Environment Agency Approach to Assessing Acceptable Level of Abstraction in the Vicinity of Wetland Sites: Notes on the Approach and the 'Decision Table'

1. Introduction

The purpose of this Technical Note is to provide background information on the Environment Agency methodology for assessing the acceptable level of abstraction in the vicinity of groundwater-fed wetland sites. This Technical Note is a supporting document to the Environment Agency's Groundwater Summary Report (Environment Agency, 2014). The Groundwater Summary Report is an internal Environment Agency report which has been prepared as part of the process of determining the applications by Mr. Alston to renew his groundwater abstraction licences in the Ludham-Catfield area.

For the purposes of this Technical Note, the 'acceptable level of abstraction' (hereafter referred to as the Acceptable Level of Abstraction) is defined as the level of total, or 'in combination' abstraction which does not significantly alter the hydrological functioning of a wetland site, and which the Environment Agency is confident would not adversely affect the ecology of the wetland site.

This Technical Note covers the general approach to assessing the Acceptable Level of Abstraction, and provides an explanation of the 'Decision Table' which is used to score changes to the hydrological functioning of a wetland site.

2. Approach to Assessing Acceptable Level of Abstraction

The approach to assessing the Acceptable Level of Abstraction was developed during the Habitats Directive Review of Consents (HD RoC). Initially, an approach was developed for assessing the Acceptable Level of Abstraction in the vicinity of component Sites of Special Scientific Interest (SSSIs) forming the Norfolk Valley Fens Special Area of Conservation (SAC). This approach is set out in detail in the document presented in Appendix 1 and was agreed with Natural England during the course of Stage 4 of the HD RoC.

The approach developed for assessing the Acceptable Level of Abstraction in relation to the Norfolk Valley Fens was then generalised to other sites designated under the Habitats Directive and the Birds Directive. This approach is presented in Appendix 2.

The wetland SSSI potentially affected by the Alston abstractions is the Ant Broads and Marshes and the approach relevant to the Alston licence renewals is that presented in Appendix 2, The Norfolk Valley Fens approach is also presented because, although the method is the same, the documentation in Appendix 1 includes some useful notes in relation to the application of the approach to an example wetland site.

The main steps in the approach to assessing the Acceptable Level of Abstraction are summarised in Box 1. These steps are described in detail in Appendix 1 and Appendix 2.

The approach is intended to provide a good practice process for collating and combining the appropriate information for assessing the impacts of abstraction and assessing whether these are acceptable. The key elements of the approach are:

- To develop a good groundwater model representation of the aquifer system in the vicinity of the wetland, and particularly to achieve a good representation of dip-well data monitoring the behaviour of the water table;
- To assess the condition of the ecological interest features for which the site is designated;
- To characterise the abstraction in the vicinity of the site;
- To define reference model time-series representing hydrological behaviour based on an acceptable level of historical abstraction;

- To set threshold levels based on the model time-series to help quantify the degree of change to hydrological behaviour represented by the fully licensed level of abstraction;
- To judge whether the fully licensed level of abstraction could be viewed as an Acceptable Level of Abstraction.

Box 1: Main steps of approach to assessing the Acceptable Level of Abstraction

1. Collate and evaluate hydrological, geological and topographical information for the site and the surrounding catchment, in particular new information since Stage 3.
2. Characterise the abstraction licensing position (fully licensed) and history within the catchment.
3. Collate and evaluate information on site ecology and ecological history including Environmental Outcomes and Conservation Objectives provided by Natural England, in particular new information since Stage 3.
4. Develop updated integrated ecological and hydrological conceptual understanding.
5. Describe and evaluate the model representation.
6. Characterise the hydrological regime based on the model ('hydrological functioning') and evaluate if conceptual understanding is captured.
7. Based on ecological history establish if historical (actual) abstraction has been acceptable.
8. If historical (actual) abstraction apparently acceptable from an ecological point of view, assume that modelled historical time series (water levels and flows) represent acceptable conditions.
9. If historical abstraction <u>not</u> acceptable establish point in the past when level of abstraction <u>was</u> acceptable to identify acceptable hydrological conditions.
10. Use acceptable modelled historical time series (water levels and flows) for assessment cell to identify thresholds.
11. Compare time series (water levels and flows, soil moisture content) produced for the fully licensed abstraction scenario against the historical baseline and thresholds.
12. Decide whether or not the fully licensed abstraction scenario is acceptable.
13. If the fully licensed abstraction scenario is not acceptable identify scale of licence modifications and need for options appraisal (application of 'SOP decision table').

The approach requires that the condition of the ecological interest features on the wetland site is assessed. For the HD RoC, this task was undertaken in consultation with Natural England and other bodies as appropriate. It is important to understand what designated ecological interest features are present on a site and where they occur. Information on the condition of ecological interest features through time can be patchy, but it is important to obtain an up-to-date assessment of condition to assess whether there has been any damage to the site.

The approach further requires an assessment of abstraction quantity, and particularly how stable this has been. It is generally found that abstraction quantities reflect water company abstractions, and these have been relatively steady since the early 1990s.

Combining information on the condition of the ecological interest features and the quantity of historical abstraction allows a reference condition to be defined. For instance, for the situation where the ecological interest features are found to be in favourable condition and the abstraction has been steady for 20 years, it can generally be safely concluded that the historical level of abstraction has not led to any damage to the site, or any adverse effect on the ecology, and can be viewed as acceptable. For the case of the Ant Broads and Marshes and the Alston renewals, it was decided on a precautionary basis to set a reference condition based on levels of abstraction prior to 1986, and also to examine the sensitivity of setting a reference condition based on the no abstraction condition.

The reference condition can be used to define a portion of the model time-series which can be viewed as representing an acceptable degree of hydrological impact, and therefore a proven acceptable level of historical abstraction. The reference condition, together with threshold levels based on the reference condition, is then used to judge the acceptability of the fully licensed level of abstraction.

The groundwater model is used to generate the fully licensed abstraction scenario. It is the only tool that is able to do this. It is generally accepted across the groundwater professional community that groundwater models, subject to being adequately calibrated, are the best available tools for predicting the impacts of abstraction on hydrological functioning. The use of the groundwater model is therefore an important part of the Environment Agency approach to assessing the Acceptable Level of Abstraction.

3. Ecohydrological Guidelines

The Ecohydrological Guidelines were developed during the HD RoC to offer guidance on the hydrological needs of a range of ecological interest features and communities. The Guidelines were originally published in 2004 (Wheeler et al, 2004) and then updated and re-published in 2010 (Wheeler et al, 2010).

The Guidelines are based on observations of the hydrological conditions, particularly water table conditions that support different ecological interest features. For instance, the S24 feature, as found across the Ant Broads and Marshes, is reported to be supported by a water table regime that can vary from ground level, or just above ground level (inundation) in the winter, to below ground in the summer (15cm is quoted as typical but 30-40cm appears acceptable based on the data in the Guidelines). This is judged to represent an acceptable range; S24 is however also seen to occur where the water table extends outside of this range.

The implications of the guidance offered by the Ecohydrological Guidelines are that it is important to install monitoring to assess the water table range at any particular wetland site, and that it is then important to ensure that the water table range, as a component of the overall hydrological functioning is maintained in the acceptable range as indicated by the Guidelines and the local monitoring.

The approach to the assessment of the Acceptable Level of Abstraction seeks to capture the acceptable water table range in the groundwater model calibration so that the groundwater model can then be used to judge the acceptability of the fully licensed level of abstraction. It is important to appreciate that while abstraction may cause drawdown, a water table range generated by a fully licensed level of abstraction may be acceptable if the water table stays within the acceptable range. Again, the approach to the assessment of the Acceptable Level of Abstraction seeks to judge this with the aid of threshold levels and the extent to which the fully licensed abstraction scenario falls outside of the thresholds.

4. Primary and Secondary Criteria

The approach to assessing the Acceptable Level of Abstraction is based on generating model output for a reference model cell. Groundwater levels, groundwater flows, flows to watercourses and water balance information are generated for the reference condition and for the fully licensed abstraction scenario to judge the change in hydrological functioning that would potentially result from the fully licensed level of abstraction.

A scoring approach, incorporated within the ‘Decision Table’, is used to measure the change in the hydrological functioning by increasing to the fully licensed level of abstraction. The scoring approach is based on the so called ‘Primary Criteria’ rather than the full range of model water balance information available for the reference cell. The Primary Criteria are the water table level and the soil moisture content (see Box 2). It is possible to focus the scoring on a limited set of model water balance information because the water balance information for the reference cell is integrated and all the water balance components behave with reference to each other.

The remaining model water balance information is referred to as the Secondary Criteria (Box 2). This is still examined as part of the approach and is very important to assessing the Acceptable Level of Abstraction.

The Decision Table is presented in Section 5 below.

5. Decision Table

This section presents figures relating to Cell G (Catfield Fen) as an example of a reference model cell for which a Decision Table is completed:

Figure 1: shows model time-series relating to the discharge to watercourses, water table level, deeper groundwater levels, upward vertical flows and soil moisture.
Figure 2: shows model time-series relating to the Primary Criteria – water table and soil moisture.
Figure 3: illustrates the setting and use of the thresholds.
Table 1: presents the Decision Table for Cell G.

The Decision Table is largely populated with information drawn from Figure 1 and Figure 2. An explanation of the criteria which are scored is presented in Appendix 3. An explanation of the scoring system is presented in Appendix 4.

The Decision Table is used to score the changes in hydrological functioning due to the fully licensed level of abstraction compared to the reference historical condition. The reference historical condition is set up to represent the proven, acceptable level of historical abstraction. The fully licensed model results need to stay as close to the reference historical condition as possible to also be acceptable.

The Decision Table generates scores in a low, medium or high range, based on the degree of change in the hydrological functioning. A score in the low range would confirm to the Environment Agency that the change to the hydrological functioning due to the fully licensed level of abstraction would be very slight, and the presumption would be that the fully licensed level of abstraction would not lead to an adverse effect on the ecology of the wetland site.

Box 2: Primary and secondary criteria typically used for Norfolk Valley Fens.

Primary Criteria:

Drought summers

- Modelled water level in top active layer to remain above the lowest historical water level modelled.
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Non-drought summers

- Modelled soil moisture content to remain above field capacity (as the lower limit of a range that represents conditions where "water oozes from soil under foot") or above the stress threshold. (field capacity generally used for M13 and M5, stress threshold generally used for M24, S24/25, W5 and W6; no soil moisture threshold used for Desmoulin's Whorl snail)

Secondary Criteria:

Drought summers

- Soil moisture content to remain above stress threshold (only if appropriate).
- Modelled flows to remain above the regime of upward flow and stream discharge associated with the lowest historical water level modelled in drought summers.
-

Non-drought summers

- Modelled water level in top active layer to remain above the lowest historical water level modelled in non-drought summers; flows to remain above the associated upward flow and stream discharge.
-

Drought winters

- Soil moisture to return to saturation (no soil moisture threshold used for Desmoulin's Whorl snail)
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in drought winters; flows to recover to the associated regime of upward flow and stream discharge.
-

Non-drought winters

- Soil moisture to return to saturation (no soil moisture threshold used for Desmoulin's Whorl snail)

Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in non-drought winters; flows to recover to the associated regime of upward flow and stream discharge

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Issue Date: 18 March 2014

Appendix 1

Anglian Region Habitats Directive Review of Consents Stage 4 Summary Note: Technical Approach, Criteria and Threholds Applied for Inland Sites – Norfolk Valley Fens

Anglian Region Habitats Directive Review of Consents Stage 4

Summary Note
Technical approach, criteria and thresholds applied for inland sites

NORFOLK VALLEY FENS

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1. Introduction

In Stage 4 of the Habitats Directive Review of Consents (RoC) a Site Action Plan (SAP) and an Appendix 19 (list of licences to be affirmed, modified and revoked) has to be produced.

In Anglian Region the technical work that supports this process involves the production of a Site Option Plan (SOP). The SOP will be followed by Options Appraisal work if required.

The purpose of the Stage 4 Site Option Plan (SOP) is to confirm the predicted impacts of abstraction on the hydrological regime at the site in view of additional information that has become available since RoC Stage 3. The SOP then aims to identify whether these impacts are acceptable or unacceptable in terms of the effects on the ecology and structure and functioning of the site and therefore achieving the Environmental Outcomes for the site. The SOP will also identify any changes which the Agency believes are necessary to allow a conclusion of no adverse effect on the site to be reached and will make general proposals as to how those changes could be achieved.

