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THE SIZEWELL C PROJECT

NNB Generation Co (SZC) Ltd

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WRITTEN REPRESENTATION

EXPERT REPORT

A critical review of SZC Co's site characterisation, impact assessment, and proposals for impact mitigation, in relation to the risks posed to the ecohydrological integrity of Sizewell Marshes SSSI

Dr Rob Low, Dr David Mould, Jonathan Graham

s.coastalfoe@yahoo.co.uk

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A critical review of SZC Co.'s site characterisation, impact assessment, and proposals for impact mitigation, in relation to the risks posed to the ecohydrological integrity of Sizewell Marshes SSSI by the development of Sizewell C Nuclear Power Station, as proposed.

Authored by Dr. Rob Low (lead), Dr. David Mould and Mr. Jonathan Graham.

This Written Representation to the Sizewell C hearing concerns the serious risks to the viability of wetland plant communities and species of interest within Sizewell Marshes Site of Special Scientific Interest (SSSI), leading from the proposals to develop the Sizewell C Nuclear Power Station, brought forward by NNB Generation Company (SZC) Ltd (*SZC Co.* hereafter). It has been written on behalf of Friends of the Earth and Suffolk Wildlife Trust by Dr Rob Low, Dr David Mould and Jon Graham.

1 Names, qualifications and experience

1.1 Dr. Rob Low

I am Dr. Rob Low, and I am the Managing Director of Rigare Ltd (Abergavenny), a company which provides expert services and advice on the subjects of wetland ecohydrology and hydrogeology.

I have a BSc (Hons) in Geography from the (former) University of Wales (Swansea), an MSc in Environmental Management from the University of Stirling, and a PhD in hydrogeology from the University of East Anglia. I am a Fellow of the Geological Society of London, and I am a Chartered Geologist.

I have 24 years' of experience as an environmental consultant. Between 1997 and 2006, I concentrated solely on providing expert services and advice in hydrogeology, primarily relating to groundwater resources. Since 2006, I have provided expert services and advice in both wetland ecohydrology and hydrogeology, working mostly for regulatory agencies (e.g., Natural Resources Wales and Natural England) and Non-Governmental Organisations (e.g., Wildlife Trusts and the RSPB).

I founded Rigare Ltd in 2008, and I am currently the sole shareholder.

1.2 Dr. David Mould

Dr. David J. Mould is a surface water hydrologist. I have provided expert technical advice on surface water systems over 18 years. I have a BSC (Hons) in Geography from the University of Leeds (2002). In 2003, I began working with the Hydro-Ecology and Wetlands research group at the Centre for Ecology and Hydrology (now UKCEH), instrumenting wetland systems for research projects. I was sponsored by the Natural Environment Research Council through UKCEH to complete a PhD looking at the hydrological functioning of wetland systems (2008). I worked for 4.5 years as a consultant hydrologist at Wallingford HydroSolutions Ltd, with a focus on hydrological monitoring, hydropower resource assessment and flood hydrology. I am Chartered through CIWEM and am due to Chair CIWEM's Rivers and Coastal Group from 2022.

I work (currently part-time) as Principal Hydrologist for the Canal & River Trust (previously British Waterways), having been employed there since 2012. This work has included the emergency response (and subsequent provision of technical advice) for the Toddbrook Reservoir spillway failure in Whaley Bridge in August 2019. This included work leading a modelling exercise with SAGE (UK Government scientific advisors) to enable evacuation orders to be cancelled. Other major projects have included coordinating the Trust's operational response to the 2018 drought, which was a benchmark event in northwest England, and responding to legislative change in the application of 154 abstraction licenses. I provide out of hours support as Duty Hydrologist for the Trust's 2,000 miles of network of waterways and 72 reservoirs.

Since 2016 I have practiced through my private company, Milestone Environmental Ltd. This work has focused on the provision of multi-disciplinary technical advice for improved wetland management. This has been for varied clients including Natural England, Wildlife Trusts, local authorities and larger consultancies.

1.3 Jonathan Graham

Jonathan J. Graham is a botanical and ecological specialist with a BSc (Hons) in Botany from Bangor University (North Wales). Jon has worked for the Countryside Council for Wales (now Natural Resources Wales) and English Nature (now Natural England) and since 2007 has been an independent consultant.

A large proportion of Jon's work has related to aquatic and wetland habitats such as assessments of rivers and drainage channels, vegetation surveys of fen, swamp and washlands, hydro-ecological assessment of base-rich flushes (including tufa sites) and their restoration, and has published research in relation to bryophytes of springs and water chemistry.

2 Structure of this written representation

This Written Representation to the Planning Inspectorate (PINS) details our serious reservations concerning the methods and conclusions of the assessment, and management of the possible impacts, of the proposed development on the ecohydrological functioning, and therefore the conservation status and sustainability of key interest features within Sizewell Marshes SSSI. To allow this:

- The nature and conservation values of the interest features within the SSSI are described in Section 3.
- The concept of hydrological supporting conditions, i.e., aspects of the current hydro-environmental functioning of the SSSI on which the interest features rely, is explored in Section 4.
- A critical review of SZC Co.'s assessment of the current hydrological functioning of the SSSI and environs is provided in Section 5.
- A critical review of SZC Co.'s predictions of the possible ecohydrological impacts of the proposed development is provided in Section 6.
- A description of the fundamental shortcomings of SZC Co.'s approach to detecting and managing ecohydrological impacts on the SSSI caused by the development, in the not unlikely event that they occur, is included as Section 7.
- Summary and conclusions are provided in Section 8.

Documents within the PINS referencing system are referred to solely by their PINS reference number, whilst other sources are referenced by author/date, with the full reference provided in the References section.

3 Wetland plant communities and species of ecohydrological interest in this context

Sizewell Marshes are notified as a SSSI and described in the SSSI citation[1] as a '*large area of lowland, unimproved meadows which supports outstanding assemblages of invertebrates and breeding birds*' with '*an extensive network of ditches across the site*'.

