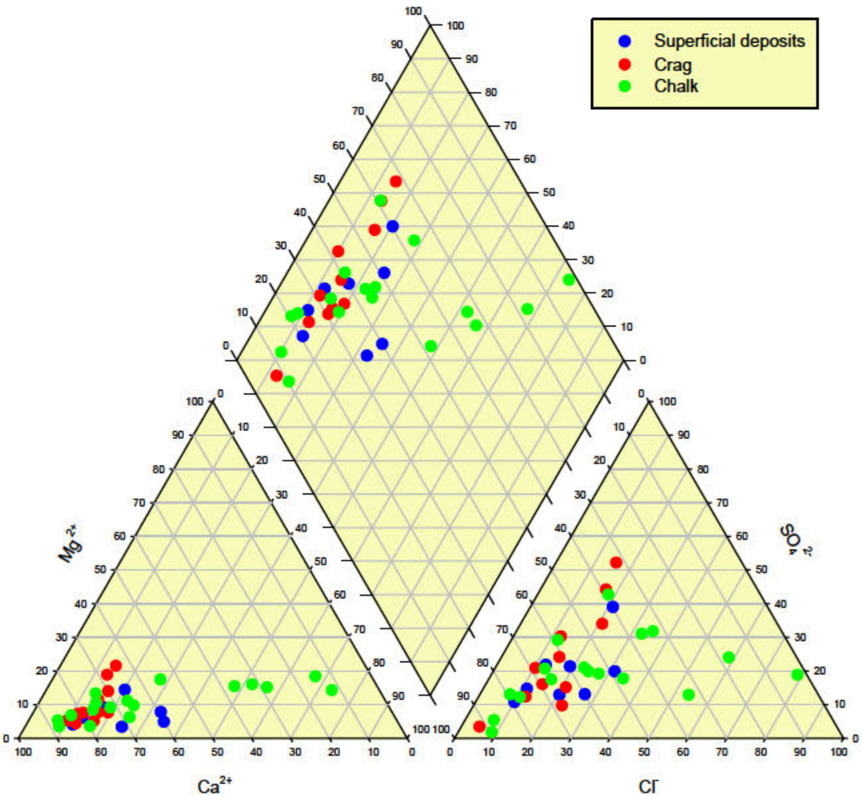


Figure 6.18 Comparative Piper Plot of different aquifers in the Waveney catchment

The close parallels in the hydrochemical trends of selected parameters is shown in the cumulative frequency plot (Figure 6.19). The higher concentration of Cl in most Chalk groundwater samples reflects the mixing with more saline waters, whilst there is no evidence for such a process in the Crag, and it would not be a process anticipated to occur in the superficial sediments (which are well away from the coastline and above sea level). Whilst the SO_4 content of the Crag is more dominant than that of the Chalk, it can be seen that the distribution of concentrations is very similar in these two aquifers. Calcium concentration distributions are almost identical in all the aquifer units sampled, and the shape of the cumulative frequency curve indicates a solubility control on Ca concentrations in all three aquifer units (Box 5.1), suggesting that availability of calcite (or aragonite) is not limited at the regional scale in the argillaceous sediments. Despite the purity of the Chalk it can be seen that Si concentrations are higher in the Chalk than in the arenaceous and argillaceous sediments of the Crag and glacial deposits, and appears to be limited by solubility controls of two different mineral phases. The mobility of the trace element As is seen to be greater in the Crag and Quaternary sediments, which may be due a greater source term (i.e. more As mineralisation in the aquifer), but will also reflect conditions more generally favouring the aqueous transport in the aquifer units. It can be seen that there is very little regional difference between the Crag and Quaternary aquifer units, and that the intra-aquifer variations in major and trace element chemistry are greater than those between the aquifers. Notwithstanding the small sample size, these data also support the occurrence of more than one baseline system for the Quaternary aquifers (cf. Figures 6.18 and 6.19), with a variation in major and trace element chemistry as large as that found in the Crag aquifer.

