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Catfield Renewal: "An initial calculation of the potential impact of groundwater abstraction on the hydrology of Catfield fen"

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1.0 Introduction

This submission has been prepared by David Gilvear, Head of the Catchment and River Science Research Group at Plymouth University. Professor Gilvear is a river scientist with expertise in wetland hydrology. His post-doctoral research in the late 1980s focussed on the hydrogeology and vulnerability of East Anglian wetlands to groundwater abstraction. He is currently President Elect of the International Society of River Science and on the Editorial Board of the international journal River Research and Applications. He has more than 75 international journal and book chapter publications including:

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Gilvear DJ, Sadler PJK, Tellam JH & Lloyd JW 1997. Surface water processes and groundwater flow within a hydrologically complex floodplain wetland, Norfolk Broads, UK. *Hydrology and Earth Systems Sciences* 1, 115-135.

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2.0 Context

This submission represents that of a synthesis of information provided to Natural England and the Environment Agency in the form of a report dated 30th April 2012, a follow up report on the 22nd August 2012 and in a letter to the Environment Agency dated 16th December 2012. At that time the analysis was undertaken to provide an initial assessment of the potential impacts of groundwater withdrawal within the vicinity of Catfield fen on its hydrology.

The purpose of the initial report and follow up report and communications was to simply illustrate and communicate in an understandable way:

(i) The significance of the volume of water licensed for abstraction from the groundwater aquifer within the vicinity of Catfield fen in terms of the wetland itself.

(ii) The possible significance of multiple groundwater abstraction boreholes on the small groundwater catchment that supplies base-rich water to Catfield Fen.

2.0 Source of information and assumptions of the Catfield fen

The text below outlines the sources of information and assumptions behind this initial calculation of the potential impact of groundwater abstraction on Catfield fen and values of potential maximum drawdown in groundwater levels on Catfield Fen in response to nearby abstraction. Water level declines presented can be viewed as a “worst case” scenario. In the absence of scientifically valid alternatives it can be viewed as a preliminary assessment of the impacts of groundwater abstraction on Catfield fen.

1. The groundwater catchment area was determined with reference to the Figure B2 in the AMEC report (2012). This is the best known source of information on the groundwater contours. The boundary of the catchment was determined as the marked catchment divide to the east of Catfield and then to the north and south drawn at right angles to the groundwater contours (groundwater will flow perpendicular to the groundwater contours as a result of the hydraulic head difference) meeting up with the margins of the internal system at Catfield fen. The catchment area was approximated as 2.0km^2 (see Figure 1 attached). This is a very small catchment.
2. The area of Catfield fen was estimated from a 1:10,000 map of the fen. The value used for this analysis was 0.5 km^2 (See Figure 1). It is worth noting that the fen to catchment area ratio is 0.25. This is a very high ratio of wetland area to catchment area. As such any groundwater lost to abstraction that would have flowed to the fen is likely to have a large effect.
3. The location and extent of the spray irrigation groundwater cones of depression were based on them being centred on the abstraction point, them being circular in form and with a radius of 750 metres. These theoretical cones of depression occupy an area of 1.77 km^2 (based on πr^2). Theis modelling predicts a drawdown of 1cm at 600 metres from the borehole and no drawdown at 1000 metres for the Plumsgate Road spray irrigation borehole (AMEC 2012; Page 54). It is realised that the full extent and shape of the cone of depression is difficult to quantify but in the presence of no

conflicting information these assumptions seem valid. Given these assumptions it is estimated that 10% (0.180 $km^{2)}$, 25% (0.44 km^2) and 45% (0.80 km^2)of the cone of depressions for Overton, Plumsgate Rd, and Ludham Rd (Alston) lie within the groundwater catchment draining to Catfield fen (see Figure 1). In total these areal extents equates to almost 71% of the estimated groundwater catchment. The equivalent value of the extent of AWS Ludham Road cone of abstraction within the catchment is estimated as 33%. Here the radius of the cone of depression was estimated as 1.2km.