2. Purpose of this Summary Note

The purpose of this note is to summarise the main features of the technical approach applied to RoC Stage 4 for inland sites in Anglian Region. In this note, the approach is illustrated and explained using examples from the application to the Norfolk Valley Fens SAC.
Further details on the site specific approach and the numerical models used can be found in the site specific SOPs and reports produced as part of the Regional Groundwater Modelling Strategy.

3. Overall Approach

From a RoC perspective it is essential that we are able to conclude that abstraction is not or will not have an adverse effect on site integrity and that our interpretation of Natural England's Environmental Outcomes can be achieved.

It is accepted that there are many pressures on these sites which can affect the hydrological structure and functioning and that all sites are subject to pressures and stresses.

The overall approach in the SOPs aims to allow definition of an acceptable level of abstraction based on an acceptable level of impact at the site. The SOP presents a detailed integrated hydrological and ecological conceptual understanding of the site based on all available information. Particular attention is given to the ecological history of the site and the hydrological functioning of the site in the location of the ecological features and under different climatic conditions.

The potential impact of abstraction at a site is assessed using a regional groundwater model. Through sequential chapters in the report the SOP aims to confirm the suitability of the model for use in the assessment by concluding that the model is adequately representing and reproducing our conceptual models at both a site and cell scale, where the cell is chosen to represent the location of the ecological features.

To provide a link between groundwater levels and available moisture in the plant root zone a soil moisture model has also been developed. This is used to assess the effects of abstraction on the soil moisture content above the water table.

Our interpretation of the Stage 4 Environmental Outcomes for the site agreed with Natural England, observations from the past and the modelled historical time series are used to develop site-specific model-based hydrological criteria against which different abstraction scenarios are then assessed.

Model results are generated for individual model cells (200m x 200m). Modelled water tables relate to the uppermost model layer in a whole grid square and can therefore not be compared directly to the real water table as observed in dipwells. 'Surrogate' model-based criteria and thresholds are therefore developed for the model cell used in the assessment. These 'surrogate' model-based hydrological criteria are designed to ensure the hydrological functioning of the site as a whole so that the Environmental Outcomes can be achieved.

4. Detailed Approach

The main steps of the approach are summarised in Box 1 for overview. The following text then gives more detailed explanation and examples for each of those steps.

Box 1: Main steps of approach

1. Collate and evaluate hydrological, geological and topographical information for the site and the surrounding catchment, in particular new information since Stage 3.
2. Characterise the abstraction licensing position (fully licensed) and history within the catchment.
3. Collate and evaluate information on site ecology and ecological history including Environmental Outcomes and Conservation Objectives provided by Natural England, in particular new information since Stage 3.
4. Develop updated integrated ecological and hydrological conceptual understanding.
5. Describe and evaluate the model representation.
6. Characterise the hydrological regime based on the model ('hydrological functioning') and evaluate if conceptual understanding is captured.
7. Based on ecological history establish if historical (actual) abstraction has been acceptable.
8. If historical (actual) abstraction apparently acceptable from an ecological point of view, assume that modelled historical time series (water levels and flows) represent acceptable conditions.
9. If historical abstraction <u>not</u> acceptable establish point in the past when level of abstraction <u>was</u> acceptable to identify acceptable hydrological conditions.
10. Use acceptable modelled historical time series (water levels and flows) for assessment cell to identify thresholds.
11. Compare time series (water levels and flows, soil moisture content) produced for the fully licensed abstraction scenario against the historical baseline and thresholds.
12. Decide whether or not the fully licensed abstraction scenario is acceptable.
13. If the fully licensed abstraction scenario is not acceptable identify scale of licence modifications and need for options appraisal (application of 'SOP decision table').

Step 1: Collate and evaluate hydrological, geological and topographical information for the site and the surrounding catchment, in particular new information since Stage 3

As a first step all information available from field investigations, hydrological monitoring and other sources is collated and evaluated to build up the conceptual understanding of the site and its surrounding catchment. How does the site and the catchment "work" hydrologically and hydrogeologically?

Example: Buxton Heath

See SOP Sections 3.1, 3.3, 3.4 and 3.6.

Step 2: Characterise the abstraction licensing position (fully licensed) and history within the catchment.

This step includes the characterisation of the 'fully licensed' abstraction licensing position with regards to size, distribution, uptake and general abstraction pressure in the vicinity of the site. It also summarises the development of abstraction over the last 35 years. The consideration of the 'fully licensed' situation includes new licences that have been issued under Reg. 48.

This provides information for the following key questions:

- How does the historical (actual) abstraction compare to the fully licensed situation that has to be assessed for RoC and will be modelled for the assessment?
- Is it likely that the licence uptake will reach 100% in the near future?

Although it might be likely that individual abstractions may take close to 100% of the fully licensed especially in dry years, this will not realistically happen with all licences included in the model area at the same time and not in every year, which is assumed for the fully licensed scenario in the model. In most of the catchments considered for the RoC Stage 4 work the recent actual abstraction represents 20-70% of the total fully licensed abstraction, with only a few individual abstractions reaching 90% or more of the full licensed quantity.

In general, licensed abstraction quantities are designed to meet the requirements in dry years rather than average years. Especially licences for spray irrigation are set up for peak demand in very dry summers periods. Therefore, actual abstraction in 'normal' years does generally not reach 100% of the full licence. Looking at the abstraction history, in a lot of catchments an almost constant 'gap' between licensed and actual abstraction can be seen from the early 1990s to today indicating that uptake of licensed abstraction has not significantly increased over the last 15 years.

If the demand increases in the future, it can be expected that this will require licensing of new sources and additional quantities before 100% of the current licensed abstraction is utilised in order to ensure security of supply also in future drought periods. Any applications for new sources and additional abstraction quantities will however go through the usual licensing process including environmental impact assessment.

- Has the actual abstraction over the last 10-15 years (i.e. including drought conditions in the 1990's) been decreasing, increasing or comparably stable?

If actual abstraction has been *decreasing or stable* over the last 10-15 years it can be assumed that any impacts from abstraction on the ecology would have become apparent by now. If actual abstraction has been *increasing* any impacts from abstraction may not have become apparent yet due to time lag in the ecological response. In most of the catchments considered for the RoC Stage 4 work actual annual abstraction has been fairly stable since about 1991. Before then, abstraction has generally built up gradually throughout the 1970s and 1980s.

Understanding how actual historical abstraction has developed over time is also necessary to interpret modelled time series e.g. for water levels, for different abstraction scenarios. The scale of difference between water levels and flows in a naturalised (no abstraction) scenario and the historical scenario is a function of the level of abstraction in the vicinity of the site.

Example: Buxton Heath

See SOP Section 3.2.

Since the early 1990's actual abstraction in the vicinity of Buxton Heath has been more or less stable (see SOP Figure 3.4 below). The actual uptake of abstraction in 2005 was about 40% of the total licensed quantity.

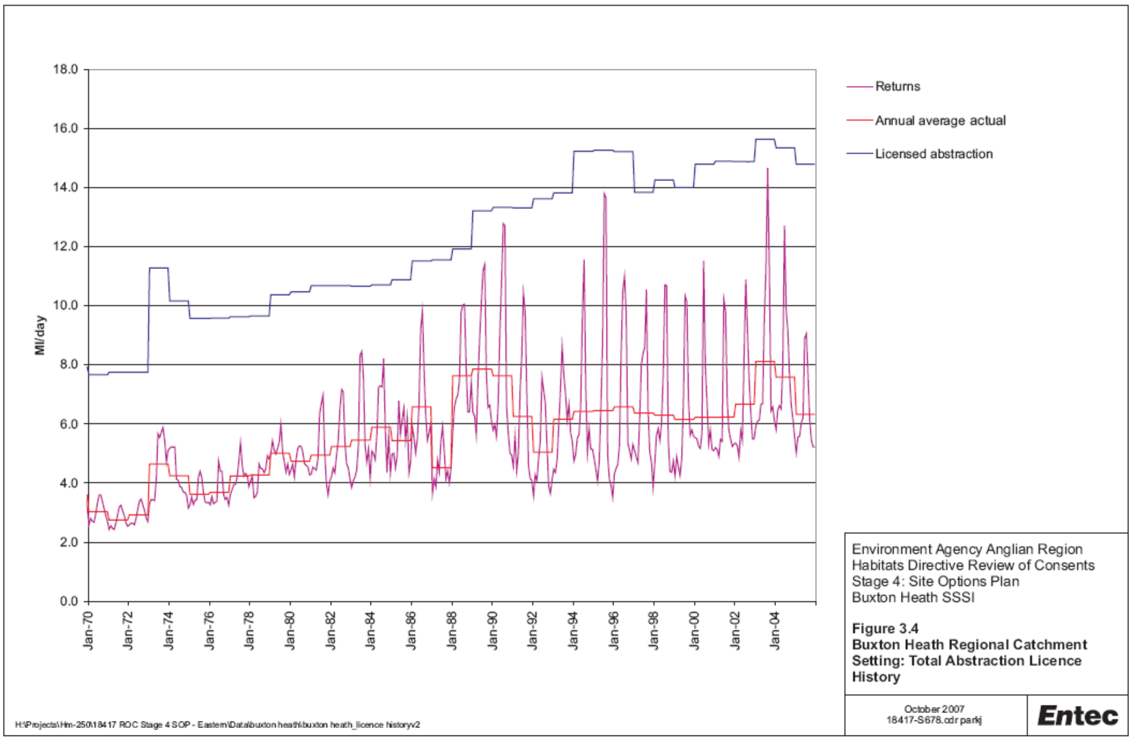

Figure 3.4
Buxton Heath Regional Catchment Setting: Total Abstraction Licence History

Step 3: Collate and evaluate information on site ecology and ecological history including Environmental Outcomes and Conservation Objectives provided by Natural England, in particular new information since Stage 3.

The current site ecology is recorded and the likely reasons for the development of the particular ecology explained. This step takes account of the Environmental Outcomes provided by Natural England and any documents that describe the requirements of the particular ecology, such as published ecohydrological guidelines. It also involves the collation and evaluation of all ecological survey data available and tries to establish if there is evidence for ecological change (and damage) based on changes to the extent, quality and number of characteristic species.

Example: Buxton Heath

See SOP Section 3.5.

Moderately to highly species rich M13. No clear evidence of ecological decline in terms of M13 extent and species-richness. Environmental Outcomes mainly referring to M13 requirements described in Ecohydrological Guidelines and also quoting that "It is the best professional opinion of NE staff that the Site is not under apparent water stress in non-drought years (under recent abstraction levels)."

Step 4: Develop updated integrated ecological and hydrological conceptual understanding.

This step pulls together all the information from steps 1 to 3 and develops an integrated ecological and hydrological conceptual understanding based on best available information.

- How does the site function ecologically and hydrologically?
- What are the key hydrological features that appear to support the ecology at a particular location, especially where the key habitats are found, e.g. water table close to ground surface in normal years, permanent upward flow of groundwater to the surface ("flushing"), characteristic relationship between water table and piezometric head in main aquifer?

Example: Buxton Heath

See SOP Section 3.7.

Step 5: Describe and evaluate the model representation.

The model representation of the saturated and unsaturated zone is described and compared to the conceptual model at a regional, local and single cell scale. The adequacy of the model at this particular location is evaluated. Model cells that best represent the condition at the European features and that will be used for the assessment are identified.

For sites where soil moisture content forms part of the assessment the soil moisture model for the assessment cell is calibrated against historical observation of wetness/dryness and water table data from dipwells, e.g. if a site appears to be generally wet in normal years ("water oozing from soil under foot") the modelled historical soil moisture content time series is calibrated to be above field capacity in non-drought years (soil moisture threshold applied for M13).

Example: Buxton Heath

See SOP Section 4.

The model adequately simulates the hydrological mechanisms that are believed to sustain the SSSI and ecological features within and is consistent with the WETMECS models.
Modelled soil moisture content is calibrated against anecdotal evidence and dipwell data. Ecology appears to currently be in good condition and not under apparent stress in normal years, depth to water table observed in dipwells, water level and wetness regimes ("water oozing from soil under foot") as described in Ecohydrological Guidelines.