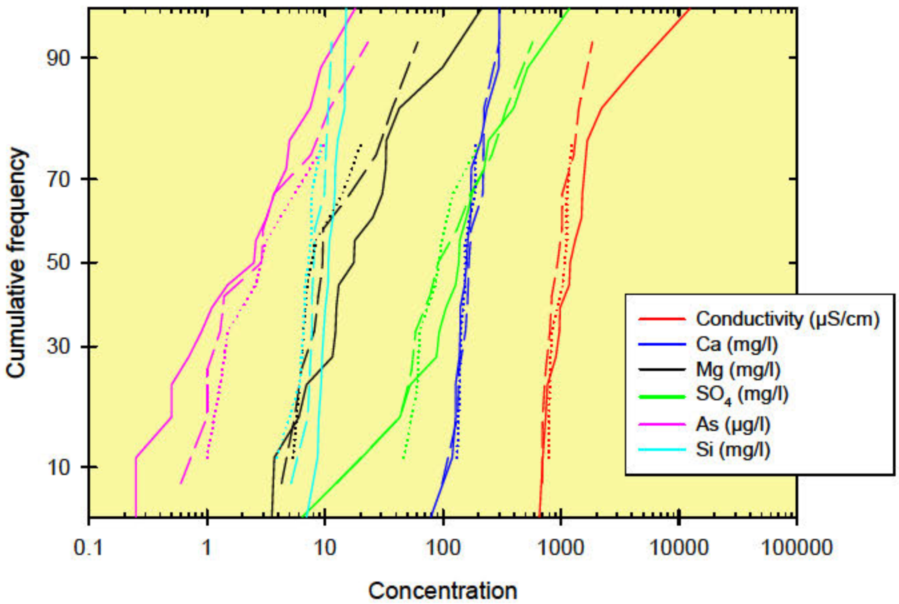


Figure 6.19 Cumulative frequency plot of different aquifers in the Waveney catchment

7. BASELINE CHEMISTRY OF THE AQUIFERS

7.1 Chalk

The calcium carbonate composition of the Chalk matrix dominates the major element chemistry of the groundwaters in all the samples collected in North Norfolk and the Waveney catchment. The waters contain significantly enhanced concentrations in comparison to rainfall (Section 3.5), showing that considerable water rock interaction has taken place. The proximal marine influence on recharge is reflected in the moderate, but higher Cl and SO_4 concentrations in the modern groundwaters of the North Norfolk coastal than those observed in other similar boreholes from other baseline aquifer regions (e.g. Shand et al., 2003). The low-Mg calcite of the matrix gives rise to waters which are predominantly Ca-HCO3 in their composition. The data indicate mixing of waters of an older age and more saline composition beneath the Palaeogene cover of the lower Waveney catchment. This study has been able to take advantage of a series of observation and sampling piezometers installed by the EA in the Waveney catchment, which has avoided a common problem in studying the Chalk aquifer, of most boreholes being situated in highly transmissive zones (e.g. Ander et al., 2004, Shand et al., 2003). These samples have a considerable cover of till and Crag sediments, before becoming confined by the Palaeogene clays in the lower part of the catchment, allowing mixing and increasing age to be observed, by major and trace element analysis and using isotopic indicators. Whilst ion exchange is commonly observed when Chalk aquifers become confined (Edmunds et al., 1987, Shand et al., 2003), there is no evidence for this process occurring the Waveney groundwater samples, from the samples collected. The samples from North Norfolk were from PWS or commercial boreholes, and thus generally reflected a more modern composition, although vertical and lateral variations in composition underneath till cover in this area have been published elsewhere (e.g. Feast et al., 1997, Hiscock et al., 1996).

The range of concentrations of major and trace elements is high across both areas of the aquifer, reflecting the variation in the degree of residence time, and thus water-rock interaction or mixing with older waters, observed. The concentration variations of many of the trace elements are (generally) adequately explained by natural processes, and are not thought to reflect contamination.