The principal wetland vegetation type of importance is the National Vegetation Classification (NVC[2]) M22 *Juncus subnodulosus-Cirsium palustre* fen-meadow (Rodwell, 1991) as presented by recent surveys (APP-229, AS-021, Stone 2019), and includes forms of M22 that are both species-rich (34-48 species in permanent monitoring plots, Stone, 2019) and with a high frequency of low-growing species such as *Carex panicea, Galium uliginosum, Hydrocotyle vulgaris, Lysimachia tenella*. This fen-meadow vegetation comprises the ***Neutral Grassland - Lowland*** conservation feature for the purposes of reporting on condition by Natural England, and the most recent condition assessment by Natural England (Sept. 2009) notes all four units

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[1] https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/1003416.pdf, accessed 28th May 2021.

[2] The British National Vegetation Classification is a system for classifying natural habitat types within Great Britain according to the vegetation they contain, documented in a compendium of five volumes of *British Plant Communities*, edited by J.S. Rodwell. There are a total of 286 separate vegetation communities.

of the SSSI as being favourably maintained with respect to both the fen meadow and associated ditch system. In addition, English Nature's (now Natural England's) Suffolk Team agreed in 2004 that '*those permanent plots located within the Sizewell Marshes SSSI are sufficient to provide a framework for an adequate record for condition assessment of the Neutral Grassland - Lowland conservation feature*' (Stone, 2019). The most recent condition assessment of permanent plots (Stone, 2019) concluded that the lowland grassland feature was 'favourable recovered" and noted management as a combination of mowing, hay cutting and aftermath grazing. Favourable condition of the M22 fen-meadow principally relies on the following three attributes being within a favourable regime: water supply mechanism (to maintain the correct water table, particularly during summer), water quality (to provide water chemistry within the range required for many component wetland plants), and mowing and grazing (to keep the fen vegetation open by suppressing taller species such as reed, some species of rush and preventing encroachment of willow scrub). Risks to the water supply mechanism and water quality are considered here.

Table 1 (included at the end of this document) lists a number of key species recorded from surveys of M22 vegetation and the associated ditch network for the SSSI (AS-021, APP-229, Stone 2019) that are considered sensitive to changes in the water supply mechanism or water chemistry and/or are listed in *A Vascular Plant Red List for England* (Stroh *et. al*, 2014). In summary, the vegetation of Sizewell Marshes is of exceptional importance especially in the context of East England and it is this vegetation (the ***Neutral Grassland - Lowland*** conservation feature) that supports the equally exceptional invertebrate and bird interests.

It is important to note here that:

1. The follow-up (2020) vegetation survey (AS-021) only looked at a small area of the SSSI (Fields A-E) and did not reference earlier sample points (APP-229) stating that "*no direct comparison is possible*" and did not assess ditches.
2. The number of Red List status (Stroh, *et al*., 2014) and other key plant species occurring within the SSSI (Table 1) has not been updated in relation to all surveys and therefore the importance of the SSSI is underestimated. The Red List (Stroh *et. al*. 2014), in particular, is based on statistical analysis of an extensive dataset and provides the most up to date assessment of the rarity of a species, and it is particularly important in highlighting species most vulnerable to loss or modification of habitat in England. Sizewell Marshes has 17 Red List species (Table 1) the vast majority of which are wet grassland or ditch species sensitive to changes in hydrological supporting conditions and/or water chemistry.

It is our view that these are serious shortcomings of the SZC Co. submissions.

4 Favourable Hydrological Supporting Conditions for communities and species of interest

4.1 The concept of hydrological supporting conditions for wetland plant communities

Wetland plant communities can be associated with more-or-less specific hydrological supporting conditions which allow survival and competitive advantage of constituent species, often through functional adaptations (e.g., Mitsch and Gosselink, 2000). A significant effort was made to collate information on hydrological supporting conditions for a wide range of wetland and other habitats in the UK (~2000-2010), in order to support hydrological impact assessments under the EU Habitats and Water Framework Directives; the resulting information was reported primarily in a series of Ecohydrological Guideline publications, e.g., Environment Agency (2010).

Three elements can be considered in order to define hydrological supporting conditions:

- A <u>variable</u>, which describes a fundamental property of the incident hydrological regime, such as the depth of the water table below the ground surface, the rate or velocity of flow in a channel, or the pH of soil water.
- A <u>metric</u> (or metrics) which describe important characteristics of the behaviour of the variable, such as the annual range of water level, and the lowest or highest annual water levels.

- Thresholds or bounds which describe the limits within which the metric(s) should fall in relation to favourable or unfavourable supporting conditions.

4.2 Generic information on hydrological supporting conditions for the M22 plant community

Environment Agency (2010) contains collated ecohydrological information relating specifically to the M22 *Juncus subnodulosus* – *Cirsium palustre* fen meadow community in question here, in terms of both potential damage and loss at Sizewell Marshes SSSI, and development at the three fen meadow compensation sites. The ecohydrology of M22 represents a vital context for nature conservation-related assessment of the development proposals. The following information is of particular note from Environment Agency (2010):

General

- Substratum and irrigating water are typically of circumneutral pH (pH~7), though there are examples of low pH on upland margins or partly drained sites.
- Approximately 70% of stands were irrigated by groundwater and 10% by surface water, with the remaining 20% either irrigated by a mixture of groundwater and surface water, or sites with low summer water tables (where the surface can be exclusively rain-fed). Examples on floodplains tend to be surface water-fed, whilst examples at valleyheads are mostly groundwater-fed. In some topogenous[3] situations, surface water may be derived from proximate groundwater.
- M22 has been associated with a wide range of water supply mechanisms, with most associated with permanent or intermittent seepages or where the water table is shallowly sub-surface all year, sometime peripheral to permanent seepages.
- Mean summer water tables in monitored stands were; mean = 0.108 mbGL (metres below ground level), minimum = 1.750 mbGL, maximum = -0.122 mbGL (above surface). Much of the variation in species composition can be attributed to differences in the kind and degree of waterlogging. For example, species such as Lesser Pond-sedge *Carex acutiformis*, Greater Tussock-sedge *C. paniculata* and Brown Sedge *C. disticha* tend to be associated with wetter conditions, whilst species such as Hairy Sedge *C. hirta* and Tufted Hair-grass *Deschampsia cespitosa* are more typical of summer-dry conditions.

Optimal water levels

- M22 is usually characterised by a summer water table that is below the ground surface (0.05-0.18 mbGL), with the highest summer water tables being groundwater-supported.
- The most species-rich stands are found where summer water tables are between 0.05 and 0.20 mbGL.

