Cookley Nitrate Investigation Summary

Report details

This document is a summary of the detailed information provided in the main nitrate investigation report for the site (ref. 63684K R4), completed by ESI. Its purpose is to provide an overview of the nitrate modelling work and catchment assessment for the site, for internal use by South Staffordshire Water (SSW) and as a communication tool with relevant stakeholders. Referenced acronyms are described in the glossary section and figures are included at the end of the summary report.

Site details

NGR:	SO 8440 8068	Number of boreholes:	3 (CK1, CK2, and CK3)
Catchment area:	25.2 km^2	Average monthly abstraction (1970 – present):	12.2 Ml/d

Water quality details

Average monthly nitrate concentration (Mar 1994-Apr 2016):	CK1: 26.4 mg NO_3/l CK2: 35.9 mg NO_3/l CK3: 41.4 mg NO_3/l	Observed nitrate range (as monthly average across site):	CK1: 14 - 44 mg NO_3/l CK2: 22 - 51 mg NO_3/l CK3: 22 - 53 mg NO_3/l
Overall observed nitrate trend:	Increasing until 2013 followed by a gradual declining trend.	Nature of peaks:	Peak in long term trend shown in 2013 at all three boreholes.

Site background

Cookley groundwater abstraction, or pumping station (PS), is located approximately 6.8 km south west of the centre of Stourbridge. The nearest SSW PWS abstractions to Cookley are Churchill (2.7 km east) and Kinver (2.7 km north). A STWL emergency abstraction site (Beechtree Lane) is also located 2 km east of Cookley PWS.

The site comprises three licensed boreholes (CK1, CK2, and CK3). CK1 is the northern most borehole, CK2 is located ~50 m west south west and CK3 is located ~60 m south of CK1. The base of all three boreholes is at approximately 182.9 m depth. CK1 and CK2 are cased with plain lining to 27.6 mbd, slotted lining to 89.7 mbd and then unlined to the base. There are no construction details for CK3 but it is assumed to be the same as CK1 and CK2.

All boreholes are completed in the Kidderminster Pebble Bed (of the Triassic Sherwood Sandstone Group) and Bridgnorth Sandstone Formation. Marl bands are present and noted to be intruding through the slots in the casing, although their thickness and extent are unknown. The Cookley site is in close proximity to the River Stour and as such there are alluvium deposits comprising clay, silt, sands and gravel surrounding the boreholes and further sand and gravel deposits throughout the western side of the catchment along the course of the river. The unsaturated zone is thickest along the eastern and western boundaries of the catchment (up to 70 m), reducing in thickness (to c.10 m) towards the centre of the catchment (following the course of the River Stour) (Figure 1).

According to SSW borehole logs, rest water levels in the boreholes are approximately 12-14 mbd. Pumped water levels typically range between 12 and 22 mbd with the greatest drawdown being observed in CK1.

Model results from the Environment Agency's West Midland Worfe model were used to delineate a catchment that contributed yield to the boreholes at Cookley. Total abstraction at the site remained reasonably stable over the data period available, so the historical modelled catchment was considered most suitable for the assessment (using data from January 1970 to March 2011), which covers 25.2 km^2 (Figure 1). Most of the yield (>70%) is from cells north of Cookley and in the predominantly rural centre of the catchment.

The split of abstraction between the boreholes has varied over time, from the majority of abstraction from CK3, to a more even balance from all three boreholes since mid-2012.

Observed nitrate at the site

The average concentration of nitrate differs across the three Cookley boreholes; in order from highest average concentration is CK3 (43 mg NO_3/l), CK2 (38 mg NO_3/l) and CK1 (27 mg NO_3/l) (Figure 2).

The data for CK2 and CK3 show rising trends until approximately 2014, with nitrate concentrations increasing by approximately 15-19 mg NO_3/l over the previous 20-year period. The data for CK1 illustrate a reasonably flat trend, with nitrate concentrations generally ranging between 24.5 and 29.5 mg NO_3/l. More recently, in early 2014, all boreholes show a sudden reduction in nitrate followed by a more gradual increase in nitrate concentrations, before suddenly falling again around late 2015/early 2016 (Figure 2). The PCV has only been exceeded at CK3.