Whilst natural processes dominate the hydrochemical characteristics of these waters, the high concentrations observed of NO_3 in the Chalk of North Norfolk cannot be considered natural. In half the samples studied concentrations range between 3.0-11.9 mg l^{-1} NO_3-N, and 7.7 mg l^{-1} NO_3-N in one borehole in the upper Waveney catchment. These data are, with one exception, in excess of the baseline value of 2-4 mg l^{-1} NO_3-N suggested by Shand et al. (2003), and approach the present MAC for drinking water (11.3 mg l^{-1} NO_3-N). All reflect highly transmissive areas, with relatively low total solute concentrations, in comparison with other areas of the aquifer. The other samples all have very low concentrations of NO_3-N, which frequently reflects a reducing environment where NO_3 is removed by natural processes (see box 5.1). However, NO_3-N concentrations in this study are generally lower than those of the adjoining baseline area of the Great Ouse Chalk (Ander et al., 2004).

An understanding of spatial and temporal variations in the aquifer is important in assessing the local baseline. Spatial presentation of the data has facilitated this understanding. A previous pore-water study (Bath and Edmunds, 1981) provides useful information against which to compare the data obtained from pumped groundwaters, for a limited range of trace elements as well as for the major ions and some stable isotopes. The paucity of very long-term data with which to analyse historical variations hinders the understanding of any long-term effects of groundwater use or ingress of diffuse pollutants on the baseline quality currently observed in the aquifer.

7.2 Crag

The Crag aquifer is a heterogeneous (locally and regionally) series of intercalated sediments with locally abundant shelly material. The hydrochemical data indicates that the abundance of shelly material is sufficient to maintain the circum-neutral pH expected from calcite weathering, and thus exerts a strong control on the major element characteristics of the groundwaters of the Crag aquifer in North Norfolk and the Waveney catchment. Systematic variations are seen between the Waveney catchment where more argillaceous till covers the upper part of the catchment, and the EA piezometers, which provided the majority of the samples collected are screened off to a deeper sampling interval than it is thought that the public and private supplies in North Norfolk are. The waters are generally of a Ca-HCO_3 composition, with an evolution towards a Ca-SO_4 type observed in several of the samples collected in this study. Other regional studies have also observed saline mixing (Na-Cl types) as a result of the low-lying nature of the land surface of the Broadlands, resulting in areas where saline intrusion is occurring. Thus for the samples collected in this study, natural processes in the aquifer govern the major ion composition. The concentrations of Fe can be elevated locally which is likely to be due to the weathering of glauconitic material in the aquifer (the subsequent precipitation of insoluble Fe minerals when the groundwater becomes oxidised is responsible for the almost ubiquitous reddening of the sediments where they are exposed).

The range of concentrations observed is generally small, although where older samples, with very reducing environments occur in the deeper areas of Crag sedimentation in the Waveney catchment, concentrations of trace elements may increase. This is not found to be associated with mixing with a Na-Cl saline end-member, in contrast to the Chalk aquifer in the Waveney catchment.

Where the aquifer is confined by overlying argillaceous till, particularly in the Waveney, or protected by intra-formational clay horizons as is the case for the Ludham public supply in North Norfolk, concentrations of NO_3 are low (<0.7 mg l^{-1}). However, in shallow Crag private supplies of North Norfolk the concentrations is much higher (13.0-17.8 mg l^{-1} NO_3-N), exceeding what may be expected in truly baseline conditions and that of the present drinking water MAC of 11.3 mg l^{-1} NO_3-N (Shand et al., 2003). There is no historical data available to this study to assess whether the concentrations at these sources have remained unaltered for some period of time, or whether there is a systematic trend in their composition. It is suggested that these high concentrations do not reflect natural baseline conditions for this parameter in this aquifer.