Based on the above observations it is assumed that soil moisture conditions have been appropriate for M13 in the past. Therefore, the soil moisture model is calibrated such that the historical soil moisture content roughly stays within 'ooziness band' (i.e. between ooziness threshold and field capacity) in non-drought years but can go below in drought years. Using 1970-2004 climatic time series and modelled historical water level in top active layer the model is used to "re-create likely historical wetness conditions".

Step 6: Characterise the hydrological regime based on the model ('hydrological functioning') and evaluate if conceptual understanding is captured.

This step sets out the current understanding of the groundwater and surface water flow regimes around the site based on the regional groundwater model. The characterisation is based on the historical time series for the whole modelled time period (e.g. 1970-2005) and also its comparison with the non-abstraction ('naturalised') scenario for the same time period. Water balances for areas and cells of interest are calculated and hence, quantities are put against individual water balance components e.g. upward flow into uppermost model layer, discharge to stream cells, horizontal and vertical GW flow between different cells and layers

This step provides some key information:

- What is the general hydrological functioning under non-abstraction ('naturalised') and historical conditions, e.g. is any upward flow to the uppermost model layer permanent or does it reverse to downward flow in some years in the modelled time series even under naturalised conditions?
- Is the piezometric head in the main aquifer always higher than the water table or does this relationship vary between seasons or years under historical and naturalised (no abstraction) conditions?
- Does the modelled hydrological regime capture the key features of our conceptual understanding developed through steps 1 to 4, e.g. vertical hydraulic gradients, upward flow and discharge of groundwater at surface?

Example: Buxton Heath

See SOP Section 5.1.

Comparison between the naturalised (non-abstraction) and historical abstraction scenario (see Figure 5.16) shows that

- *water level in top active layer is very similar for both scenarios and effects of abstraction become more visible from late 1980's onwards due to higher level if abstraction. The maximum difference is only about 5 cm.*
- *upward hydraulic gradient between Chalk layer and top active layer is maintained throughout the whole time series for both abstraction scenarios although in some years the head difference is getting close to zero. Under the historical abstraction scenario the head difference is reduced by 5-10 cm at maximum.*
- *upward flow into top active layer from underlying layer is very similar for both abstraction scenarios with increasing difference from late 1980's onwards due to higher level of abstraction. Maximum difference is about 5 m3/day. Upward flow does not cease (i.e. fall below 0 m3/day) under both abstraction scenarios.*
- *discharge to stream cell is very similar for both abstraction scenarios with increasing difference from late 1980's onwards due to higher level of abstraction. Maximum difference is about 5 m3/day. Discharge to stream cell falls below 0 m3/day in a few drought years even under naturalised conditions.*

The above characterisation appears to capture the conceptual understanding and the hydrological functioning described in the Environmental Outcomes, e.g. groundwater flushing.

Based on the above it appears that historical (actual) abstraction has not significantly altered the hydrological functioning of the site. This would correspond with the finding that there is no clear evidence of ecological decline in terms of M13 extent and species richness (see Step 7).

Step 7: Based on ecological history establish if historical abstraction has been acceptable.

It is a key step in the whole approach to establish whether or not historical actual abstraction (i.e. as shown in a time series derived from actual returns) has been acceptable based on evidence for ecological change related to European features and abstraction history especially over the last 10-15 years, i.e. including drought conditions as experienced in the 1990s.

- Referring to outcomes of Step 2, has historical (actual) abstraction decreased or stayed the same over the last 10 – 15 years i.e. including the drought conditions as experienced in the 1990s?
- Referring to Step 3, is there any evidence that, overall, the site's condition has declined in a way that is attributable to changes in the hydrology of the site?

Abstraction may have caused some stress to the ecology, especially during drought periods, but if there is no evidence for change or damage to the European features e.g. in terms of extent, quality and characteristic species, it is assumed that the ecology has recovered from those stress periods.

If the answer to this step is yes, go to Step 8. If no, go to Step 9.

For most of the sites considered at RoC Stage 4 it has been concluded that there is no clear evidence for ecological change or damage that can be linked to historical abstraction. In a lot of cases, this step includes some uncertainty due to the lack of ecological monitoring data or survey methods differing over time.

Example: Buxton Heath

See SOP Sections 3 and 5.

For Buxton Heath it is concluded that there is no clear evidence to suggest that historical abstraction has caused any long-term damage to the M13 on site. Conditions during drought may have caused some stress but the ecology appears to have recovered from that. Hence, the modelled historical time series for the period 1970-2004 can be used as baseline for assessment of the fully licensed abstraction scenario.

Step 8: If historical (actual) abstraction apparently acceptable from an ecological point of view, assume that modelled historical time series (water levels and flows) represent acceptable conditions.

If Step 7 concludes that historical abstraction has been acceptable, it is assumed that

- modelled historical time series (water levels and flows) represent acceptable conditions that can be used as baseline to assess abstraction scenarios against; and
- European features have experienced hydrological conditions that are acceptable because they did not result in long-term damage (including less ideal conditions in droughts from which the ecology has subsequently recovered) and therefore should achieve the Environmental Outcomes.

The key conclusion is that broadly maintaining these acceptable historical conditions and hydrological structure and functioning will ensure that European features are not adversely affected and that Environmental Outcomes are achieved.

Step 9: If historical abstraction not acceptable, establish point in the past when level of abstraction was acceptable to identify acceptable hydrological conditions.

If Step 7 concludes that historical abstraction has not been acceptable, it is necessary to establish a point in the past when the hydrological regime has been acceptable and therefore what level of abstraction can be regarded as acceptable, e.g. in the 1970s before general build-up of abstraction when the modelled historical time series is very similar to the ‘naturalised’ (no abstraction) scenario. In detail, finding this point in the past depends on the abstraction history in the individual catchment surrounding the site and how changes in abstraction manifest themselves in the modelled time series.

Step 10: Use acceptable modelled historical time series (water levels and flows) for assessment cell to identify thresholds.

The modelled historical time series, from the period of time when abstraction was deemed acceptable for the assessment cell based on steps 8 and 9, is used to set thresholds, e.g. lowest historical water level. This threshold (“line on a graph”) is only used for the purpose of assessing other abstraction scenarios against the historical baseline. The thresholds cannot be used for comparison with actual water levels or flows observed on site.

If historical abstraction is judged to be acceptable, the thresholds are usually based on the ‘lowest historical’ in the modelled time period (usually 1970-2006)

If historical abstraction is judged not to be acceptable after a certain point in time, e.g. 1990, then the ‘lowest (level or flow) prior to that point in time’ could provide the threshold. In detail, this will be a case by case decision.

Setting this threshold does not mean that it would be acceptable to reduce e.g. water levels down to the lowest water level as experienced under drought conditions in every year. Since we are using fully licensed abstraction scenarios for the assessment, the modelled abstraction quantities are generally 100% of the licensed quantity in every year of the modelled time period. As a result, the general pattern of the time series, which is caused by the climatic conditions over the modelled time period rather than abstraction, is maintained and breaches of any thresholds will always occur in years with lower water levels first.

The model-based hydrological criteria and thresholds are related to specific water balance components such as the modelled water level in the top active model layer. Since the model maintains water balances, the different parameters are linked. For example, low water levels in the top active layer are generally linked with low discharge to stream cells. Therefore, by only choosing a threshold for one parameter, this, at the same time, sets a threshold for the other parameters (although there is no linear relationship and hence the lowest water level does not necessarily coincide with the absolutely lowest stream discharge) and hence encompasses a certain hydrological regime.

The proposed model based hydrological criteria for deciding acceptable levels of abstraction at a site are further divided into ‘Primary’ and ‘Secondary’ criteria:

- **Primary Criteria** ‘Hard’ targets with a presumption not to be breached; based partly on observations of site conditions during drought and non-drought years; usually only water level in top active model layer and soil moisture since those parameters can be related and calibrated to actual observations on site; related to critical periods in the seasonal cycle. The thresholds for those criteria will generally direct the assessment.
- **Secondary Criteria** ‘Soft’ targets which can be breached if the overall hydrological functioning is roughly maintained, e.g. stream discharge, hydraulic gradients and upward flow into top active model layer maintained. These secondary criteria provide additional guidance for the assessment and are related to hydrological mechanisms that cannot directly be observed, e.g. upward flow to top active model layer, and to less critical periods of the seasonal cycle. Secondary criteria also recognise the need for certain conditions of wetness during winter months and a year-on-year recovery from any water stress caused by abstraction.

Box 2 lists the primary and secondary criteria typically used for Norfolk Valley Fens.

Box 2: Primary and secondary criteria typically used for Norfolk Valley Fens.

Primary Criteria:

Drought summers
- Modelled water level in top active layer to remain above the lowest historical water level modelled.

Non-drought summers
- Modelled soil moisture content to remain above field capacity (as the lower limit of a range that represents conditions where “water oozes from soil under foot”) or above the stress threshold. (field capacity generally used for M13, M22 and M5, stress threshold generally used for M24, S24/25, W5 and W6; no soil moisture threshold used for Desmoulin’s Whorlsnail)

Secondary Criteria:

Drought summers
- Soil moisture content to remain above stress threshold (only if appropriate).
- Modelled flows to remain above the regime of upward flow and stream discharge associated with the lowest historical water level modelled in drought summers.

Non-drought summers
- Modelled water level in top active layer to remain above the lowest historical water level modelled in non-drought summers; flows to remain above the associated upward flow and stream discharge.

Drought winters
- Soil moisture to return to saturation (no soil moisture threshold used for Desmoulin’s Whorlsnail)
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in drought winters; flows to recover to the associated regime of upward flow and stream discharge.

Non-drought winters
- Soil moisture to return to saturation (no soil moisture threshold used for Desmoulin’s Whorlsnail)
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in non-drought winters; flows to recover to the associated regime of upward flow and stream discharge

Example: Buxton Heath

See SOP Section 5.2.

The following Primary Criteria were chosen for Buxton Heath:

Drought periods - *Modelled water level in top active layer to remain above the lowest historical water level modelled.*
In this case, the threshold is 27.21 mAOD as modelled for July 1976 (see Figure 6.2). It should be noted that in this case, this threshold virtually represents the naturalised (non-abstraction) situation in July 1976.
The criterion for drought periods is directly linked to a statement in the Environmental Outcomes and makes sure that occurrence of drought conditions is not increased (in terms of frequency, intensity and duration) compared to what was experienced over the period 1970-2004. This means that, as soon as the modelled fully licensed abstraction is greater than the abstraction in the past, this threshold will be breached. In the first instance this will normally happen in the year on which the threshold was based, in this case 1976.

Non-drought summers *– Modelled soil moisture content to remain above field capacity (as the lower limit of a range that represents conditions where "water oozes from soil under foot").*
This criterion is linked to the general requirement for M13 of a high water table and "oozy" soil moisture conditions in normal (non-drought years) as described in the Environmental Outcomes. Although the criterion only refers to soil moisture content, it is actually linked to the modelled water level in the top active layer. But rather than looking at changes in modelled water level, which cannot directly be compared to the actual water table on the site, the model looks at resulting changes in soil moisture content. High soil moisture content generally corresponds with a high water table but varies with soil type. By choosing a threshold related to soil moisture content this actually aims to maintain a certain range of water levels that maintain this soil moisture content under climatic conditions as experienced over the period 1970-2004. That means that in any given year (with certain climatic characteristics) of the modelled time series, reduction in soil moisture content occurs if the water level in the top active layer in the model is reduced as a result of increased abstraction. This is illustrated by the graphs in Figure 6.2.
This criterion cannot directly refer to the exact water table regime as described in the Environmental Outcomes, e.g. "The average 'normal year' shallow groundwater table should throughout a normal year not drop more than 10cm below ground level". However, it is thought to be an appropriate surrogate criterion that will ensure that required water table and soil moisture conditions are achieved on site.

Step 11: Compare time series (water levels and flows, soil moisture content) produced for the fully licensed abstraction scenario against the historical baseline and thresholds.

The fully licensed abstraction scenario is set up with actual historical climatic conditions as background but with abstraction from all licences in the model at 100% of their licensed quantity in every year of the modelled time period, e.g. 1970-2006. This scenario therefore presents a worst case situation.

The time series produced for the fully licensed abstraction scenario is compared against the historical baseline and thresholds.

- How often does the modelled time series breach the thresholds and by how much?
- Is the hydrological functioning significantly changed compared to historical (and naturalised) conditions, e.g. permanent reversal of vertical hydraulic gradient, cessation of upflow into to top active layer, cessation of stream discharge?