4. To estimate the volume of water lost as water equivalent depth over Catfield Fen the licensed daily rate was used for each abstraction. This volume was then divided by the area of the internal system at Catfield fen and expressed as water depths equivalent per day .The values are 0.2 mm for Overton (based on licensed daily rate of 1.2MLD), 0.5mm for Plumsgate Road (based on a licensed daily rate of 1.090 MLD), and 0.7 mm Ludham Road (Alston) (based on a licensed daily rate of 0.8 MLD) (see worked example in Appendix 1). Thus the abstraction is withdrawing a combined total of 1.4 mm per day of water in terms of fen water depth equivalent. If we assume a dry weather period of 30 days this represents 42 mm or 4.2 centimetres as a maximum possible water loss. These values assume all the water abstracted would have made its way to the fen. However, the actual drawdown in fen groundwater levels will be more if we take in to account the fen porosity. Porosity values area not known but if they were say 50% the actual value of fen groundwater level drawdown would double to 8.4 centimetres. In comparison to the spray irrigation, the AWS Ludham Road abstraction (based on a licensed daily rate of 2.27 MLD) with an assumption of 33% of cone of depression within the Catfield fen groundwater catchment area has a similar value - 1.5 mm per day or over 30 days 45 mm or 4.5 centimetres. If once again we take a porosity value of 50% then the predicted actual maximum water level drawdown would be 9 centimetres. The effect of AWS Ludham and the spray irrigation would be 17.4 centimetres

4.0 The underlying theory and output of the assessment approach

In terms of the drying out of Catfield fen the ecologically critical time is when water levels are low in summer and there is a high soil moisture deficit due to lack of rainfall and high evapotranspiration. Such periods will normally correspond with periods of abstraction for spray irrigation. The study by AMEC (2012) in relation to the impacts of groundwater abstraction on Catfield fen focussed on the extent of water level drawdown below the fen and around its margins with the assumption being made that zero drawdown at the fen margins represents no impact. Here consideration is given to water fluxes from the wider groundwater catchment to the fen and possible impacts of the cones of depression caused by the groundwater abstraction. It is not a detailed analysis but is seen as highlighting a missed component of the assessment by AMEC (2012) and one that warrants attention. The real issue under scrutiny is the drying out of the fen in the summer months and from a hydrological perspective this has to be a result of either a reduction of water inputs or increased water losses over the summer.

During dry weather conditions the fall in the water table will be a function of the balance between water inputs and losses (see section 5.). It is accepted that lateral inputs of groundwater, presumably from the shallow layers of the aquifer occur and this together with any movement of water through unsaturated layers will be the only input in times of no rainfall. The total contribution of groundwater input to the budget may be relatively small but in dry weather it will be 100% of the input. In effect these groundwater inputs will trickle charge the fen with water helping to offset water storage decline. The dominant loss from the internal system at Catfield fen during times of low water will be evapotranspiration (likely to be in the order of 3mm per day). This is in the absence of downward head gradients in the groundwater systems caused by groundwater abstraction. In the discussion below we will assume no vertical leakage of fen waters to the groundwater system. If this does occur it will heighten falls in fen water levels during periods of drought stress.

The precise catchment area feeding groundwater to the fen is unknown but based on interpolated groundwater contours (AMEC, 2012, Figure B2) for the Upper Crag it is small and approximately 2km^2 in extent. The internal system at Catfield fen is about 0.5 km^2 in area. Within this catchment the effects of 4 groundwater abstractions (Plumsgate Road (Alston) Ludham Road (Alston), Overton and AWS Ludham) will be fully or partially present and because of the connectivity in the system impact on the Upper Crag. Assuming the cones of depression for spray irrigation (Plumsgate Rd, Ludham Rd, and Overton) have a radii of 750 metres none will extend to the fen margins but they would during pumping prevent the natural movement of water to the fen over approximately half of the catchment area. Cones of depression with a radius of 1000 metres would impact the majority of the Upper Crag groundwater catchment feeding Catfield fen. It should also be noted that the majority of these assumed cones of depression in the case of Overton and Plumsgate Road do lie outside of the catchment area. If the AWS Ludham source has an assumed cone of depression with a radius of 1200m, which is a real possibility, it would be impacting on groundwater levels in the same areas as Ludham Road (Alston) and Overton and thus there will be a cumulative effect, resulting from overlap, on the groundwater system.