There is a possible correlation between groundwater level in the boreholes and the three distinct trends in nitrate concentration. In general the highest nitrate concentrations are found in the borehole with the highest groundwater level (CK3). No clear correlation can be made between nitrate concentration and abstraction (although abstraction rate does seem to be determined by the groundwater level and the response of the borehole. CK1 generally has the lowest yield).

Treatment is not in place at the PS.

Land use and sources of nitrate

66% of the catchment is classed as arable land, 7% is pasture and 23% is urban land use (Stourbridge to the east). The remainder of the catchment (~4%) is forest and an area of 'industrial or commercial units' in the centre of the catchment (the Roundhill sewage treatment works). Aerial imagery shows there to also be a sand pit (in the glaciofluvial drift deposits) just west of the Roundhill works, 4 km north east of the Cookley abstraction.

Agricultural nitrate: Within the catchment, NEAP-N nitrate concentrations are generally highest in the centre of the catchment, north and north east of the PS; being up to 60 mg NO_3/l. Nitrate loadings decrease around the boundary of the catchment (23-34 mg NO_3/l), mainly north east of the PS, which corresponds with urban land cover. Between 1980 and 2010 there has been an average decrease of 0.5 mg NO_3/l across the catchment. Most nitrate loading is from fertilised arable land (57%), while 22% is from pasture and 9% from urban land (12% is from other sources such as woodland and atmospheric N).

Surface water infiltration: The FlowSource analysis suggests that up to 12% of the Cookley historical yield was derived from model cells through which the River Stour and Staffordshire and Worcestershire Canal pass. The concentration of nitrate in the River Stour in 2009 (latest available data) was approximately 73 mg NO3/l.

Point sources: Two key point sources were identified in the review of the catchment area: Roundhill Sewage Treatment Works (STW) and Whittington Hall Sewage Farm. The former of these sites is located 4 km north east of Cookley PS. Treated water is returned to the River Stour and the Gallows Brook (and it is believed that this discharge point is located within the delineated Cookley PS groundwater catchment). Whittington Hall Sewage Farm is located 3 km north east of Cookley PS. The site was in use until Dec 1983 as a sewage farm and average flows to the site amounted to around 12 Ml/d (with 2 Ml/d thought to discharge directly to the River Stour, therefore around 10 Ml/d discharging to ground).

Summary of model parameters and results

Hydrogeological parameters:

Hydraulic conductivity of the aquifer (K) of 4 m/d	Hydraulic gradient (i) of 0.015
Porosity (n) of 15%	Hydraulic conductivity of the unsaturated zone (K_{usz}) of 0.0015 m/d
Unsaturated zone thickness ranging between 5 and 80 m (Figure 1)	

Observed nitrate data and the modelled trends are illustrated in Figure 2. With the information currently available for the site, regarding potential sources of nitrate within the catchment, the following parameters were used:

- Groundwater dilution: 66% of borehole yield at CK1 comprises fresh (3.3 mg/l as NO_3) groundwater, 51% at CK2 and 42% at CK3.
- Surface water contribution: 12% of borehole yield comprises surface water (73 mg/l as NO_3).
- Point source contribution: No point source included

The standard deviation of the data about the modelled trend has been quantified as 3.1 mg NO_3/l for CK1, 4.1 mg NO_3/l for CK2 and 5.07 mg NO_3/l for CK3 (used to calculate the trend envelopes, as shown in Figure 2).

The quality of fit of the modelled nitrate trend is reasonably good for each of the three boreholes and the historical annual average dataset also fits within the trend envelope for both CK2 and CK3 (Figure 2). To fit the three distinct observed nitrate trends of the Cookley boreholes, only the percentage contribution of fresh groundwater to the yield was altered. The apparent correlation between groundwater level and the concentration of nitrate at the three boreholes suggests a varied dilution rate from cleaner/deeper groundwater in each borehole is likely. No point source was needed to achieve the model fits shown.

The counterfactual (or 'do nothing'/'business as usual') scenario (the 'Source Model' line of Figure 2) predicts a relatively flat future long term average trend in the concentration of nitrate at all three boreholes. The average trend line for all three boreholes is predicted to remain below the PCV (50 mg NO3/l).