Since in most catchments fully licensed abstraction is greater than historical abstraction, and therefore modelled water levels/flows under the fully licensed scenario are lower than under the historical scenario, there is one default breach which occurs in the year with the lowest historical water level/flow on which the threshold is based. This is a function of the way the thresholds are set.
If, for example, the threshold is based on the historical water level modelled for the drought year 1991, the fully licensed scenario will normally breach this threshold under the same climatic conditions as in 1991, i.e. the time series graph for the fully licensed scenario falls below the threshold line on the graph.

Example: Buxton Heath

See SOP Section 6.1.

The appraisal of the abstraction scenarios against the thresholds of the primary and secondary criteria is summarised in Table 6.2.
Figures 6.1 and 6.2 illustrate how the time series for the fully licensed scenario compares to the naturalised and the historical scenario and against the thresholds.

Water levels:
See Figure 6.2. Up to the late 1980's the historical time series is very similar to the naturalised (no abstraction) time series due to the generally low level of abstraction. From the later 1980's a small difference is visible. Since the fully licensed scenario assumes the same abstraction quantity in every year, the difference between naturalised/historical and fully licensed therefore is larger in the 1970's and 1980's but becomes smaller from 1990 onwards.
The time series of the fully licensed scenario exceeds the drought summer threshold (primary criterion) in two years, 1974 and 1976, by up to 14cm. (Since 1976 was such an extremely dry year in East Anglia, breaches are likely to occur in this year for a large number of sites.)
Soil moisture content:
See Figure 6.2. The modelled soil moisture content for the fully licensed scenario goes below field capacity (primary criterion) in one non-drought year, 1975. This corresponds with 1975 also being the year with the lowest modelled water level in non-drought summers. In fact, the water levels in 1975 actually show similar or even lower levels as seen in some of the 1990's drought years such as 1989, 1992 or 1995.
The modelled soil moisture content returns to saturation in all drought and non-drought winters. This indicates that there are no cumulative effects on the soil moisture store. Therefore, it appears acceptable that the lowest winter peak water levels are not reached in every winter.
Upward flow to top active model layer:
See Figure 6.1. The modelled time series for the fully licensed scenario breaches the thresholds (secondary criteria) on several occasions. In 3 years out of 34, the upward flow goes below zero.
Discharge to stream:
See Figure 6.1. The modelled time series for the fully licensed scenario breaches the thresholds (secondary criteria) on several occasions. In 10 years out of 34, the discharge to stream goes below zero. However, this appears to happen also in 5 years under naturalised (no abstraction) conditions.

Step 12: Decide whether or not the fully licensed abstraction scenario is acceptable.

For the SOP there is a presumption that the fully licensed abstraction scenario is not acceptable if a threshold for a primary criterion is breached.

In some cases, specific reasons may be put forward, e.g. based on the model representation or some technical limitations, to allow breaches of thresholds to a certain degree.

Since there is usually one primary criterion for non-drought summers and one for drought summers, it is possible to further qualify the 'acceptability' of the fully licensed scenario. In a lot of cases, only the threshold related to drought summers is breached while the fully licensed scenario appears to be acceptable in non-drought summers.

Example: Buxton Heath

See SOP Section 6.2.

Since the fully licensed scenario results in breaches of primary criteria, the current conclusion in the SOP is that fully licensed abstraction is potentially greater than acceptable. That means that 'no adverse effect' cannot be concluded and that the Environmental Outcomes potentially can not be achieved. It is concluded that licences need to be modified in order to control actual abstraction, especially in drought periods.

If action would be taken and licences modified in such a way that the thresholds for the primary criteria are not breached this would also result in less breaches of the secondary criteria since the water balance components are linked.

Step 13: If the fully licensed abstraction scenario is not acceptable identify scale of licence modifications and need for options appraisal (application of 'SOP decision table').

If the fully licensed abstraction scenario is not acceptable based on the SOP, the necessary scale of licence modification and the need for options appraisal are then identified considering a risk-based approach.

The risk-based approach described below is strictly only applied to sites where historical levels of abstraction have been judged to be acceptable or where thresholds have been based on a period in time when historical levels of abstraction are thought to have been acceptable. For sites were historical levels of abstraction have been judged not to be acceptable site specific considerations and discussion with Natural England are required to establish an acceptable baseline or improvements that need to be achieved.

The need for this step involving a risk-based decision was identified for the following reasons:

For sites where we judge that historical levels of abstraction have been considered acceptable (see Step 8) the use of thresholds as described in steps 10 to 12 above inherently results in at least one threshold breach if the abstraction under the fully licensed abstraction scenario is greater than historical abstraction, which is the case in most catchments in Anglian Region. In addition to the one 'default' breach, there is often only a very small number of breaches (if at all) and most of the breaches may only be in the order of millimetres or a few centimetres or a few percentages of soil moisture content.

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

We are therefore applying a **risk-based approach** that scales any licence modification based on the risk to the site.

The so-called 'SOP decision table' (also referred to as 'risk-matrix', see attached) is applied to scale the licence modifications by assigning a 'risk category' to each site (generally component SSSIs if a SAC/SPA consists of more than one SSSI). The 'SOP decision table' takes into account the scale and frequency of breaches to primary criteria thresholds, in the context of changes to the overall hydrological functioning, the general level of fully licensed and historical abstraction in the catchment surrounding the site and uncertainties around the ecological 'evidence' available, the conceptual understanding or the model representation. In addition, professional judgement will be applied to decide on the risk category as appropriate.

There is a presumption that, for sites which are assigned a 'low risk category', no abstraction licence modifications need to be investigated through the options appraisal process because the risk of adverse effect on site integrity and not achieving the Environmental Outcomes is sufficiently low despite some (small and infrequent) breaches of thresholds.

For sites in the 'medium risk' and 'high risk' categories the risk of adverse effect on site integrity is generally considered to be unacceptable and abstraction licence modifications will be investigated during the options appraisal process. The presumption is that licences would need to be modified so that the site then falls into the 'low risk' category.

The difference between 'medium risk' and 'high risk' is the scale of risk and therefore presumably the scale of abstraction licence modification that is required to reduce the risk to the site to an acceptable 'low'. The actual scale and detail of any modification will depend on the individual site and the licences implicated and will be investigated through the options appraisal. At the options appraisal stage, in addition to considering technical viability, we will also apply Habitats Regulations Principles (fair, reasonable, least onerous etc.) and compare options with regard to risks, costs, sustainability, social consequences and economic effects.

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

Example: Buxton Heath

The application of the draft risk matrix has assigned a 'medium risk' category to Buxton Heath. This means that there would be a presumption that control over actual abstraction, e.g. through licence conditions, would be introduced.

SOP (Site Option Plan) Decision Table

Environment Agency Anglian Region

DEFINITION OF RISK CATEGORIES (Standard for Norfolk Valley Fens)

Proposal for SOP (site option plan) decision table

Risk to site integrity of fully licensed abstraction where historical abstraction appears to be acceptable

Criteria	Risk Category		
	Low	**Medium**	**High**
1) Performance against model-based hydrological criteria			
Scale of breach for water levels (related to threshold for drought summers)	≤ 5 cm	≤ 10 cm	> 10 cm
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	≤ 3 out of 10 (= ≤ 9 out of 35)	> 3 out of 10 (= > 9 out of 35)
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5 %	≤ 10 %	> 10 %
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	≤ 3 out of 10 (= ≤ 9 out of 35)	> 3 out of 10 (= > 9 out of 35)
Timing of breaches	droughts only	non-droughts only	droughts AND non-drought periods
Soil moisture returning to saturation in winters	always	not in a few winters	not in most winters
Impact on overall hydrological functioning	not significantly impacted	impacted in some years	significantly impacted in most years
2) Appraisal of resources and abstraction scenarios			
Modelled water level under fully licensed scenario similar to naturalised/historical or close to 50% LTA recharge scenario	similar to naturalised or historical	between historical and 50% LTA recharge abstraction scenario	close or above 50% LTA recharge abstraction scenario
Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%	20-40%	>40%
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	small	medium	large
Sensitivity to water table fluctuations indicated by field data (site generally wet?)	small	medium	large
3) Uncertainties			
Evidence to allow judgement of no ecological change available and clear?	available and clear	available but not clear	not available
Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	~ stable or decreasing	slightly increasing	increasing
Model representation adequate?	adequate	less adequate	not adequate
Ecohydrological conceptual understanding clear and agreed?	clear and agreed	less clear, not agreed	not clear, not agreed
Field data available and sufficient?	available and sufficient	available but not entirely sufficient	not available and not sufficient

Further considerations that may influence the overall risk category:			
Add site specific considerations as appropriate…			
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?			

NOTE: This table shows the standard for Norfolk Valley Fens. For other sites the SOP decision table has been modified to account for different hydrological criteria and thresholds.

Appendix 2

Anglian Region Habitats Directive Review of Consents Stage 4 Summary Note: Technical Approach, Criteria and Thresholds Applied for Inland Sites including North Norfolk Coast

Anglian Region Habitats Directive Review of Consents Stage 4

Summary Note
Technical approach, criteria and thresholds applied for Inland Sites including North Norfolk Coast

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1. Introduction

In Stage 4 of the Habitats Directive Review of Consents (RoC) a Site Action Plan (SAP) and an Appendix 19 (list of licences to be affirmed, modified and revoked) has to be produced.

In Anglian Region the technical work that supports this process involves the production of a Site Option Plan (SOP). The SOP will be followed by Options Appraisal work if required.

The purpose of the Stage 4 Site Option Plan (SOP) is to confirm the predicted impacts of abstraction on the hydrological regime at the site in view of additional information that has become available since RoC Stage 3. The SOP then aims to identify whether these impacts are acceptable or unacceptable in terms of the effects on the ecology and structure and functioning of the site and therefore achieving the Environmental Outcomes for the site. The SOP will also identify any changes which the Agency believes are necessary to allow a conclusion of no adverse effect on the site to be reached and will make general proposals as to how those changes could be achieved.

2. Purpose of this Summary Note

The purpose of this note is to summarise the main features of the technical approach applied to RoC Stage 4 for inland sites in Anglian Region.
Further details on the site specific approach and the numerical models used can be found in the site specific SOPs and reports produced as part of the Regional Groundwater Modelling Strategy.

3. Overall Approach

From a RoC perspective it is essential that we are able to conclude that abstraction is not or will not have an adverse effect on site integrity and that our interpretation of Natural England's Environmental Outcomes can be achieved.

It is accepted that there are many pressures on these sites which can affect the hydrological structure and functioning and that all sites are subject to pressures and stresses.

The overall approach in the SOPs aims to allow definition of an acceptable level of abstraction based on an acceptable level of impact at the site. The SOP presents a detailed integrated hydrological and ecological conceptual understanding of the site based on all available information. Particular attention is given to the ecological history of the site and the hydrological functioning of the site in the location of the ecological features and under different climatic conditions.

The potential impact of abstraction at a site is assessed using a regional groundwater model. Through sequential chapters in the report the SOP aims to confirm the suitability of the model for use in the assessment by concluding that the model is adequately representing and reproducing our conceptual models at both a site and cell scale, where the cell is chosen to represent the location of the ecological features.

To provide a link between groundwater levels and available moisture in the plant root zone a soil moisture model has also been developed. This is used to assess the effects of abstraction on the soil moisture content above the water table.

Our interpretation of the Stage 4 Environmental Outcomes for the site agreed with Natural England, observations from the past and the modelled historical time series are used to develop site-specific model-based hydrological criteria against which different abstraction scenarios are then assessed.

Model results are generated for individual model cells (200m x 200m). Modelled water tables relate to the uppermost model layer in a whole grid square and can therefore not be compared directly to the real water table as observed in dipwells.

Model results are also produced for groups of cells, e.g. to assess the inflow of groundwater into specific hydrological compartments. The modelled flow for a group of cells is calculated as total of the flows from individual model cells (200m x 200m) and can therefore not be compared directly to flows observed in ditches or lakes.

'Surrogate' model-based criteria and thresholds are therefore developed for the model cell(s) used in the assessment. These 'surrogate' model-based hydrological criteria are designed to ensure the hydrological functioning of the site as a whole so that the Environmental Outcomes can be achieved.

4. Detailed Approach

The main steps of the approach are summarised in Box 1 for overview. The following text then gives more detailed explanation and examples for each of those steps.