Sub-optimal or damaging water levels

- Very wet sites (summer water table usually above the surface between tussocks) tend to be less species-rich. Prolonged inundation, particularly in summer, is likely to be damaging.
- Moderate lowering of the water table may increase species-richness, but long-term lowering of the summer water table beneath high-quality stands can be expected to result in the loss of some botanical interest.

Nutrients/hydrochemistry

- The pH of interstitial water in monitored stands was (pH units); mean = 6.6, minimum = 4.5, maximum = 8.1.

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[3] Wet conditions are described as topogenous if their primary cause is a downstream impediment to flow; this might be natural (e.g. the downstream lip of a basin in the topography) or artificial (e.g. a dam or earth bund). Topogenous wetness is generally associated with more potential for inundation, stagnation, and low dissolved oxygen and related hydrochemical effects.

- The conductivity of interstitial water was (μS cm^{-1}); mean = 612, minimum = 113, maximum = 1,780.
- The community is typically found is base-rich conditions over a wide range, but usually with a moderate level of fertility. Some of the least fertile sites were the most species-rich. Low fertility may help to retard invasion by tall-herb fen and scrub into unmanaged stands.

Vulnerability

- The wide range of water table conditions makes it difficult to comment on how vulnerable M22 is to drainage. The community can accommodate eutrophication[4] without change to the basic composition provided active management continues, although eutrophication of low fertility stands could cause floristic change and possible loss of distinctive features.
- Accurate assessment of vulnerability should require careful site-specific investigations.

4.3 Hydrological supporting conditions and the M22 plant community within Sizewell Marshes SSSI

APP-229 describes several stands of vegetation that are likely to be influenced by groundwater seepage – vegetation stand FM2 (at the valley foot slope) '*may reflect the influence of groundwater seepage or localized inundation hollows*'. In addition, the local (in England) moss *Scorpidium cossonii,* a species characteristic of calcareous fens[5] often where these are spring-fed (Graham *et. al*, 2019), was recorded from stand FM3c described as an '*inundation hollow'*.

APP-229 also provides plant data for a number of uncommon submerged aquatic species, as well as two rare emergent species (*Sium latifolium, Carex diandra*). Many of these submerged aquatics are intolerant of eutrophication (having an Ellenberg N value of 4-5), and species such as Fragile Stonewort *Chara globularis,* Water-violet *Hottonia palustris* and Fen Pondweed *Potamogeton coloratus* are characteristic of calcareous water with low turbidity and low concentration of the key nutrients phosphate and nitrate. Such water chemistry is most often associated with a water supply mechanism strongly reliant on groundwater. In addition, the majority of these key aquatics require ditches to permanently hold water (at least 30 cm depth) through the summer months and will not tolerate prolonged periods of drawdown.

Many of the species listed in Table 1 are characteristic of low nutrient conditions, shown by average vascular plant Ellenberg values for Nitrogen of around 3. Ellenberg Nitrogen (N) values estimate the position along a productivity/macro-nutrient availability gradient at which a species reaches peak abundance. The Ellenberg N Index allows allocation of a N score to each plant species, so that the overall mean score for a plant community lies on a scale of nutrient poor (1) to nutrient rich (10). In addition to a generally low nutrient status, vegetation data (APP-229) strongly indicate localized but wide-ranging variation in pH where areas with calcifuge species (such as Common Cottongrass *Eriophorum angustifolium,* Bogbean *Menyanthes trifoliata,* Purple Moor-grass *Molinia caerulea*) can exist in close proximity to calcicoles (such as Marsh Valerian *Valeriana dioica,* Carnation Sedge *Carex panicea,* Intermediate Hook-moss *Scopridium cossonii*). All of these findings characterise a hydrologically very complex, low fertility site where some groundwater seepage occurs involving both calcareous and mildly acidic water chemistries, with much variation at a microtopographic level.

5 Assessment of the current hydrological functioning of Sizewell Marshes SSSI, which leads to the occurrence of favourable hydrological supporting conditions for M22

The ecohydrological analysis and conceptual model presented by SZC Co. has failed to identify the controlling variables and mechanisms which directly control the variables defining the hydrological supporting conditions for the M22 community within Sizewell Marshes SSSI. This means that knowledge of the sensitivity and vulnerability of this community to the proposed

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[4] Caused by an excess of nutrients, which reduces growth-limiting factors, leading to changes in vegetation communities.

[5] Fens which depend on a supply of groundwater discharge with relatively high concentrations of calcium and other base cations.

development, and therefore the impact assessment, falls significantly short of current knowledge and practice in wetland ecohydrology.

Some examples of the above are:

- Section 4.1 of Appendix A of APP-304, where the status of the monitored stands of M22 in terms of various environmental gradients (pH, moisture) is explored descriptively using Ellenburg values. It is concluded in para 5.1.8 that '*these key patterns and trends have been compared against the conceptualisation outlined in the groundwater conceptual site model (CSM) to identify likely mechanisms for the patterns and trends observed. It is considered that the CSM provides a suitable mechanism that offers an explanation for the patterns of vegetation distribution observed*'. Our firm view is that with more detailed and informed ecohydrological monitoring and analysis, it would have been possible to identify the actual, rather than the 'likely' mechanisms which explain the expression of M22, and therefore to develop a more detailed and certain ecohydrological conceptual model.
- Highlighting a higher water table elevation in the Peat, compared to the water level in the ditch system, Section 6.4.4 (APP-304) concludes that "*it may therefore be that groundwater contributes to the surface water during dry conditions in the eastern (downstream) part of the Marshes*". Our view is that fully-screened shallow (c. 1 m deep) dipwells should have been installed in the Peat at the most notable stands of M22 (e.g., FM2 and FM3c, see Section 4.3), in order to allow assessment of the relative contribution of groundwater discharge as a water source at these points. It appears that this was not carried out, and therefore we are reliant on descriptions in reports, or the presence of species such as Intermediate Hook-moss *Scorpidium cossonii*, to infer direct groundwater discharge to the ground surface.
- The omission of a comprehensive surface water and shallow groundwater monitoring programme has prevented the development of a satisfactory conceptual understanding of the fine-scale ecohydrological dynamics of the system. Such an understanding was critical if an effective assessment of risk was to be developed, which would understand the impacts of the development to the designated site. Low-growing M22 species (such as Carnation Sedge *Carex panicea,* Marsh Pennywort *Hydrocotyle vulgaris*) and bryophytes are sensitive to such changes at a microscale.
- Collection and interpretation of groundwater and surface water quality data in Section 6.5 (APP-304) concentrates on water-typing and salinity dynamics using major ions data. While this may help to explain the occurrence of characteristic brackish species towards the eastern edge of the marsh (such as *Bolboschoenus maritimus, Juncus gerardii, Triglochin maritimus*), no information has been found within the SZC Co. submissions on the nutrient concentration of Peat and Crag groundwaters; evidence or otherwise of low-nutrient groundwaters would test the importance of groundwater support for the M22 fen-meadow communities.
- It is highly instructive that within the hydrographs presented in Appendix B of Chapter 19 of the ES (APP-304), and in the CSM addendum (APP-304 to APP-308 incl.), water table elevation in the Peat is never plotted in relation to the ground surface. This variable is very widely recognised as the most important in relation to defining hydrological supporting conditions for M22 (see Section 4.2). Its use also allows more effective analysis of near-surface hydro-dynamics, which in turn can inform identification of key water supply mechanisms; this appears to be absent from the SZC Co. submissions.
- Rainfall data are absent from the groundwater level hydrographs presented in Appendix 19B1.1 (CSM addendum, APP-305 to APP-308 incl.) for large parts of 2016 and the whole of 2017-9, and it must be assumed that there was a failure to collect rainfall data during this period. The absence of rainfall data, which obviously represents a primary control on surface water and groundwater behaviour, will have compromised the analysis of all other hydrological responses at a fundamental level, as demonstrated through the hydrographs in Appendix 19B1.1. If rainfall data do exist for this period, they should have been included in the SZC Co. submissions.

It is our view that the hydro(geo)logical functioning of the shallow zone within Sizewell Marshes SSSI, which controls the variables which define the hydrological supporting conditions for the M22 fen-meadow, should have been monitored, analysed and characterised in much more detail, using a contemporary ecohydrological approach. This would have allowed the hydrological dependencies and vulnerabilities of the M22 to be understood in more detail, and with less uncertainty, which would in turn have greatly improved the quality of the impact assessment.

From the available evidence we conclude that direct, upwards groundwater flow and discharge, in response to the hydraulic gradient from the Crag to the Peat, is almost certainly a critical source of water to some of the stands of M22. It is critical because it allows favourable hydrological supporting conditions to be maintained, in terms of water table elevation regime and water quality, for these stands.

6 Assessment of the risks on the current favourable hydrological supporting conditions for M22 posed by the proposed development

There are three major developments that have the potential to have a major impact on the sensitive ecohydrological functioning of the wetland system. These are:

1. The new cut-off wall adjacent to the platform base for the new site, and related internal lowering of groundwater levels (dewatering) during the construction phase;
2. The re-routing of the Sizewell Drain (e.g., Figure 19C.1, APP309); and
3. The new crossing at the drainage outlet for the Sizewell Drain and the Leiston Drain (SZC Co. Document No. 6.15 of 10th March 2021).

6.1 Summary of potential impacts

Changes to the wetland system will have unknown impacts given the lack of understanding of how the system is operating at the fine scale, as noted in the section above. This is compounded by a lack of detail on the design of the three main critical developments. It is not sufficient with such a significant development to design the mitigation plan at a later stage. The acknowledgement that dewatering activities have the potential to alter the existing flow regime characteristics is welcome, but mitigation is not appropriate. Paragraph 19.6.35 (APP-297), for example, states that '*the dewatering activities have the potential to increase or lower the water levels of the Sizewell and Leiston Drains and the Sizewell Marshes SSSI*'. It is our opinion that the subsequent ecological impacts are more severe than both the qualitative risk assessment and numerical modelling appreciate.

19.5.8 of APP-297 provides an overview of the plans for two of the three developments, but for each there is a distinct lack of detailed plans or assessments of the likely impacts on the combined surface water-groundwater system. For example, the "*low permeability*" of the hydraulic cut-off wall is referred to, but no absolute value is given to the design criteria, and no previous demonstrations of successful emplacements of cut-off walls are provided. Nor is there an assessment of the impact if the cut-off wall has insufficient isolation for the wetland system, which presumably would induce drainage of the wetland (see Section 6.3). Further, "*There is a potential for slumping to occur of the Peat adjacent to the main platform, which could have a detrimental effect on the Sizewell Marshes SSSI. A secondary cut-off wall would be installed at the toe of the embankment slope leading to the main platform. This cut-off wall would utilise sheet pile methods to prevent the surrounding Peat and Crag formations from slumping.*" The planned approach appears to be reactionary when it will need to be proactive to avoid catastrophic damage to readily mobile SSSI substrate material.

The improved amended submission (AS-181) providing more detailed plans for the SSSI crossing is welcome, but the submissions remain unsatisfactory in terms of assessing the impact on the combined surface water-groundwater system. Although the single span bridge (detailed in Section 2.2 b vi) is much improved over the previous culvert design, it is considered to remain a high impact design. A free span bridge would be far less impacting, as it would leave a significantly wider corridor unchanged, to facilitate original, undisturbed hydraulic control and subsurface drainage of the SSSI site.

The wider impacts of changes to the hydrological system are not accounted for in the submission. Paragraph 19.6.36-37 of APP-297 discuss the clear hydraulic connection between the Leiston Drain (and therefore the Sizewell Drain and SSSI site) and Scott's Hall Drain, given that they share the southern discharge chamber of the Minsmere Sluice. The submission states that '*The back flooding could lead to adverse impacts on the Minsmere to Walberswick Heaths* *and Marshes SSSI, SAC, SPA and Ramsar site*'. It is asserted that flows across the hydrological regime are likely to cause impacts, i.e., that low flow changes could impact summer water levels also. Some appreciation of this is mentioned in Paragraph 19.6.103, but these risks have not been assessed sufficiently, with little appreciation for the real risk to sensitive habitats from unforeseen hydrological change.

6.2 Regarding the qualitative assessment

The qualitative assessment undertaken in the submission (APP-297) is fundamentally undermined by a lack of appreciation for the delicate groundwater-surface water interactions across the SSSI. The lack of description of these processes, or an attempt to monitor them effectively, is a basic omission, as detailed above.