Catchment management

Catchment management mitigation measures (for nitrate) considered suitable for the groundwater catchment are listed below. Further information on these measures including nitrate loading reduction rates and costing estimates (on an individual farm basis) is provided in a separate technical note (63684K TN1). The timing and magnitude of an estimated impact of such measures (light touch catchment measures) to the concentration of nitrate at the PS is shown on Figure 2 ('Future Model' trend line).

Measures for Severn Valley, arable farms, free-draining soils	Measures for Lichfield area, livestock farms, free-draining soils
Use plants with improved nitrogen use efficiency	Establish cover crops in the autumn
Use a fertiliser recommendation system	Use plants with improved nitrogen use efficiency**
Use manufactured fertiliser placement technologies	Use a fertiliser recommendation system**
Fertiliser spreader calibration	Integrate fertiliser and manure nutrient supply
Unfertilised cereal headlands*	Use clover in place of fertiliser nitrogen

*Very expensive option, which may prove unpopular with landowners/farmers.

**Listed for both arable and livestock farms.

The impact of catchment measures may reach the abstraction in 20-40 years.

Predicted impact of catchment management:

Predicted maximum reduction of peak counterfactual concentration	5 mg NO_3/l for all three boreholes (14% for CK1, 11% for CK2 and 9% for CK3)
Impact to average concentration	Reduces long term average further below PCV for all three boreholes.
Impact to peak concentration	At CK1 and CK2 the peak concentration is expected to remain below the PCV from catchment measures (as is also expected for the counterfactual scenario at these two boreholes). For CK3 catchment management measures may bring peak concentrations below the PCV by 2044.

The spatial outputs (Figure 3) can be used to inform catchment management options. Most of the yield, and nitrate, reaching the boreholes comes from the arable and pasture land in the centre of the catchment area (north east of the pumping station). Some areas within the catchment have increased in nitrate loading between 1980 and 2010 (as shown in Figure 3). These areas should be reviewed, to assess whether the existing land use could be an existing or future nitrate source to the PS.

Key outcome and recommendation

Catchment management measures are considered suitable for the groundwater catchment. A relatively good model fit was achieved using the model parameters assessed (clean/deep groundwater dilution and surface water interaction). However, it is recommended that, before mitigation measures are proposed for the site, the potential impact of the point sources within the catchment plus further information into the surface water features is collated. This would allow for the model parameters to be reviewed and confirmed. Additional, this will help to improve the predicted impact of mitigation on the concentration of nitrate at the site (and in each of the active boreholes).

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Glossary

bgl	Below ground level
bd	Below datum
CK	Cookley borehole
NEAP-N	The National Environment and Agriculture Pollution Nitrate model
PCV	Prescribed concentration or value*
PS	Pumping station
PWS	Public water supply
SPZ	Source protection zone
SSW	South Staffordshire Water Ltd
STWL	Severn Trent Water Ltd

*Note that in this case, PCV is interchangeable with drinking water standard (DWS), which is also 50 mg NO_3/l.