The baseline data presented in this aquifer represents that of pumped groundwaters; in the case of those from the Waveney catchment a great deal of confidence exists as to their depth and thus the interpretation of the data with respect to that parameter. The siting of the EA piezometers was based on considerations of representative sampling of the aquifer, rather than water supply considerations. However, no information could be found on porewater compositions in the Crag, and it is recommended that such a study is undertaken, so that the baseline of matrix porewaters can also be established. The aquifer matrix and geochemical environment can be extremely important in terms of natural attenuation processes. Diffusional exchange and mixing between fracture water and porewater may lessen the initial effects of pollution, but equally may retain pollutants for long periods of time, or retard surface applied diffuse pollutants.

8. SUMMARY AND CONCLUSIONS

The chemistry of groundwaters in the two aquifers studied in the Waveney catchment and North Norfolk are both dominated by natural geochemical processes taking place between the aquifer minerals and the groundwater. Most of the parameters measured in the groundwaters represent baseline. The reaction of carbonate minerals in the soil, unsaturated zone and saturated zone are key in the evolution of recharge and groundwater in both aquifers. In the Crag aquifer the much higher abundance of clay minerals than in the very pure Upper Chalk do not appear to have a substantial influence on the baseline chemistry of many elements in the shallow aquifer, where the groundwaters least affected by water-rock interaction were sampled.

It is suggested that in both aquifers more than one baseline system exists. In the Chalk, a variation between waters with a low concentration of solutes, where the chalk is unconfined and the boreholes are located in highly transmissive valley zones, to those where confinement by till or Crag shows a greater influence on the groundwater evolution, with a general increase in the concentration of many elements, to that of a mixing zone with old saline water in the most easterly samples, confined by the Palaeogene clays. In the Crag there are at least two baseline systems which have been sampled; those of a very shallow nature with the least chemical evolution as a result of water-rock interaction, but with the most vulnerability to surface applied diffuse contaminants (such as nitrate from agriculture and septic tanks). The second baseline system is one of waters with a far greater degree of hydrochemical evolution, as a result of a longer residence time in the aquifer. These waters are very reducing, with higher concentrations of trace elements, but no evidence of mixing with older saline waters.

Historical records are available from some public sources, providing time-series data for iron and manganese over a relatively short time period. Longer term time series data have not been found in this study, and would be extremely useful in establishing baseline concentrations for those solutes (particularly nitrate) which are elevated as a result of diffuse anthropogenic sources. The importance of establishing long term historical records for aquifers cannot be overstated, in order to permit the determination of baseline hydrochemical quality.

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The assistance of Rob Heath (EA) in providing WIMS data, Simon Eyre and Mike Cook (Anglian Water) and Paul Saynor (Essex and Suffolk Water) in providing information on PWS boreholes, permission to sample and staff at site to give us access, and PWS historical data and Kevin Hiscock (UEA) for providing his PhD data is acknowledged.

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21 October 2021

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A. Approved Judgement Pearce v SoS BEIS dated 18/02/2021.
B. ESO Offshore Coordination Project Autumn Update – 18 October 2021.
C. The Race to the Water for Offshore Renewable Energy: Assessing Cumulative and In-combination Impacts for Offshore Renewable Energy Developments published 03 December 2019

Attachment:
Norfolk Boreas ES Figure 29.5 Scenario 1 - Zone of Theoretical Visibility Onshore Project Substation

NORFOLK BOREAS PROJECT - REFERENCE EN010087

WRITTEN REPRESENTATION IN RESPONSE TO THE SECRETARY OF STATE FOR BUSINESS ENERGY & INDUSTRIAL STRATEGY (SoS BEIS) LETTER DATED 22 SEPTEMBER 2021

Dear Secretary of State,

Thank you for the opportunity to make further comment regarding the Norfolk Boreas DCO application.