Critically, where the qualitative assessment concluded that a potential impact was not significant, further detailed analyses were not undertaken. This is a process failure, not following the precautionary principle to account for potential errors in the qualitative assessment. The impact of the SSSI crossing has an obvious potential to cause alteration to the hydrological processes at the outlet of a designated wetland site.

The requirement for detailed knowledge is demonstrated by some key observations within the submission. Paragraph 19.4.26 in APP-297 states that '*Groundwater levels within the Peat Deposits were noted to be highly responsive to temporary pumping during maintenance works at the Minsmere Sluice from October 2013 to February 2014 suggesting a high degree of connectivity between the surface water network and the Peat groundwater system*'. This high degree of connectivity fundamentally undermines the qualitative assessment, as it shows that changes to water levels in one part of the site will induce a change in other parts. As demonstrated below, the impacts of these changes are significant. This is followed by the following quote from Paragraph 19.4.78 of the same reference: *'The water types observed across the site indicate that there is continuity between the Peat Deposits and the surface water drains, with proximity to the drains influencing the observed water type within the Peat.'* Although we need to assume that the term 'water types' means water in different parts of the system, it suggests that water in the main body of the soil profile across the wetland responds to that in the ditches, and therefore that there is a high degree of lateral hydraulic conductivity. This indicates significant damage is likely to be induced by the development as it changes water levels in the Sizewell Drain for example.

6.3 Regarding the design and application of the numerical model (the quantitative assessment)

The hydrological impacts of the proposed development on the various receptors are assessed within the submission mainly through the use of a combined surface water and groundwater numerical model (Appendix 19A, APP-298 to APP-303) which is based on the hydro(geo)logical conceptual model which is presented in the (illogically) subsequent Appendix 19B (APP-304 to APP-308). The hydrological and hydrogeological conceptual model has not been appropriately developed to allow robust assessment of the impacts of the three developments. For example:

- There is projected to be an 11 cm lowering of groundwater levels in the Peat in late-2024 (Paragraph 5.1.15, APP-298). Following the initial phase of dewatering the maximum projected drawdown in the majority of Peat piezometers[6] is 7-8 cm, typically during summer (Paragraph 5.1.16). Unfortunately, it is difficult to assess the significance of this projected drawdown as the current groundwater level (i.e., water table elevation) relative to the ground surface has not been presented in the documentation (see Section 5). The magnitude of the projected drawdown is c. 50% of the range in optimal summer water table depth observed in stands of M22 (0.05-0.18 mbGL, Section 4.2); this indicates that the projected drawdown could easily take the water table elevation outside of the optimal range for the summer water table, and therefore shows that the M22 community and key aquatic plants within the associated ditch system are significantly vulnerable to the projected

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[6] Instrument which allow measurement of groundwater level, in this case within the Peat within Sizewell Marshes SSSI.

drawdowns. This is not considered as anything more than a 'not significant' risk to the designated site, which is a major failing of the risk assessment process.

- Sensitivity analysis was carried out to take account of the uncertainties in some of the model input parameter values. To address uncertainty in the hydraulic conductivity of the cut-off wall, a model run was performed in which the hydraulic conductivity was doubled (Paragraph 5.2.4, APP-298). It was found that this doubling in hydraulic conductivity caused a doubling of water table drawdown within the Peat in Sizewell Marshes SSSI. A directly proportional relationship between the hydraulic conductivity of the cut-off wall and water table drawdown, within reasonable limits, is implied.

  It is our view, given that the overall hydraulic conductivity of the cut-off wall will be highly sensitive to less-than-perfect emplacement of the cut-off wall (no evidence has been provided on the established efficacy of the cut-off wall technique - see Section 6.1), that consideration of only a doubling in hydraulic conductivity is unrealistically optimistic, and that the possibility that the overall hydraulic conductivity would be three- to five-times higher than designed should be assessed. If the directly proportional relationship between hydraulic conductivity of the cut-off wall and water table drawdown is assumed, this would give predicted drawdowns of the summer water table in the region of 30-50 cm; M22 is clearly extremely sensitive to this magnitude of drawdown (Section 4.2) and this could be catastrophic for key aquatic plants within the ditch system (such as such as Fragile Stonewort *Chara globularis,* Greater Bladderwort *Utricularia vulgaris,* Fen Pondweed *Potamogeton coloratus,* Whorled Water-milfoil *Myriophyllum verticillatum,* Frogbit *Hydrocharis morsus-ranae)*.

- It is notable that combinations of sensitivity analyses have not been carried out, i.e. model runs where more than one of the inputs to the baseline model is changed. It is our view that the scenarios considered within the sensitivity analyses are not sufficiently unlikely that one or more could not occur simultaneously; that is, for example, it is not very unlikely that the hydraulic conductivity of the cut-off wall could be higher than assumed <u>and</u> a three-year drought occurs during the dewatering period. It is therefore our view that reasonable combinations of sensitivity analyses should have been carried out.

Given the above, our view can be summarised as:

- The M22 within Sizewell Marshes SSSI is significantly more vulnerable to the projected lowering of the water table elevation within the Peat during the period of construction dewatering than is portrayed in the SZC Co. submissions.
- The design of the sensitivity analyses is overly optimistic; the effects of a three- to five-fold increase in the hydraulic conductivity of the cut-off wall should have been tested, and some (not unlikely) combinations of single sensitivity analysis scenarios should have been tested. If this had been done, it would have shown that there is a reasonable chance that projected drawdowns will be significantly larger than the base-case model, and in turn that the M22 community is potentially significantly more vulnerable to the proposed development.

7 The proposed water monitoring and mitigation strategy

The proposed water monitoring and response (or, more accurately, monitoring and *mitigation*) <u>strategy</u> is set out in Appendix 2.14.A (AS-236) which is titled as an update to Appendix 19F of Volume 2 of the original ES (APP-309). The following sections detail our fundamental concerns in relation to the approach taken to monitoring and mitigation in relation to the potential impacts on the ecohydrology of Sizewell Marshes SSSI from the proposed development.