The exact 3-dimensional form of the cones of depression in the groundwater aquifer during abstraction is not known but during test pumping in 1987 at an average rate of 860 m^3 d (licensed rate is currently 800 m^3 d) a water drawdown of 12.56m was observed at Ludham Road (Alston) (AMEC 2012) and thus their effect can be large – it is accepted that further away from the borehole drawdown will be much less and diminish with distance. Such cones of depression during pumping will intercept water moving from upgradient hydraulic head areas within the groundwater catchment and also reverse flow away from the fen and to the borehole down gradient/slope. Thus lateral flow of groundwater to the fen will be stopped and restricted to any unaffected areas of the catchment.

The volumes of water abstracted during spray irrigation abstraction represent a theoretical loss of groundwater that would otherwise drain towards the fen. It is worth assessing how these volumes may impact on fen groundwater levels. This can be done by dividing the volumes abstracted by the fen area and expressing it as mm drawdown of water levels per day or over a period of dry weather when daily pumping may occur. Here it is assumed that 10%, 25% and 45% of the cone of depressions for Overton, Plumsgate Rd, and Ludham Rd (Alston) lie within the groundwater catchment draining to Catfield fen. The values are 0.2 mm for Overton (based on licensed daily rate of 1.2MLD), 0.5mm for Plumsgate Road (based on a licensed daily rate of 1.090 MLD), and 0.7 mm Ludham Road (Alston) (based on a licensed daily rate of 0.8 MLD). Thus the abstraction is withdrawing a combined total of 1.4 mm per day of water in terms of fen water levels. If we assume a dry weather period of 30 days this represents 42 mm or 4.2 centimetres. This is not a statement of the drawdown that will occur due to spray irrigation abstraction but gives an indication of the potential impact and significance. Modelled abstraction effects and evapotranspiration combined could lead to a potential drawdown of over 4mm a day if not offset by groundwater inputs from beneath the fen. In comparison to the spray irrigation abstraction the AWS Ludham Road abstraction (based on a licensed daily rate of 2.27 MLD) with an assumption of 33% of cone of depression within the Catfield fen groundwater catchment area has a similar value - 1.5 mm per day or over 30 days 45 mm or 4.5 centimetres.

This narrative and analysis, although a theoretical modelling exercise based on a number of assumptions, illustrates clearly the potential impact of groundwater abstraction on Catfield fen. The analysis and values used in estimating the extent of the groundwater cones of depression and their location in relation to the groundwater catchment draining to the fen are based on information are based on information in the AMEC (2012) report.

5.0 Discussion and justification of the of the approach and linked methodology of potential Catfield fen water level drawdown analysis

It section discusses and justifies the use of the catchment based water budget approach as a way of undertaking a preliminary analysis of the effects of groundwater abstraction on the hydrology of Catfield fen. Water levels given were expressed as water depth equivalents per day (mm). The actual water level change within the fen deposits will depend upon their porosity (e.g. peat is 90% water), the percentage of the water abstracted that would naturally makes its way to the fen and the natural time of travel of groundwater from the abstraction point to the fen. The water depth equivalent value should be seen as a possible maximum effect although it should be noted that if fen deposits had a porosity of for example 50%, a 10mm water equivalent loss would result in a fen water level drawdown of 20mm. As stated above the catchment based water water budget approach was undertaken to increase awareness of the hydrological significance of the licensed volumes of groundwater being abstracted nearby to Catfield fen and the role of near surface catchment hydrology to the fen water balance. It was always presented as theoretical and based on assumptions and as such some people dismissed it as “simplistic”, of no use as “a rival theory”, and not a challenge “to well established techniques in hydrogeology” in assessing the effects of groundwater abstraction on Catfield fen. This dismissal is disappointing and reflects a lack of awareness of purpose of presenting this way of thinking about the Catfield fen “groundwater issue” and the role of near surface catchment hydrology in sustaining fen environments. Few fens will have water supplied solely by precipitation from above and vertical groundwater flow from beneath the fen. As such groundwater heads do no have to be depressed immediately below the fen surface area for groundwater abstraction to be implicated in a drying effect. The lowering of groundwater heads by abstraction on hillslopes draining to a fen can reduce water input by reducing spring flows above and to the fen and movement of water through saturated and unsaturated soils to the fen. Modelling as to whether a fall in groundwater head beneath a fen occurs is therefore not a fool-proof way of safeguarding fen hydrology.