Throughout our representations to the Norfolk Vanguard ExA and the Norfolk Boreas ExA we have maintained that the projects should have been examined as a single application from the outset. We contend that the developer deliberately separated the two projects, in order that the possibility of achieving a DCO for both projects separately, would be more likely. Alternatively, if Boreas and Vanguard were examined as a whole project, especially regarding the cumulative environmental impacts for such a large project, the DCO application would fail. There is nothing in the submissions made by the Applicant for Norfolk Boreas examination in solus to change our view.

In the Judgement of the Judicial Review (JR) for the Norfolk Vanguard DCO consent at Reference A, which was granted contrary to the recommendation of the ExA by your predecessor, Justice Holgate rejected the submissions that the procedure for re-determining a development consent order ("DCO") that has been quashed is dictated by rule 20 of the Infrastructure Planning (Examination Procedure) Rules 2010 ("the 2010 Rules"). Instead, rule 20 provides simply for minimum procedural requirements. Furthermore, the Judge noted that rule 19 expressly provides for the re-opening of examinations and went on to say that, where a fundamental error had been made affecting the decision- making process, it might be necessary to 'rewind' the process to the beginning. We submitted to the Norfolk Vanguard examination that this would be appropriate, and we hereby submit the same to Norfolk Boreas. It is our contention that the *"specific and targeted joint consultation on onshore landscape impacts"* as now being undertaken by the SoS BEIS are materially deficient unless the cumulative impacts and justification for Norfolk Vanguard and Norfolk Boreas more generally are considered. This is explicitly what the now quashed Norfolk Vanguard application improperly avoided by submitting successive applications. However, the applications are no longer successive. They are concurrent and can – and should – be considered together.

The Judgment of the High Court set out a non-exhaustive list of matters that would need to be addressed. Those matters included obviously material considerations that were not addressed either by your predecessor or the Norfolk Vanguard ExA. It is therefore our view that these matters clearly required re-examination so that the impacts of the Norfolk Vanguard and Norfolk Boreas developments could properly be considered together. We therefore respectfully ask the SoS BEIS to take heed of Justice Holgate's advice: "to give careful consideration as to how the cumulative impacts relating to the development at Necton, for both projects, should be approached." We contend that, from the information currently available for the Norfolk Boreas examination, a proper assessment of the cumulative impacts at the Necton substation has not been completed.

In its submissions, the Applicant consistently under plays the cumulative impacts of the proposed substations. By way of example, and with regards to the LVIA for **both** projects, we refer you to Attachment 1 [submitted as APP-488] which depicts where there will be a high theoretical visibility of the project substations. It is the Applicant's assertion that visual impacts of the proposed substation are localised (within a 1.2km radius) and any effects would attract only limited weight. However, the grey areas on the map (Attachment 1) show the 'High Theoretical Visibility' splay with over 90% of the properties in the village of Necton having a high visibility view of the proposed substation. There are areas with a high visibility view beyond even the 3km dotted line, never mind the 1.2km radius which Justice Holgate pointed out, "… is only an assessment tool." The Judgement makes clear that: "… the evaluation of the cumulative impacts is a matter for proper fact-finding by the person responsible for taking the decision on the DCO …" Therefore, we respectfully ask that "proper fact finding," with special care and regard for the cumulative impacts of the onshore elements, especially around the Necton substation, are carried out for Norfolk Boreas and Norfolk Vanguard as a whole.

We further reiterate the findings of Justice Holgate that a full and complete assessment of the cumulative impacts of the two projects should be completed and not limited to design. Further the Judge held, the approach taken by both the SoS BEIS and the ExAR's recommendation for Norfolk Vanguard was fundamentally flawed both as a matter of environmental impact assessment ("EIA") and rationality as an entire category of impacts were omitted from consideration. The EIA requires that **all** of the environmental information be taken into consideration in making a decision. That cannot be done in a piecemeal way. We ask again for the SoS BEIS to revisit the overall planning balance, which Holgate J noted concluded in favour of the proposed development "on balance" only.