7.1 The absence of a monitoring and mitigation plan

The water monitoring and response <u>strategy</u> (AS-236) sets out a standard hydro(geo)logical 'monitor and mitigate' approach, where up-to-date field monitoring data are used continuously to test the current conceptual model, and the distribution and magnitude of predicted impacts. However, it is important to note that a monitoring <u>plan</u> does not yet exist; it is proposed that (Paragraph 1.3.2) such a plan will be '*developed following consultation with appropriate stakeholders*, and that it could '*also be used to inform a revised Water Level Management Plan for the SSSI'*.

The description of the proposed monitoring plan within the strategy document is insufficiently detailed. The parameters to be recorded at each site are not specified within the main body of text within the documentation (e.g., AS-236; 1.2.5 through 2.2.8). Ideally, flow would be measured (or estimated), along with water level, given the reliance on the main channels in the system – the Leiston Drain and the Sizewell Drain – for conveying flow through the system.

The interpretation is similarly superficial. It is not stated which monitoring points are upstream and downstream; this critical information must be inferred from existing knowledge of the system from a desktop study. Despite this, the hydrological monitoring of the surface water drainage system appears largely comprehensive. The ability to inspect the quality assurance of the data, post-processing and derived datasets would have been welcome and provide transparency and improve confidence in the programme from independent experts.

In contrast, the proposed in-field monitoring programme across the Sizewell Belts appears to have been poorly designed and not able to facilitate an appropriately detailed understanding of the hydrological dynamics of the wetland system. This is especially true to the west of the designated site. This prevents a robust demonstration of zero impact on the fragile wetland system.

It is important to realise in this context that many aspects of the development of a monitor and mitigate plan can be contested amongst stakeholders, and that the implied relatively short timescale for determination is not realistic:

- The volume and related cost of monitoring, processing of monitoring data and periodic reporting can clearly be contentious. It will be necessary to agree, for example, data quality-checking procedures and reporting, detailed actions and timescales in relation to the loss of a monitoring point, periodic reporting requirements, and the requirements of the stakeholders which review the reports; these all has long-term cost and logistical implications for the developer, and must be agreed.
- Setting of trigger levels is often difficult and highly contentious, with stakeholders being concerned that trigger levels will be exceeded too often, or that they don't protect the receptor in question. Recourse could be made to comparison of monitoring data with model-predicted values (see, for example, the Water Level Management Plan for the Cornelly Group of Quarries in South Wales), in order to make the impact-detection process more sensitive, but development of the related models and assessment techniques is technically challenging.

All of the above are inevitably time-consuming and have large scope for disagreement. It is our view, based on direct experience of work in a similar context at a large number of sites, that the implied assumption that the development of a hydro(geo)logical 'monitor and mitigate' plan with stakeholders will be relatively straightforward and to schedule is completely unrealistic. Development and agreement of the monitoring and mitigation plan, since it forms a part of the ecohydrological viability of the proposed development, should therefore be addressed at the earliest stage in the planning process.

7.2 Principle-level inappropriateness of the apparent ecohydrological mitigation strategy for Sizewell Marshes SSSI

Paragraph 1.3.16 of AS-236 states....

'Trigger levels would be defined, which would relate to the degree of change observed such as change in level or flow, and duration of the change. Each trigger level would involve suitable intervention to avoid or mitigate predicted significant environmental effects on groundwater or the site or surrounding area. For example, this may require altering the management arrangements for existing and proposed water control structures within the Sizewell Marshes SSSI to modify the movement of water through the wetland'.

And Paragraph 1.3.19 of AS-236 states…

'It is envisaged that the principal mitigation options would relate to the new control structure to be installed at the northern end of the realigned Sizewell drain and operational practice within the Sizewell Marshes SSSI. Consequently, this approach is consistent with the existing operational management regime within the system'.

These passages would appear to be the only information on possible mitigation strategies for Sizewell Marshes SSSI, to be applied if, in practice, hydro(geo)logical impacts are found to be larger than predicted. From them, we are forced to infer that, if drawdown of the water table in the Peat within Sizewell Marshes is larger than predicted, water levels in the drainage ditch network will be raised, such that water migrates from the ditches into the Peat layers to maintain in-field water table elevations. This would appear to be a safe inference as inflowing surface waters are the only source of 'extra water' to effect drawdown mitigation. This principle for mitigation is completely inappropriate, as follows.

From an eco-hydrochemical perspective

Paragraph 19.4.63 of APP-297 notes that '*although water quality in the drainage catchments generally meets WFD 'good' status, there are failures. Parts of Leiston Beck are affected by consented discharges from the Leiston water recycling centre and display elevated concentrations of ammonia, nitrate, nitrite and phosphate'*.

Further information is given in Appendix 19E of the ES (APP-309) which, in Table 1.9, notes that long-term (2010-2013) average nitrate concentrations in surface waters were 18.3 mg/l NO_3, with a maximum of 94 mg/l NO_3. At seven of the monitoring sites maximum nitrate concentrations were in excess of 50 mg/l. High nutrient concentrations in the Leiston Drain/Beck would be expected, since the surface water conceptual model (Appendix 19E, APP-309) notes that *flows in the Leiston Drain are heavily influenced by the consented discharge of treated effluent from the Leiston Sewage Treatment Works* (STW) (Executive Summary, Appendix 19E, APP-309). For example, STW discharge represented an average of 40% of total flows in the Leiston Drain between March and December 2011 (Paragraph 1.3.29, Appendix 19E, APP-309). STW discharges are widely accepted (including by the submission) to have higher nutrient concentrations.

Section 1.3.2 of AS-236 states that the future post-development monitoring will be '*developed following consultation with appropriate stakeholders'*. It is expected that this will include the technical experts acting on behalf of the charities objecting to the development, and that these costs will be covered by the developer. Section 1.3.3 of the same document states that water quality monitoring will be included here, and this is welcome. However, it is very poor project management that these have been left wanting thus far. As per Section 1.3.5, it is imperative that the objectors' technical experts are involved in the annual review of the datasets.

In general, nutrient concentration data for the surface waters within and around Sizewell Marshes SSSI, at least in the public domain, appears to be lacking. It is regrettable in this context that a summary of terrestrial surface water quality (APP-292) was withdrawn from the SZC Co. submissions.