Box 1: Main steps of approach

1. Collate and evaluate hydrological, geological and topographical information for the site and the surrounding catchment, in particular new information since Stage 3.
2. Characterise the abstraction licensing position (fully licensed) and history within the catchment.
3. Collate and evaluate information on site ecology and ecological history including Environmental Outcomes and Conservation Objectives provided by Natural England, in particular new information since Stage 3.
4. Develop updated integrated ecological and hydrological conceptual understanding.
5. Describe and evaluate the model representation.
6. Characterise the hydrological regime based on the model ('hydrological functioning') and evaluate if conceptual understanding is captured.
7. Based on ecological history establish if historical (actual) abstraction has been acceptable.
8. If historical (actual) abstraction apparently acceptable from an ecological point of view, assume that modelled historical time series (water levels and flows) represent acceptable conditions.
9. If historical abstraction not acceptable establish point in the past when level of abstraction was acceptable to identify acceptable hydrological conditions.
10. Use acceptable modelled historical time series (water levels and flows) for assessment cell to identify thresholds.
11. Compare time series (water levels and flows, soil moisture content) produced for the fully licensed abstraction scenario against the historical baseline and thresholds.
12. Decide whether or not the fully licensed abstraction scenario is acceptable.
13. If the fully licensed abstraction scenario is not acceptable identify scale of licence modifications and need for options appraisal (application of 'SOP decision table').

Step 1: Collate and evaluate hydrological, geological and topographical information for the site and the surrounding catchment, in particular new information since Stage 3

As a first step all information available from field investigations, hydrological monitoring and other sources is collated and evaluated to build up the conceptual understanding of the site and its surrounding catchment. How does the site and the catchment "work" hydrologically and hydrogeologically?

Step 2: Characterise the abstraction licensing position (fully licensed) and history within the catchment.

This step includes the characterisation of the 'fully licensed' abstraction licensing position with regards to size, distribution, uptake and general abstraction pressure in the vicinity of the site. It also summarises the development of abstraction over the last 35 years. The consideration of the 'fully licensed' situation includes new licences that have been issued under Reg. 48.

This provides information for the following key questions:

- How does the historical (actual) abstraction compare to the fully licensed situation that has to be assessed for RoC and will be modelled for the assessment?
- Is it likely that the licence uptake will reach 100% in the near future?

Although it might be likely that individual abstractions may take close to 100% of the fully licensed especially in dry years, this will not realistically happen with all licences included in the model area at the same time and not in every year, which is assumed for the fully licensed scenario in the model. In most of the catchments considered for the RoC Stage 4 work the recent actual abstraction represents 20-70% of the total fully licensed abstraction, with only a few individual abstractions reaching 90% or more of the full licensed quantity.

In general, licensed abstraction quantities are designed to meet the requirements in dry years rather than average years. Especially licences for spray irrigation are set up for peak demand in very dry summers periods. Therefore, actual abstraction in 'normal' years does generally not reach 100% of the full licence. Looking at the abstraction history, in a lot of catchments an almost constant 'gap' between licensed and actual abstraction can be seen from the early 1990s to today indicating that uptake of licensed abstraction has not significantly increased over the last 15 years.

If the demand increases in the future, it can be expected that this will require licensing of new sources and additional quantities before 100% of the current licensed abstraction is utilised in order to ensure security of supply also in future drought periods. Any applications for new sources and additional abstraction quantities will however go through the usual licensing process including environmental impact assessment.

- Has the actual abstraction over the last 10-15 years (i.e. including drought conditions in the 1990's) been decreasing, increasing or comparably stable?

If actual abstraction has been *decreasing or stable* over the last 10-15 years it can be assumed that any impacts from abstraction on the ecology would have become apparent by now. If actual abstraction has been *increasing* any impacts from abstraction may not have become apparent yet due to time lag in the ecological response. In most of the catchments considered for the RoC Stage 4 work actual annual abstraction has been fairly stable since about 1991. Before then, abstraction has generally built up gradually throughout the 1970s and 1980s.

Understanding how actual historical abstraction has developed over time is also necessary to interpret modelled time series e.g. for water levels, for different abstraction scenarios. The scale of difference between water levels and flows in a naturalised (no abstraction) scenario and the historical scenario is a function of the level of abstraction in the vicinity of the site.

Step 3: Collate and evaluate information on site ecology and ecological history including Environmental Outcomes and Conservation Objectives provided by Natural England, in particular new information since Stage 3.

The current site ecology is recorded and the likely reasons for the development of the particular ecology explained. This step takes account of the Environmental Outcomes provided by Natural England and any documents that describe the requirements of the particular ecology, such as published ecohydrological guidelines. It also involves the collation and evaluation of all ecological survey data available and tries to establish if there is evidence for ecological change (and damage) based on changes to the extent, quality and number of characteristic species.

Step 4: Develop updated integrated ecological and hydrological conceptual understanding.

This step pulls together all the information from steps 1 to 3 and develops an integrated ecological and hydrological conceptual understanding based on best available information.

- How does the site function ecologically and hydrologically?
- What are the key hydrological features that appear to support the ecology at a particular location, especially where the key habitats are found, e.g. water table close to ground surface in normal years, permanent upward flow of groundwater to the surface ("flushing"), characteristic relationship between water table and piezometric head in main aquifer?

Step 5: Describe and evaluate the model representation.

The model representation of the saturated and unsaturated zone is described and compared to the conceptual model at a regional, local and single cell scale. The adequacy of the model at this particular location is evaluated. Model cells that best represent the condition at the European features and that will be used for the assessment are identified.

For sites where soil moisture content forms part of the assessment the soil moisture model for the assessment cell is calibrated against historical observation of wetness/dryness and water table data from dipwells, e.g. if a site appears to be generally wet in normal years ("water oozing from soil under foot") the modelled <u>historical</u> soil moisture content time series is calibrated to be above field capacity in non-drought years (soil moisture threshold applied for M13).

Step 6: Characterise the hydrological regime based on the model ('hydrological functioning') and evaluate if conceptual understanding is captured.

This step sets out the current understanding of the groundwater and surface water flow regimes around the site based on the regional groundwater model. The characterisation is based on the historical time series for the whole modelled time period (e.g. 1970-2005) and also its comparison with the non-abstraction ('naturalised') scenario for the same time period. Water balances for areas and cells of interest are calculated and hence, quantities are put against individual water balance components e.g. upward flow into uppermost model layer, discharge to stream cells, horizontal and vertical GW flow between different cells and layers

This step provides some key information:

- What is the general hydrological functioning under non-abstraction ('naturalised') and historical conditions, e.g. is any upward flow to the uppermost model layer permanent or does it reverse to downward flow in some years in the modelled time series even under naturalised conditions?
- Is the piezometric head in the main aquifer always higher than the water table or does this relationship vary between seasons or years under historical and naturalised (no abstraction) conditions?
- Does the modelled hydrological regime capture the key features of our conceptual understanding developed through steps 1 to 4, e.g. vertical hydraulic gradients, upward flow and discharge of groundwater at surface?

Step 7: Based on ecological history establish if historical abstraction has been acceptable.

It is a key step in the whole approach to establish whether or not historical actual abstraction (i.e. as shown in a time series derived from actual returns) has been acceptable based on evidence for ecological change related to European features and abstraction history especially over the last 10-15 years, i.e. including drought conditions as experienced in the 1990s.

- Referring to outcomes of Step 2, has historical (actual) abstraction decreased or stayed the same over the last 10 – 15 years i.e. including the drought conditions as experienced in the 1990s?
- Referring to Step 3, is there any evidence that, overall, the site's condition has declined in a way that is attributable to changes in the hydrology of the site?

Abstraction may have caused some stress to the ecology, especially during drought periods, but if there is no evidence for change or damage to the European features e.g. in terms of extent, quality and characteristic species, it is assumed that the ecology has recovered from those stress periods.

If the answer to this step is yes, go to Step 8. If no, go to Step 9.

For most of the sites considered at RoC Stage 4 it has been concluded that there is no clear evidence for ecological change or damage that can be linked to historical abstraction. In a lot of cases, this step includes some uncertainty due to the lack of ecological monitoring data or survey methods differing over time.

Step 8: If historical (actual) abstraction apparently acceptable from an ecological point of view, assume that modelled historical time series (water levels and flows) represent acceptable conditions.

If Step 7 concludes that historical abstraction has been acceptable, it is assumed that

- modelled historical time series (water levels and flows) represent acceptable conditions that can be used as baseline to assess abstraction scenarios against; and

- European features have experienced hydrological conditions that are acceptable because they did not result in long-term damage (including less ideal conditions in droughts from which the ecology has subsequently recovered) and therefore should achieve the Environmental Outcomes.

The key conclusion is that broadly maintaining these acceptable historical conditions and hydrological structure and functioning will ensure that European features are not adversely affected and that Environmental Outcomes are achieved.

Step 9: If historical abstraction <u>not</u> acceptable, establish point in the past when level of abstraction <u>was</u> acceptable to identify acceptable hydrological conditions.

If Step 7 concludes that historical abstraction has not been acceptable, it is necessary to establish a point in the past when the hydrological regime has been acceptable and therefore what level of abstraction can be regarded as acceptable, e.g. in the 1970s before general build-up of abstraction when the modelled historical time series is very similar to the ‘naturalised’ (no abstraction) scenario. In detail, finding this point in the past depends on the abstraction history in the individual catchment surrounding the site and how changes in abstraction manifest themselves in the modelled time series.

Step 10: Use acceptable modelled historical time series (water levels and flows) for assessment cell to identify thresholds.

The modelled historical time series, from the period of time when abstraction was deemed acceptable for the assessment cell based on steps 8 and 9, is used to set thresholds, e.g. lowest historical water level. This threshold (“line on a graph”) is only used for the purpose of assessing other abstraction scenarios against the historical baseline. The thresholds cannot be used for comparison with actual water levels or flows observed on site.

If historical abstraction is judged to be acceptable, the thresholds are usually based on the ‘lowest historical’ in the modelled time period (usually 1970-2006)

If historical abstraction is judged not to be acceptable after a certain point in time, e.g. 1990, then the ‘lowest (level or flow) prior to that point in time’ could provide the threshold. In detail, this will be a case by case decision.

Setting this threshold does not mean that it would be acceptable to reduce e.g. water levels down to the lowest water level as experienced under drought conditions in every year. Since we are using fully licensed abstraction scenarios for the assessment, the modelled abstraction quantities are generally 100% of the licensed quantity in every year of the modelled time period. As a result, the general pattern of the time series, which is caused by the climatic conditions over the modelled time period rather than abstraction, is maintained and breaches of any thresholds will always occur in years with lower water levels first.

The model-based hydrological criteria and thresholds are related to specific water balance components such as the modelled water level in the top active model layer. Since the model maintains water balances, the different parameters are linked. For example, low water levels in the top active layer are generally linked with low discharge to stream cells. Therefore, by only choosing a threshold for one parameter, this, at the same time, sets a threshold for the other parameters (although there is no linear relationship and hence the lowest water level does not necessarily coincide with the absolutely lowest stream discharge) and hence encompasses a certain hydrological regime.

The proposed model based hydrological criteria for deciding acceptable levels of abstraction at a site are further divided into ‘Primary’ and ‘Secondary’ criteria:

- **Primary Criteria** ‘Hard’ targets with a presumption not to be breached; based partly on observations of site conditions during drought and non-drought years; usually only water level in top active model layer and soil moisture since those parameters can be related and calibrated to actual observations on site; related to critical periods in the seasonal cycle. The thresholds for those criteria will generally direct the assessment.
- **Secondary Criteria** ‘Soft’ targets which can be breached if the overall hydrological functioning is roughly maintained, e.g. stream discharge, hydraulic gradients and

upward flow into top active model layer maintained. These secondary criteria provide additional guidance for the assessment and are related to hydrological mechanisms that cannot directly be observed, e.g. upward flow to top active model layer, and to less critical periods of the seasonal cycle. Secondary criteria also recognise the need for certain conditions of wetness during winter months and a year-on-year recovery from any water stress caused by abstraction.

Box 2a lists the primary and secondary criteria typically used for Norfolk Valley Fens SAC, Waveney & Little Ouse Valley Fens SAC, Chippenham Fen (component SSSI of Fenland SAC) and, probably in modified form, for Cavenham & Icklingham Heaths (component SSSI of Breckland SAC/SPA).