The water balance of a fen can be expressed as

S = P + GWI + HWI + SWI - GWO – SWO – ET

Where S represent fen water storage, P precipitation, GWI groundwater inflow, HWI hillslope water inputs, SWI surface water inputs, GWO groundwater outflow, SWO surface water outflow and ET evapotranspiration.

HWI and SWI inputs could be reduced where groundwater heads below the fen have been unaffected by abstraction. The obsession on depression of groundwater heads beneath the fen seen in the assessment of the vulnerability of Catfield fen to abstraction (AMEC, 2012) is poorly-informed and suggests an inability to consider fen hydrological functioning and to put fen hydrology in to a catchment context. As an analogy to illustrate this river flows can be significantly altered by groundwater abstraction reducing spring flows when the perennial channel network itself is un-impacted by groundwater head lowering.

Those who criticised the analysis as presented in its initial form (Gilvear report dated 30th April 2012) have misrepresented its original purpose and context and as such that the level of analysis was simplistic. The reason for proposing it was to illustrate the vulnerability of the Catfield fen hydrology in terms of:

(i) its size of the fen in relation to the groundwater catchment area supplying it with water,
(ii) the sizeable volume of licensed abstraction in relation to the fen area, and
(iii) the location and possible size of the groundwater cones of depression caused by abstractions during dry conditions could be a significant area of the catchment. As such there is a significant likelihood in a reduction of water reaching Catfield fen from its catchment compared to a non-groundwater abstraction scenario.

The calculations presented are for illustrative purposes and thus what others have labelled as “arbitrary values” were chosen solely to demonstrate hydrological thinking. In all cases where values were given the justification was presented (eg radii of cones of depression from output of

AMEC report, 2012) with acknowledgement that further research would be required to establish values that better approximate reality.

The theory was presented in its simplistic form whereby others could fully explore “real” groundwater abstraction scenarios and the role of lateral inputs of water to the fen. It should be considered as supplementary or refinement to the existing modelling approach never as solely as a “rival”.

6.0 Conclusions

1. Catfield fen has a small groundwater catchment feeding it and thus it is potentially highly sensitive to groundwater abstraction within the area.
2. The methodology presented is sound in terms of predicting a maximum possible loss of water to Catfield Fen from groundwater abstraction in terms of water equivalent depth
3. The methodology predicts a maximum loss of water in terms of water depth equivalent over the fen of 4.2 centimetres over 30 days of maximum licensed spray irrigation and 4.5 centimetres from AWS Ludham once again based on maximum abstraction rates over 30 days. These values combined give a value of 8.7 centimetres. If the porosity of the fen deposits is taken in to account the predicted maximum actual drawdown in fen groundwater levels will be larger.
4. In the absence of other scientifically valid approaches the water level drawdown values on Catfield fen presented should be viewed as a worst case scenarios and groundwater and wetland management decisions taken accordingly.

REFERENCES

AMEC (2012) Catfield Fen Investigation, Final Report. Report to Environment Agency (Anglian Region)