UKTAG (2014) sets out threshold values for groundwater concentration of nitrate which, if exceeded, would indicate a pressure that could cause damage to a groundwater-dependent terrestrial ecosystem (GWDTE); it is our firm view that Sizewell Marshes SSSI is a GWDTE (see Section 5). The value given for *Fen (mesotrophic and fen-meadow)*, which is the habitat category most closely aligned with M22, is 22 mg/l NO_3. This shows that the long-term (2010-2013) average surface water nitrate concentration (18.3 mg/l, see above) was relatively close to the UKTAG (2014) threshold for potential damage to a GWDTE and, assuming a reasonable distribution around the mean, indicates that surface water nitrate concentrations, including within Sizewell Marshes SSSI, are frequently above this threshold. Irrigation of the M22 fen-meadow vegetation with this water, i.e., the proposed mitigation, is therefore likely to cause further damage.

Paragraph 1.3.33 (Appendix 19E, APP-309) notes that '*the consented discharge from Leiston STW contains higher levels of nutrients (including phosphates) than the rest of the drainage system'*, and that '*in order to reduce the ingress of nutrients into the wider drainage network, SWT have attempted to reduce connectivity between Leiston Drain and the drainage network on either side (Sizewell Belts and Sizewell Marshes) via the use of flow regulating structures'*. It is of significant concern to note that the proposed mitigation strategy appears to reverse this established protective practice.

From an eco-hydrophysical perspective

Management of water table elevation within Sizewell Marshes SSSI through manipulation of surface water (ditch) water levels implies fostering of more topogenous wetness within the M22 fen-meadow, rather than the soligenous[7] wetness that is implied by upwards groundwater discharge. This would cause fundamental changes in the water supply mechanics of the wetland system with associated changes in water chemistry. M22 is strongly associated with soligenous conditions (see Section 4.2), and therefore fostering of more topogenous conditions is completely inappropriate.

8 Summary and conclusions

To summarise and conclude, our view is that:

- As noted in its citation, Sizewell Marshes SSSI is a '*large area of lowland, unimproved meadows which supports outstanding assemblages of invertebrates and breeding birds*' with '*an extensive network of ditches across the site*'. A number of key species, which have been recorded through SZC Co. and other surveys, are considered sensitive to changes in the water supply mechanism or water chemistry and/or are listed as Red Data species. The vegetation of Sizewell Marshes is of exceptional importance especially in the context of East England and it is this vegetation that supports the equally exceptional invertebrate and bird interests.
- There are a number of serious shortcomings in the analysis and interpretation of vegetation surveys within the SZC Co. submissions, as detailed in Section 3.
- Environment Agency (2010) contains collated ecohydrological information relating specifically to the M22 *Juncus subnodulosus – Cirsium palustre* fen meadow community in question here. Importantly, over 70% of recorded stands were irrigated by groundwater, and optimal summer water tables are very high (0.05-0.18 mbGL), which is consistent with groundwater support.

  Most stands of M22 are associated with permanent or intermittent seepages or where the water table is shallowly subsurface all year, sometimes peripheral to permanent seepages; this indicates a strong preference for soligenous wetness, where wet conditions are maintained by continuous incoming flow, rather than downstream (usually topographic) impoundment.

  M22 is typically found is base-rich conditions over a wide range, but usually with a moderate level of fertility. Some of the least fertile sites were the most species-rich.
- Many of the species recorded within the SSSI are highly characteristic of groundwater dependence and low nutrient conditions, to the extent that they can be used as surrogate hydrological indicators. As such, our analysis indicates a hydrologically very complex, low fertility site where some groundwater seepage occurs involving both calcareous and mildly acidic water chemistries, with much variation at a microtopographic level.
- The environmental monitoring and analysis undertaken by SZC Co. has failed to identify the controlling variables and mechanisms which directly control the variables defining the hydrological supporting conditions for the M22 community within the SSSI; this is a fundamental failing of the SZC Co. work. It is our view that the hydro(geo)logical functioning of the shallow zone within Sizewell Marshes SSSI should have been monitored, analysed and characterised in much more detail, using a contemporary ecohydrological approach.

  For example, it is highly instructive and of very significant concern that water table elevation in the Peat is never plotted in relation to the ground surface within the SZC Co. submissions. This variable is very widely recognised as the most important in relation to defining hydrological supporting conditions for M22. Its use also allows more effective analysis of near-surface hydro-dynamics, which in turn can inform identification of key water supply mechanisms; this appears to be absent from the SZC Co. submissions.

  From the available evidence we conclude that direct, upwards groundwater flow and discharge, in response to the hydraulic gradient from the Crag to the Peat, is almost

[7] In contrast to topogenous wetness (see above), soligenous wet conditions are maintained by more-or-less continuous incident water flows, for example, groundwater discharge to a seepage slope. Soligenous wetness is associated with a low potential for inundation, and relatively high dissolved oxygen concentrations.

certainly a critical source of water to some of the stands of M22. It is critical because it allows favourable hydrological supporting conditions to be maintained, in terms of water table elevation regime and water quality, for these stands.

- Prediction of the ecohydrological impacts of the proposed development must be informed by the best-possible ecohydrological conceptual model; as noted above, our view is that SZC Co.'s conceptual model is significantly flawed, and therefore that the prediction of impacts (including the design and use of the numerical model) has not been informed to the best possible degree.
- Regarding prediction of impacts through use of the numerical model:
  - For the base-case model, the magnitude of the projected drawdown is c. 50% of the range in optimal summer water table depth observed in stands of M22 (Environment Agency, 2010); this indicates that the projected drawdown could easily take the water table elevation outside of the optimal range for the summer water table, and therefore shows that the M22 community is significantly more vulnerable to the projected drawdowns than is acknowledged within the SZC Co. submissions.
  - The design of the model sensitivity analyses is overly optimistic; the effects of a three- to five-fold increase in the hydraulic conductivity of the cut-off wall should have been tested, and some (not unlikely) combinations of single sensitivity analysis scenarios should have been tested. If this had been done, it would have shown that there is a reasonable chance that projected drawdowns will be significantly larger than the base-case model, and in turn that the M22 community is potentially significantly more vulnerable to the proposed development.
- Development and agreement of a detailed monitoring and mitigation plan, since it forms a part of the ecohydrological viability of the proposed development, should be addressed at the earliest stage in the planning process. The required contents of the plan, such as the scope of monitoring, data quality-checking procedures and reporting, detailed actions and timescales in relation to the loss of a monitoring point, periodic reporting requirements, and the requirements of the stakeholders which review the reports, all have long-term cost and logistical implications for the developer, and should be agreed before determination.
- The primary measure for mitigation of ecohydrological impacts from the development appears to be that, if drawdown of the water table in the Peat within Sizewell Marshes is larger than predicted, water levels in the SSSI drainage ditch network will be raised, such that water migrates from the ditches into the Peat layers to maintain in-field water table elevations. This measure is fundamentally inappropriate, and would actually cause further damage to the M22 within the SSSI as follows:
  - The historical recorded nutrient concentrations within the ditch network indicate that the threshold value for potential damage of mesotrophic and fen-meadow fens within a GWDTE would frequently be exceeded. This is unsurprising as a significant percentage of incoming flow comes from the Leiston STW.
  - It appears to promote topogenous wet conditions, with associated hydro-chemical and hydro-physical implications, rather than the soligenous wet conditions usually favoured by M22.