Box 2a: Primary and secondary criteria typically used for Norfolk Valley Fens, Waveney & Little Ouse Valley Fens, Chippenham Fen and Cavenham & Icklingham Heaths*.

Primary Criteria:

Drought summers
- Modelled water level in top active layer to remain above the lowest historical water level modelled.

Non-drought summers
- Modelled soil moisture content to remain above field capacity (as the lower limit of a range that represents conditions where "water oozes from soil under foot") or above the stress threshold. (field capacity generally used for M13, M22 and M5; stress threshold generally used for M24, S24/25, W5 and W6; no soil moisture threshold used for Desmoulin's Whorlsnail)

Secondary Criteria:

Drought summers
- Soil moisture content to remain above stress threshold (only if appropriate).
- Modelled flows to remain above the regime of upward flow and stream discharge associated with the lowest historical water level modelled in drought summers.

Non-drought summers
- Modelled water level in top active layer to remain above the lowest historical water level modelled in non-drought summers; flows to remain above the associated upward flow and stream discharge.

Drought winters
- Soil moisture to return to saturation (no soil moisture threshold used for Desmoulin's Whorlsnail)
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in drought winters; flows to recover to the associated regime of upward flow and stream discharge.

Non-drought winters
- Soil moisture to return to saturation (no soil moisture threshold used for Desmoulin's Whorlsnail)
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in non-drought winters; flows to recover to the associated regime of upward flow and stream discharge

* Note: For Cavenham & Icklingham Heaths discussion with Natural England ongoing to decide if 'lowest historical' can be used as threshold or if different threshold more appropriate.

Box 2b lists the primary and secondary criteria typically used for Broads sites which are part of the Broads SAC and Broadland SPA.

Box 2b: Primary and secondary criteria typically used for Broads sites.

A) Individual model cells for terrestrial wetland communities (M13, M22, M5, M24, S24, S25, W5 and W6) and Desmoulin's Whorlsnail

Primary Criteria:

Drought summers
- Modelled water level in top active layer to remain above the lowest historical water level modelled.

Non-drought summers
- Modelled soil moisture content to remain above field capacity (as the lower limit of a range that represents conditions where "water oozes from soil under foot") or above the stress threshold. (field capacity generally used for M13, M22 and M5, stress threshold generally used for M24, S24/25, W5 and W6, no soil moisture threshold used for Desmoulin's Whorlsnail)

Secondary Criteria:

Drought summers
- Soil moisture content to remain above stress threshold (only if appropriate)
- Modelled flows to remain above the regime of upward flow and stream discharge associated with the lowest historical water level modelled in drought summers.

Non-drought summers
- Modelled water level in top active layer to remain above the lowest historical water level modelled in non-drought summers; flows to remain above the associated upward flow and stream discharge.

Drought winters
- Soil moisture to return to saturation; no soil moisture threshold used for Desmoulin's Whorlsnail.
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in drought winters; flows to recover to the associated regime of upward flow and stream discharge.

Non-drought winters
- Soil moisture to return to saturation; no soil moisture threshold used for Desmoulin's Whorlsnail.
- Modelled water level in top active layer to recover to the lowest historical winter peak water level modelled in non-drought winters; flows to recover to the associated regime of upward flow and stream discharge

B) Zone budget areas (groups of cells) for Natural Eutrophic Ditches/Lakes and Hard Oligo-Mesotrophic Lakes

Primary Criteria: None.

Secondary Criteria:

Drought summers
- Modelled flows (total stream discharge, upflow to top active layer or accretion over zone budget area) to remain above the lowest historical flows modelled. (sometimes also considering turnover times)

C) Stream cell e.g. to assess impacts on flows for salinity issues in River Bure

Primary Criteria: None.

Secondary Criteria:

Drought summers
- Modelled stream flows to remain above the lowest historical flows modelled.

Box 2c lists the primary and secondary criteria typically used for Benacre to Easton Bavents Lagoons SAC/Benacre to Easton Bavents SPA and Minsmere toWalberswick Heaths and Marshes SAC/Minsmere-Walberswick SPA.

Box 2c: Primary and secondary criteria typically used for Benacre to Easton Bavents Lagoons SAC/Benacre to Easton Bavents SPA and Minsmere to Walberswick Heaths and Marshes SAC/Minsmere-Walberswick SPA.

A) Zone budget area (group of cells) for swamp, reedbeds and floodplain fens (S4) and saline lagoons

Primary Criteria:

Drought summers

- Modelled flows (accretion over zone budget area, ‘stream outflow’) to remain above the lowest historical flows modelled; where the threshold is zero the number of summers with zero flow to remain the same as under historical conditions.

Secondary Criteria:

Non-drought summers

- Modelled flows (accretion over zone budget area, ‘stream outflow’) to remain above the lowest historical flows modelled in non-drought summers; where the threshold is zero the number of summers with zero flow to remain the same as under historical conditions.

Drought winters

- Modelled flows (accretion over zone budget area, ‘stream outflow’) to recover to the lowest historical winter peak flow modelled in drought winters.

Non-drought winters

- Modelled flows (accretion over zone budget area, ‘stream outflow’) to recover to the lowest historical winter peak flow modelled in non-drought winters.

B) Stream cell where river enters the estuary for assessment of freshwater flows for estuarine species (River Blyth only)

Primary Criteria: None

Secondary Criteria:

- Stream flows to remain above 90% of naturalised Q5 flows (maintenance of channel morphology)
- Stream flows to remain above 65% of naturalised Q95 flows (maintenance of the variety and distribution of site-specific biotopes)

Box 2d lists the primary and secondary criteria used for North Norfolk Coast SSSI, part of the North Norfolk Coast SAC and The Wash and North Norfolk Coast SAC and the North Norfolk Coast SPA.

Box 2d: Primary and secondary criteria used for North Norfolk Coast.

A) Lateral groundwater flow across one model row (total flow from all model layers) for assessment of groundwater flow towards the coastline for freshwater reedbeds, grazing marsh and tidal reedbeds

Primary Criteria:

Drought summers
- Modelled lateral flow to remain above the lowest historical flows modelled.

Secondary Criteria:

Drought summers
- Flow direction to remain towards the coastline to prevent saline intrusion.

Non-drought summers
- Modelled lateral flow to remain above the lowest historical water level modelled in non-drought summers.

Drought winters
- Modelled lateral flow to recover to lowest historical winter peak flow modelled in drought winters.

Non-drought winters
- Modelled lateral flow to recover to lowest historical winter peak flow modelled in non-drought winters.

B) Stream cells where rivers enter the coastline for freshwater flow to intertidal interest features within coastal habitat (saltmarsh, intertidal mudflats and sandflats and Zostera beds)

Primary Criteria:

- Stream flows to remain above 90% of naturalised Q5 flows (maintenance of channel morphology)
- Stream flows to remain above 65% of naturalised Q95 flows (maintenance of the variety and distribution of site-specific biotopes)

Step 11: Compare time series (water levels and flows, soil moisture content) produced for the fully licensed abstraction scenario against the historical baseline and thresholds.

The fully licensed abstraction scenario is set up with actual historical climatic conditions as background but with abstraction from all licences in the model at 100% of their licensed quantity in every year of the modelled time period, e.g. 1970-2006. This scenario therefore presents a worst case situation.

The time series produced for the fully licensed abstraction scenario is compared against the historical baseline and thresholds.

- How often does the modelled time series breach the thresholds and by how much?
- Is the hydrological functioning significantly changed compared to historical (and naturalised) conditions, e.g. permanent reversal of vertical hydraulic gradient, cessation of upflow into to top active layer, cessation of stream discharge?

Since in most catchments fully licensed abstraction is greater than historical abstraction, and therefore modelled water levels/flows under the fully licensed scenario are lower than under the historical scenario, there is one default breach which occurs in the year with the lowest historical water level/flow on which the threshold is based. This is a function of the way the thresholds are set.
If, for example, the threshold is based on the historical water level modelled for the drought year 1991, the fully licensed scenario will normally breach this threshold under the same climatic conditions as in 1991, i.e. the time series graph for the fully licensed scenario falls below the threshold line on the graph.

Step 12: Decide whether or not the fully licensed abstraction scenario is acceptable.

For the SOP there is a presumption that the fully licensed abstraction scenario is not acceptable if a threshold for a primary criterion is breached.

In some cases, specific reasons may be put forward, e.g. based on the model representation or some technical limitations, to allow breaches of thresholds to a certain degree.

Where there is one primary criterion for non-drought summers and one for drought summers, it is possible to further qualify the ‘acceptability’ of the fully licensed scenario. In a lot of cases, only the threshold related to drought summers is breached while the fully licensed scenario appears to be acceptable in non-drought summers.

Step 13: If the fully licensed abstraction scenario is not acceptable identify scale of licence modifications and need for options appraisal (application of ‘SOP decision table’).

If the fully licensed abstraction scenario is not acceptable based on the SOP, the necessary scale of licence modification and the need for options appraisal are then identified considering a risk-based approach.

The risk-based approach described below is strictly only applied to sites where historical levels of abstraction have been judged to be acceptable or where thresholds have been based on a period in time when historical levels of abstraction are thought to have been acceptable. For sites were historical levels of abstraction have been judged not to be acceptable site specific considerations and discussion with Natural England are required to establish an acceptable baseline or improvements that need to be achieved.

The need for this step involving a risk-based decision was identified for the following reasons:

For sites where we judge that historical levels of abstraction have been considered acceptable (see Step 8) the use of thresholds as described in steps 10 to 12 above inherently results in at least one threshold breach if the abstraction under the fully licensed abstraction scenario is greater than historical abstraction, which is the case in most catchments in Anglian Region. In addition to the one ‘default’ breach, there is often only a very small number of breaches (if at all) and most of the breaches may only be in the order of millimetres or a few centimetres, a few percentages of soil moisture content or a few litres per day of flow.

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

We are therefore applying a **risk-based approach** that scales any licence modification based on the risk to the site.

The so-called ‘SOP decision table’ (also referred to as ‘risk-matrix’, see attached) is applied to scale the licence modifications by assigning a ‘risk category’ to each site (generally component SSSIs if a SAC/SPA consists of more than one SSSI). The ‘SOP decision table’ takes into account the scale and frequency of breaches to primary criteria thresholds, in the context of changes to the overall hydrological functioning, the general level of fully licensed and historical abstraction in the catchment surrounding the site and uncertainties around the ecological ‘evidence’ available, the conceptual understanding or the model representation. In addition, professional judgement will be applied to decide on the risk category as appropriate.

There is a presumption that, for sites which are assigned a ‘low risk category’, no abstraction licence modifications need to be investigated through the options appraisal process because the risk of adverse effect on site integrity and not achieving the Environmental Outcomes is sufficiently low despite some (small and infrequent) breaches of thresholds.

For sites in the ‘medium risk’ and ‘high risk’ categories the risk of adverse effect on site integrity is generally considered to be unacceptable and abstraction licence modifications will be investigated during the options appraisal process. The presumption is that licences would need to be modified so that the site then falls into the ‘low risk’ category.

The difference between ‘medium risk’ and ‘high risk’ is the scale of risk and therefore presumably the scale of abstraction licence modification that is required to reduce the risk to the site to an acceptable ‘low’. The actual scale and detail of any modification will depend on the individual site and the licences implicated and will be investigated through the options appraisal. At the options appraisal stage, in addition to considering technical viability, we will also apply Habitats Regulations Principles (fair, reasonable, least onerous etc.) and compare options with regard to risks, costs, sustainability, social consequences and economic effects.