The Applicant has made bold statements about the number of homes the Norfolk Boreas windfarm will supply with renewable electricity. However attractive these submissions are, there is no explanation for how they came about. The Applicant further claims that the windfarm project will save huge amounts of carbon release (the comparison being solely in comparison with the carbon output of fossil fuelled power stations) but fails to inform where or when the windfarm will recover the huge amounts of carbon that will be released in the development, construction, and servicing of the onshore transmission system. We contend that the climate change impacts of producing hundreds of kilometres of cables, with hundreds of thousands of tonnes of concrete required to build the substations, and hundreds of kilometres of industrial strength plastic ducting (which will pollute the ground it is buried in for decades to come) will have an immediate detrimental impact. When considering that the construction of Norfolk Boreas' transmission system's contribution to climate change alone could tip the balance on the climate, the accumulation of years and years of production for currently 5 separate windfarms impacting Norfolk alone, will have an unprecedented environmental impact both locally and globally. We ask that either the Applicant carries out an empirical assessment the impact of producing the transmission system will have on climate change or the SoS BEIS makes a clear decision to grant the windfarm DCO whilst refusing consent for the transmission system pending the development of the OTN.

Today we attended the NGESO's webinar updating stakeholders about the progress of the OTNR. Whilst the information presented (also at Reference B) was overall positive and welcome, the progress of the OTN is being hampered, a cynic could claim purposely held up, by the requirement for the developers to "opt-in" to the Early Opportunities Workstream in order to become Pathfinder Projects for the OTN. To be clear, the Norfolk Boreas/ Norfolk Vanguard project is perfectly placed within the criteria set by the NGESO to take an immediate leading role in the OTN project. However, in its response to the SoS BEIS question regarding the OTNR the Applicant denied the project's suitability claiming the Norfolk Boreas development to be too far advanced but this not the case according to the NGESO presentation.

The time has come for the Government to step up and accelerate the development of a "World leading" OTN, either by incentivising the developments perfectly placed to take part in the OTN project or by legislating accordingly. The overall environmental impact of consenting successive onshore radial connections cannot be understated and the importance of such in the planning balance has been enabled by the Department for BEIS, the Planning Inspectorate and the SoS BEIS, all allowing offshore developers to continuously downplay and misrepresent the environmental impacts of their projects. In essence, the weight being applied in the planning balance, for the provision of renewable energy at all costs, is overriding the reasons for providing renewable energy in the first instance, that being, Global Warming. The phenomenon is adequately discussed in the academic document, "Race to the Water' at Reference C. The article identifies elements of the consenting processes which fail to provide a full assessment of cumulative and in-combination impacts and recommends changes to these processes in England and Scotland. We ask that the SoS BEIS takes account in his overall assessment of the Boreas application that if the project were to become a Pathfinder project, none of the detrimental impacts on the onshore environment would need assessment.

We consider that the overall cumulative impacts of the onshore development for either Norfolk Boreas or Norfolk Vanguard or especially, both projects, is so environmentally damaging that any DCO should be refused. Alternatively, if the SoS is minded to consent the project then he should either defer the consent decision for the transmission system (be it that it is the same system for both projects), or, give consent for the offshore elements in isolation pending the OTN. Any negative commercial impact on the Applicant for not consenting the transmission system could be taken up by incentive or repaid through the eventual CfD.

To be clear, the most efficient route to market for offshore wind projects with positive mitigations for climate change will be for **all** the inflight projects off the coast of East Anglia to collaborate and integrate their grid connections via the OTN; Norfolk Boreas is one of these projects. The regulatory changes required to deal with issues such as OFTO payments to the developer are minimal within the global challenge to combat climate change. We must accept that the resources of the planet are finite and precious, as is the countryside in Norfolk. Therefore, consent for the Norfolk Boreas DCO would be contrary to any longer-term environmental goals the UK may have.

We ask that the SoS BEIS refuses the DCO for Norfolk Boreas.

Yours sincerely,

[redacted]

Attachment 1 to Representation
R.S. & D. Pearce
Norfolk Boreas dated 21 Oct 21