And in final summary, our view is that SZC Co.'s understanding of the environmental processes which support M22 and associated communities within Sizewell Marshes SSSI is flawed, because up-to-date ecohydrological knowledge and techniques have not been applied. This has led to ill-informed impact prediction, which has resulted in the likelihood, magnitude and significance of potential impacts being significantly underestimated. These problems have been compounded by SZC Co.'s proposal of a mitigation technique which would actually cause further damage to the SSSI, rather than mitigating any unexpectedly large impacts.

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Table 1. Key species associated with M22 fen-meadow surveys and associated ditches at Sizewell Marshes SSSI considered sensitive to changes in water supply mechanism or water chemistry and/or are Red List species (Stroh *et. al*., 2014) and Ellenberg values for Nitrogen (N), Hill et. al. (2004).

M22 fen-meadow species					
Latin name	**Red List status**	**APP-229**	**AS-021**	**Stone (2019)**	**Ellenberg value (N)**
Blysmus compressus	GB vulnerable		outside quadrat (Field C)		3
Briza media		FM1a, b, d		Plot G34, G38, M09	3
Caltha palustris		FM3b, 4	Q36, 37	Plot G34, G50, M07, M09	4
Carex demissa				Plot G38	2
Carex echinata		FM1b		Plot G38	2
Carex lepidocarpa		FM1b			2
Carex nigra		FM1a-d, 2, 3a-b, 4–5	Q21, 25-26, 29, 30, 32-33, 36, 40	Plot G34, G38, G40, G50, M09	2
Carex panicea		FM1a-d, 2, 3a-b, 4	Q29, 30, 33, 38	Plot G34, G38, G40, G50, M09	2
Carex pulicaris	England Near Threatened	FM1a-b		Plot G38	2
Cirsium dissectum		FM1b		Plot G34, G38	2
Climacium dendroides		FM1d		Plot G34	
Cratoneuron filicinum		FM1a, b, d, 4		Plot G34	
Danthonia decumbens		FM1b		Plot G38	2
Eleocharis uniglumis		FM1a-c, 3b,c		Plot G38, G50, M09	4
Equisetum palustre		FM1c, d, 2, 3a, b, 4, 5	Q25	Plot G34	3
Eriophorum angustifolium		FM1a, b, 2		Plot G34	1
Galium uliginosum		FM1a-c, 2, 4		Plot G38, G50, M09	4
Hydrocotyle vulgaris	England Near Threatened	FM3a, b, 4	Q21-25, 29, 38, 40	Plot G38, G40, G50, M09	3
Isolepis cernua			Area 4	Plot G40, M09	3
Isolepis setacea		FM1a, b, 3b		Plot G40, M09	3
Lotus pedunculatus		FM1a-d, 2, 3a-b, 4, 5	Q25 – 30, 33-35	Plot G38,G40, G50, M07, M09	4
Luzula multiflora		FM1c		Plot G38, G40	3
Lysimachia tenella		FM1a-b, 3a	outside quadrat (Field E)	Plot G38, M09	3
Menyanthes trifoliata		FM1a, d		Plot G34	3
Molinia caerulea				Plot G34, G38	2
Pedicularis palustris	England vulnerable	FM1b		Plot G38	2

Plagiomnium rostratum				Plot G38	
Ranunculus flammula	England vulnerable	FM1a-d, 3a-c, 4, 5	Q26-27, 30, 32-33	Plot G34, G38, G40, G50, M07, M09	3
Scorpidium cossonii		FM3c			
Silene flos-cuculi	England Near Threatened	FM1a, c-d, 3a-b, 4	Q26	Plot G34, G38, G40, G50, M07, M09	4
Stellaria palustris	GB vulnerable	FM2		Plot 50, M07, M09	4
Succisa pratensis	England Near Threatened	FM1a-d		Plot G34, G38, G40	2
Trifolium fragiferum	England vulnerable			Plot M09	6
Triglochin palustris	England Near Threatened	FM1b, 3a-c	Q22, 24, 26, 33, 41-43	Plot G34, G38. M09	2
Valeriana dioica		FM1a-d		Plot G34, G38	3
Valeriana officinalis	England Near Threatened			Plot G40, M07	5
Associated ditch species					
Latin name	**Red List status**	**PINS APP-229**	**PINS AS-021**	**Stone (2019)**	**Ellenberg value (N)**
Carex diandra		DY1b, c, 5			3
Catabrosa aquatica	England vulnerable	DY1b, 3, 4			7
Chara globularis		DY1b, d			
Drepanocladus aduncus		DY1c, 3, 4, 7		Plot 50, M09	
Hottonia palustris		DY1a, c			5
Hydrocharis morsus-ranae	GB vulnerable	DY1a-d, 2, 6, 7	Q6, 9		7
Myriophyllum verticillatum	GB vulnerable	DY1a - c			7
Oenanthe fistulosa	England vulnerable		Q32	Plot 40	6
Oenanthe lachenalii	England Near Threatened	DY1a, c, 3a-c, 4	Q23-25, 38, 40	Plot M09	5
Potamogeton berchtoldii		DY1b-d, 2, 3, 4, 7			5
Potamogeton coloratus		DY1c			5
Potamogeton natans			Q9		4
Sium latifolium	GB endangered[1].				7
Utricularia vulgaris		DY1a - d			4
Warnstofia fluitans		DY1a, c			
1 1984 (BSBI Distribution Databse)					