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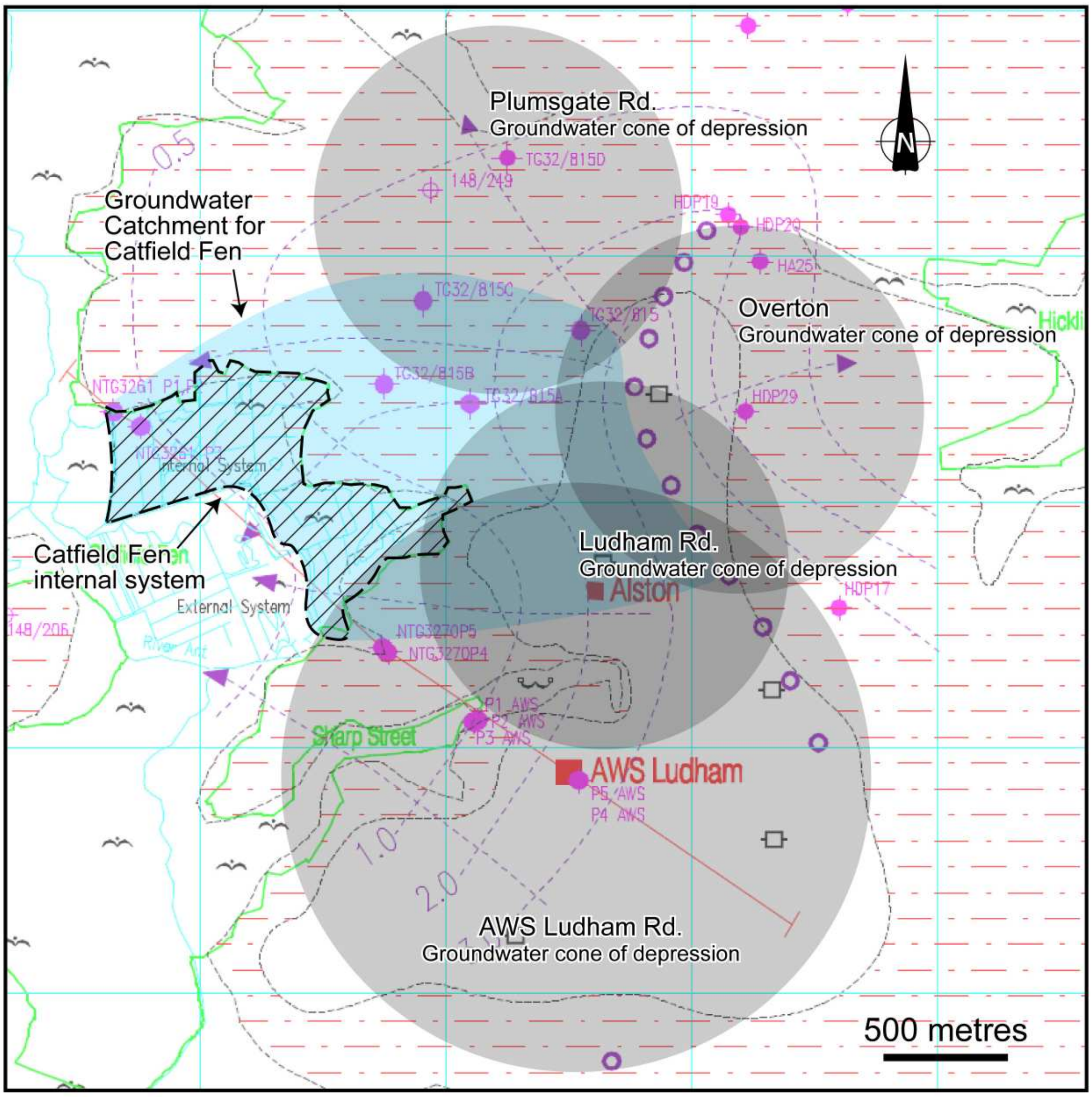
Figure 1 A map illustrating the geography of Catfield fen, its assumed groundwater catchment and theoretical cones of depression surrounding abstraction boreholes in the local region.



Appendix 1 - Method of calculation of maximum possible water level drawdown per day in water depth equivalents on Catfield fen due to the Plumsgate Road spray irrigation

Licenced maximum daily abstraction rate - 1.090 MLD

Catfield fen area (0.5km^2)

1.090 million litres = 1090m^3

0.5km^2 = 500000 metres

1090 divided by 500000 = 0.00218 metres (i.e.volume divided by area)

0.00218metres = 2.18 millimetres per day (depth of water over Catfield)

Given 25% of cone of depression is in catchment area of Catfield fen

2.18/4 = 0.545 millimetres per day