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

SOP (Site Option Plan) Decision Table

Environment Agency Anglian Region

DEFINITION OF RISK CATEGORIES (Standard for Norfolk Valley Fens)

Proposal for SOP (site option plan) decision table

Risk to site integrity of fully licensed abstraction where historical abstraction appears to be acceptable

Criteria	Risk Category		
	Low	Medium	High
1) Performance against model-based hydrological criteria			
Scale of breach for water levels (related to threshold for drought summers)	≤ 5 cm	≤ 10 cm	> 10 cm
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	≤ 3 out of 10 (= ≤ 9 out of 35)	> 3 out of 10 (= > 9 out of 35)
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5 %	≤ 10 %	> 10 %
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	≤ 3 out of 10 (= ≤ 9 out of 35)	> 3 out of 10 (= > 9 out of 35)
Timing of breaches	droughts only	non-droughts only	droughts AND non-drought periods
Soil moisture returning to saturation in winters	always	not in a few winters	not in most winters
Impact on overall hydrological functioning	not significantly impacted	impacted in some years	significantly impacted in most years
2) Appraisal of resources and abstraction scenarios			
Modelled water level under fully licensed scenario similar to naturalised/historical or close to 50% LTA recharge scenario	similar to naturalised or historical	between historical and 50% LTA recharge abstraction scenario	close or above 50% LTA recharge abstraction scenario
Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%	20-40%	>40%
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	small	medium	large
Sensitivity to water table fluctuations indicated by field data (site generally wet?)	small	medium	large
3) Uncertainties			
Evidence to allow judgement of no ecological change available and clear?	available and clear	available but not clear	not available
Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	~ stable or decreasing	slightly increasing	increasing
Model representation adequate?	adequate	less adequate	not adequate
Ecohydrological conceptual understanding clear and agreed?	clear and agreed	less clear, not agreed	not clear, not agreed
Field data available and sufficient?	available and sufficient	available but not entirely sufficient	not available and not sufficient

Further considerations that may influence the overall risk category:			
Add site specific considerations as appropriate…			
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?			

NOTE: This table shows the standard for Norfolk Valley Fens. For other sites the SOP decision table has been modified to account for different hydrological criteria and thresholds.

Appendix 3

Explanation of Decision Table Criteria which are Scored

1) Performance against model-based hydrological criteria

Scale of breach for water levels (related to threshold for drought summers)
This scores the maximum breach of the lowest historical water table threshold in a drought summer.

Low score:	breach ≤ 5cm
Medium score:	breach > 5cm and ≤10cm
High score:	breach >10cm

Environment Agency monitoring at dip-wells typically shows water table fluctuations of 0.5m. A breach of 5cm is 10% of this range. The 5cm flexibility is also set with reference to the Ecohydrological Guidelines. The guide summer water table level for M13, a particularly sensitive community, is given as 10cm BGL.

Frequency of breaches for water levels (related to threshold for drought summers)
This scores the number of breaches of the lowest historical water table threshold in a drought summer.

Low score:	≤1 in 10 years, or ≤4 in 40 years
Medium score:	≤3 in 10 years, or ≤12 in 40 years
High score:	>3 in 10 years, or >12 in 40 years

The frequency associated with the low score was suggested by Natural England in comments on the Roydon Site Action Plan, and this was adopted more generally. It is believed that a breach of the lowest historical water table threshold once in every ten years on average would not be significant, particularly when it is combined with the scale of breach criterion.

Scale of breach for soil moisture (related to threshold for non-drought summers)
This scores the maximum breach of the soil moisture threshold in a non-drought summer.

Low score:	breach ≤ 5%
Medium score:	breach > 5% and ≤10%
High score:	breach >10%

The soil moisture threshold for a non-drought summer is set at field capacity or stress threshold depending on the ecological interest feature. The 5% flexibility representing the boundary between the Low and the Medium categories is set to be precautionary. Although the soil moisture is scored for non-drought summers, the behaviour of the water table is also closely examined.

Frequency of breaches for soil moisture (related to threshold for non-drought summers)
This scores the number of breaches of the soil moisture threshold in a non-drought summer.

Low score:	≤1 in 10 years, or ≤4 in 40 years
Medium score:	≤3 in 10 years, or ≤12 in 40 years
High score:	>3 in 10 years, or >12 in 40 years

The frequencies mirror those for the frequency of water level breaches.

Timing of breaches
This scores how far breaches are contained purely in drought years, or are spreading more generally across drought and non-drought years.

Low score:	Drought years only

Medium score: Non-drought years only
High score: Drought and non-drought years

It is expected that breaches will occur in drought years. It is recognised that droughts are unpredictable in their severity, but that they are of short duration and ecology has been shown to bounce back from such events. However, if breaches spread to non-drought years it could indicate abstraction is having a more general impact.

Soil moisture returning to saturation in winters
This scores whether soil moisture returns to saturation in winters, drought or non-drought.

Low score: Always
Medium score: Not returning to saturation in a 'few' winters - 3 in 10 years
High score: Not returning to saturation in most winters - >5 in 10 years

Winter saturation on wetland sites, linked to high water tables, is an important factor in determining the unique ecology of a wetland site. For a low score, it is judged that saturation should be achieved every winter.

Impact on overall hydrological functioning
This scores the overall change in the hydrological functioning due to the fully licensed level of abstraction, looking at the Secondary Criteria, particularly the vertical groundwater level gradient and the vertical flow.

Low score: Not significantly impacted – vertical flow remains generally upwards for instance
Medium score: Impacted in some years
High score: Significantly impacted in most years

On many wetland sites, the vertical flow under the no abstraction scenario switches direction between the seasons, so reference should be made to the difference in hydrological functioning between naturalised/no abstraction and historical, as well as historical and fully licensed.

2) Appraisal of resources and abstraction scenarios

Modelled water level under fully licensed scenario similar to naturalised, historical or close to 50% LTA recharge scenario
This scores the position of the fully licensed scenario in relation to the end members of naturalised – which by definition represents an acceptable level of abstraction, and the abstraction at 50% of Long Term Average recharge scenario which is a level of abstraction which has been shown in various catchments to be unacceptable.

Low score: Similar to naturalised or historical
Medium score: Between historical and 50% LTA recharge scenario
High score: Close or above the 50% LTA recharge scenario

The naturalised, or no abstraction scenario, is by definition an acceptable level of abstraction, whereas abstraction at 50% LTA recharge has been shown from experience to be unacceptable.

Fully licensed abstraction as a percentage of long term average recharge
This scores the level of abstraction as a percentage of the long term average recharge.

Low score: 0-20%
Medium score: 20-40%
High score: >40%

This is a proportion that has been long used to judge the level of abstraction pressure. This criterion is similar to one of the WFD 'groundwater tests'. The score boundaries are set from past experience.

Sensitivity of modelled water table to changes in abstraction
This scores the difference between water table model time-series for different abstraction scenarios to judge how reactive the water table is to abstraction and to allow some assessment of the vulnerability of the site.

Low score:	Small
Medium score:	Medium
High score:	Large

Sensitivity to water table fluctuation indicated by field data
This scores the reactivity of the water table, which is typically related to water-holding capacity of the superficial deposits and the connectivity to the underlying aquifer.

Low score:	Small
Medium score:	Medium
High score:	Large

Sites formed on thick buried valley deposits where the deposits have a high proportion of clay can maintain a steady water level and are relatively resilient.

3) Uncertainties

Evidence to allow assessment of condition of ecological features
This scores the level of evidence available to allow a good assessment of the condition of the ecological interest features to be made.

Low score:	Good evidence
Medium score:	Some evidence
High score:	Poor evidence

This score is awarded to the ecological information subject to the information reaching a certain level of quality. If there was no ecological information then the approach to assessing the Acceptable Level of Abstraction would not be followed, or at least until the ecological information had been improved. This was the case for Redgrave Fen where the Agency commissioned an NVC survey to achieve a baseline of ecological information for the Fen.

Development of historical abstraction levels over the last 15 years
This scores whether the abstraction has been stable over a sufficiently long period of time to allow confidence that there are no remaining lagged impacts in the ecology on the site.

Low score:	Stable or decreasing
Medium score:	Generally stable or slightly increasing
High score:	More than a slight increase apparent

The time period of 15 years is considered long enough to allow a lagged ecological response to become manifest.

Model representation
This scores the model representation, or calibration.

Low score:	Good representation
Medium score:	Fair representation

High score: Poor representation

This score is awarded subject to the model representation reaching a minimum standard. If the model representation was very poor, further calibration work would be done before using the model to assess the Acceptable Level of Abstraction.

Ecohydrological conceptual understanding

This scores the level of ecohydrological conceptual understanding that has been achieved.

Low score: Good understanding
Medium score: Fair understanding
High score: Poor understanding

Field data

This scores the amount and quality of the field data available for the wetland site.

Low score: Good quality onsite and offsite data available
Medium score: Onsite and offsite data available
High Score: Only offsite data available

This score is awarded subject to at least some data being available. Under the HD RoC the Environment Agency invested in new monitoring at some 40 wetland sites to improve knowledge and understanding.

Appendix 4

Decision Table Scoring System

The scoring system has been established to calculate an overall score that helps to inform a decision. It should however not be used to make the definitive decision. Therefore a “further consideration” box has included that allows for thoughts/reasons/evidence to be put forward which may override or support the calculated scores (i.e. use of professional judgement).

The scoring system gives more weight to criteria related to the hydrological thresholds. Also, the scores for the hydrological thresholds are accorded more weight the higher the risk. This is intended to ensure that a site where the criteria for hydrological thresholds all score high cannot be pulled back into a lower risk category even if all the other criteria are low risk.

Two uncertainty elements do not apply when considering the naturalised scenario and the risk category score levels are reduced accordingly

Scoring:
See example Decision Tables – Table 1

Criteria	**Risk category scores/element**		
	Low Risk	**Medium Risk**	**High Risk**
1) Performance against model based criteria (7 elements)	1	2	4
2) Appraisal of resources and abstraction scenarios (4 elements)	0.5	1	1.5
3) Uncertainties (5 elements, 3 if naturalised scenario)	0.5	1	1.5
Further considerations that may influence the risk category	Professional judgement		

Scoring:
Historical

Scoring for overall risk category:

Sum of all scores	0 to 17	17.5 to 32	32.5 to
Overall risk	low	medium	high

Naturalised

Scoring for overall risk category:

Sum of all scores	0 to 16	16.5 to 30	30.5 to
Overall risk	low	medium	high

Low/Medium/High Category Score Boundaries are defined as the mid point between potential total category scores as indicated in the following diagrams.

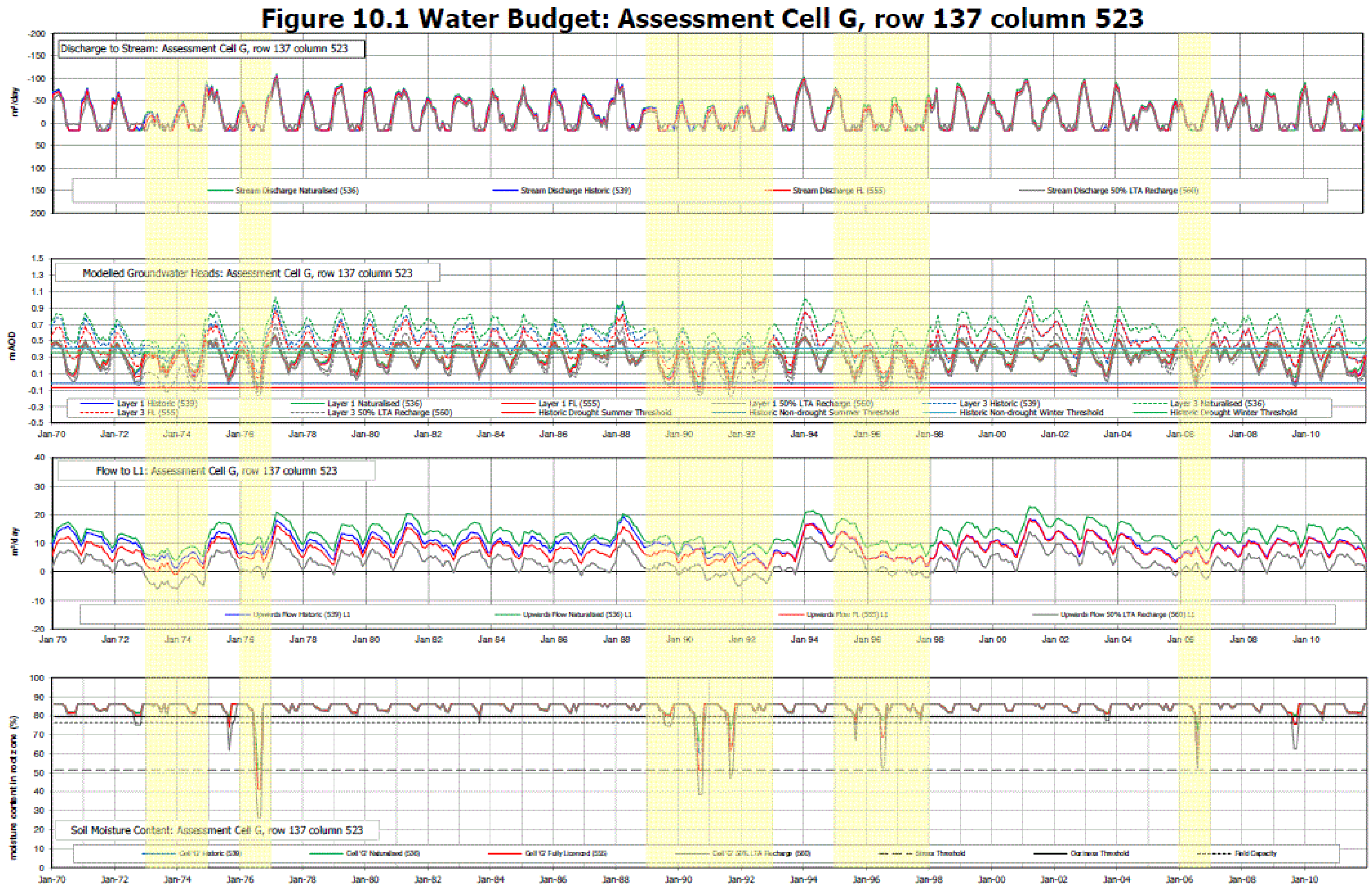
Historical:

Category and Total Potential Score	
Low 11.5	Score boundary: 11.5+23/2 = 17.25 (rounded to **17**)
Medium 23	Score Boundary: 23+41.5/2 = 32.25 (rounded to **32**)
High 41.5	

Naturalised:

Category and Total Potential Score	
Low 10.5	Score boundary: 10.5+21/2 = 15.75 (rounded to **16**)
Medium 21	Score Boundary: 21+38.5/2 = 29.75 (rounded to **30**)
High 38.5	

Figure 1 Appraisal of Abstraction Figure - Cell G (equivalent to Figure 6.1 from the SOP)



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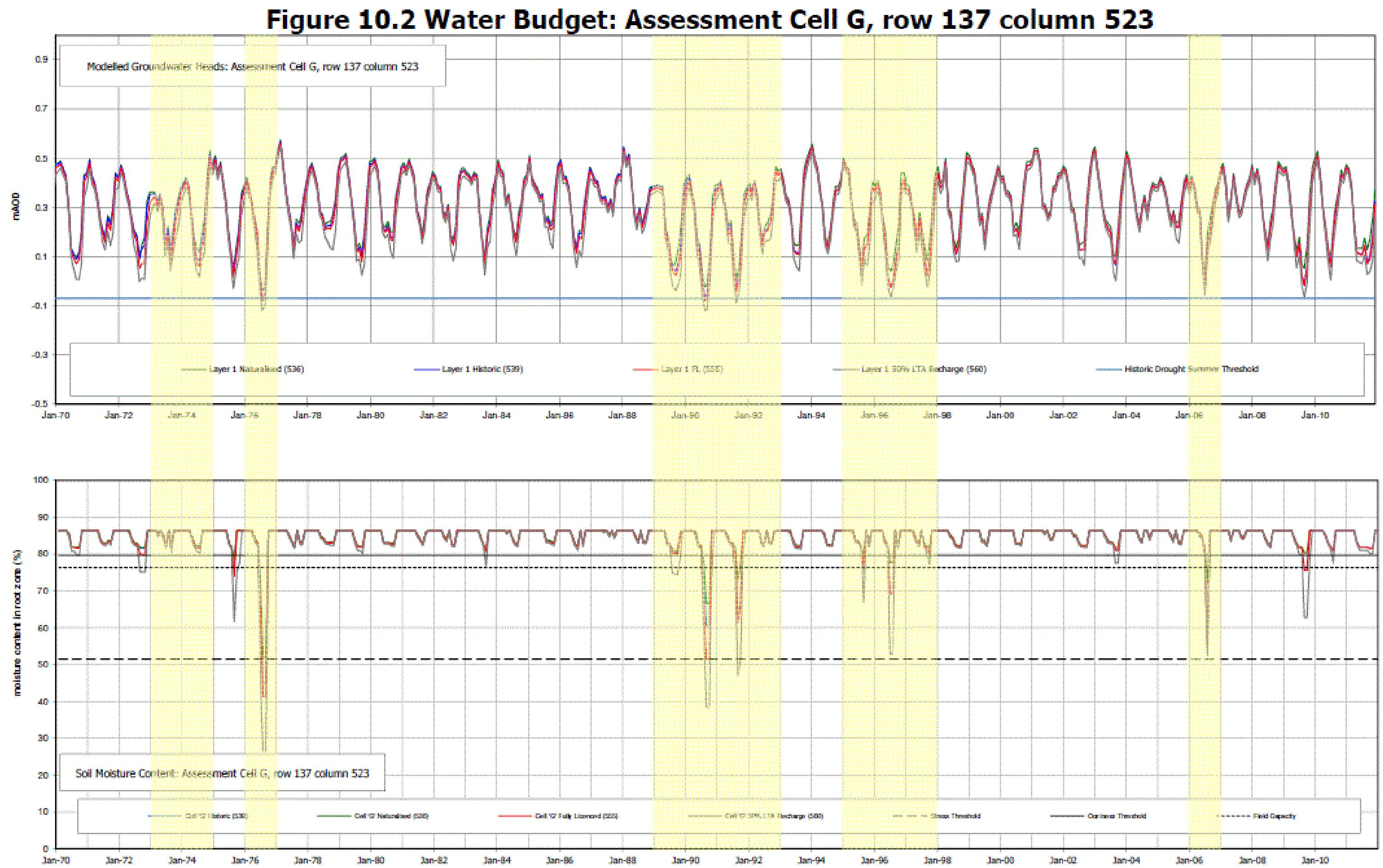
Tab: CellG_Fig 6.1_50pc

Figure 2 Appraisal of Abstraction Figure - Cell G (equivalent to Figure 6.2 from the SOP)



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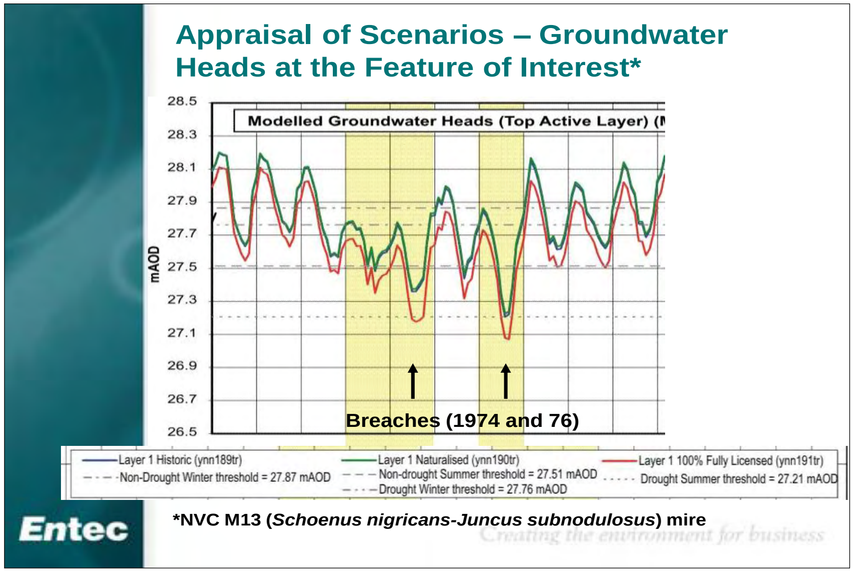
Tab: CellG_Fig 6.2_50pc

Figure 3 Example Application of Thresholds



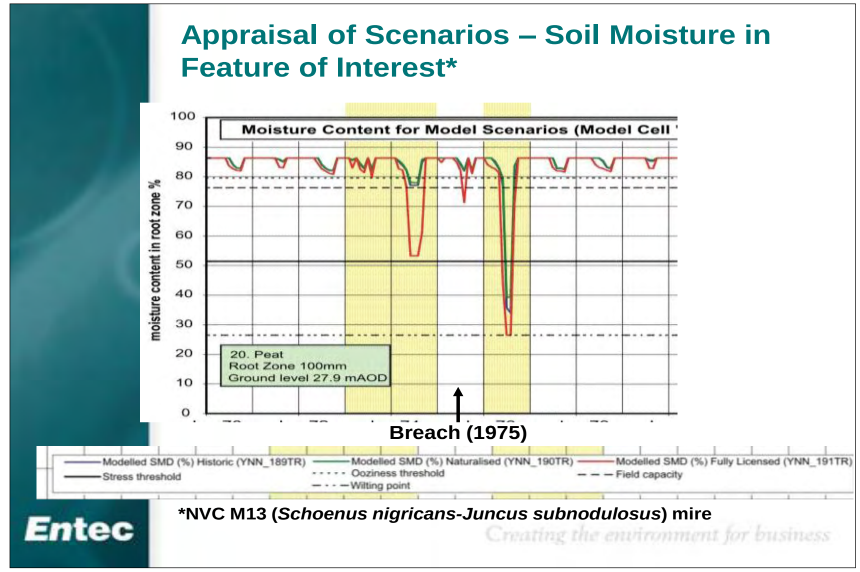


Table 1 Example Risk Matrix Decision Table Cell G – Fully Licensed scenario against Historic thresholds

Anglian Region, Environment Agency

Table 10.6 Catfield Fen Cell G

Date: February 2014

DRAFT Proposal for SOP decision table

Risk to site integrity of fully licensed against the historic scenario

	Risk Category								
Criteria	**Low**	***Site details***	**Score**	**Medium**	***Site details***	**Score**	**High**	***Site details***	**Score**
1) Performance against model-based hydrological criteria									
Scale of breach for water levels (related to threshold for drought summers)	≤ 5 cm	*1.1 cm*	*1*	≤ 10 cm			> 10 cm		
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 4 out of 40)	*2 out of 40*	*1*	≤ 3 out of 10 (= ≤ 12 out of 40)			> 3 out of 10 (=> 12 out of 40)		
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5 %	*none*	*1*	≤ 10 %			> 10 %		
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 4 out of 40)	*none*	*1*	≤ 3 out of 10 (= ≤ 12 out of 40)			> 3 out of 10 (=> 12 out of 40)		
Timing of breaches	droughts only	*yes*	*1*	non-droughts only			droughts AND non-drought periods		
Soil moisture returning to saturation in winters	always	*always*	*1*	not in a few winters			not in most winters		
Impact on overall hydrological functioning	not significantly impacted	*Upward vertical gradient and upward flow remain generally positive with one period of reversal to downward flow (1973)*	*1*	impacted in some years			significantly impacted in most years		
2) Appraisal of resources and abstraction scenarios									
Modelled water level under fully licensed scenario similar to naturalised/historical or close to 50% LTA recharge scenario	similar to naturalised or historical			between historical and 50% LTA recharge abstraction scenario	*yes*	*1*	close or above 50% LTA recharge abstraction scenario		
Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%			20-40%	*26% for Bure, Ant & Thurne Reporting Area*	*1*	>40%		
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	small	*Little difference in heads between the different abstraction scenarios*	*0.5*	medium			large		
Sensitivity to water table fluctuations indicated by field data (site generally wet?)	small			medium	*precautionary yes (since no dipwell data available for that part of Ant B&M)*	*1*	large		
3) Uncertainties									
Evidence to allow assessment of condition of ecological features	good evidence	*yes*	*0.5*	some evidence			poor evidence		
Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	stable or decreasing	*Stable/slight decrease for Bure, Ant & Thurne and Area of Interest*	*0.5*	generally stable or slight increase apparent			more than a slight increase apparent		
Model representation	good representation	*Good Representation*	*0.5*	fair representation			poor representation		
Ecohydrological conceptual understanding	good understanding	*Generally understood and agreed*	*0.5*	fair understanding			understanding inferred from other sites		
Field data	good quality onsite and offsite data available			onsite and offsite data available	*precautionary yes (since no dipwell data available for that part of Ant B&M)*	*1*	only offsite data available		
Further considerations that may influence the overall risk category:									
Add site specific considerations as appropriate...									
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?									
		Total "low":	*9.5*		*Total "medium":*	*4*		*Total "high":*	*0*

Note: If more than one assessment cell on a SSSI use the one with highest risk to decide on overall site risk category.

Scoring for overall risk category:

Sum of all scores	0 to 17	17.5 to 32	32.5 to
Overall risk	low	medium	high

Total risk score calculated: *13.5* *= low risk category*