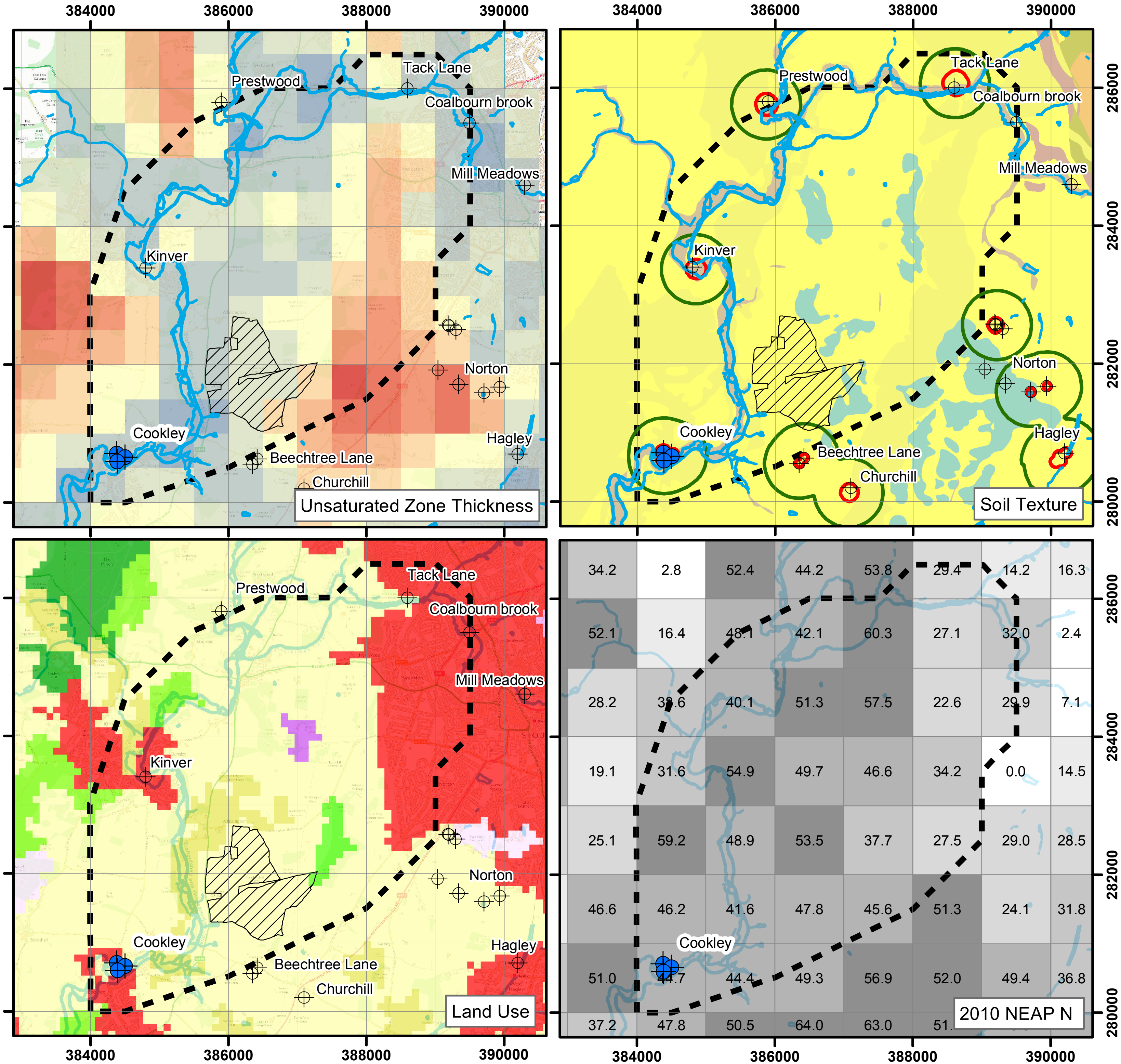

Figure 1
Cookley catchment

Legend

- Abstractions
- Other PWS groundwater abstractions
- Historical catchment
- Previous sewage farmland
- SPZ 1
- SPZ 2

Unsaturated zone thickness (m)

- < 0
- 0.1 - 5
- 5.1 - 10
- 10.1 - 20
- 20.1 - 30
- 30.1 - 40
- 40.1 - 50
- 50.1 - 60
- 60.1 - 70
- 70.1 - 80
- 80.1 - 90

Soil Texture

- Clay to Loam
- Silt to Sand
- Sand
- Loam
- Loam to Sand
- Clayey Loam to Sandy Loam

Land Use

- Discontinuous Urban Fabric
- Industrial or Commerical Units
- Green Urban Areas
- Sport and Leisure Facilities
- Non-irrigated Arable Land
- Pastures
- Broad Leaved Forests
- Coniferous Forest
- Mixed Forest

NO3 Concentration (mg/l)

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 50
- 51 - 75
- 76 - 100
- 101 - 200

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Date	Mar 2017	Drawn	EJC
Scale	1:75,000	Checked	RFF
Original	A3	Revision	V1

File Reference
O:\63684K SSW AMP6 NO3 modelling\GIS\Map documents\Site summary

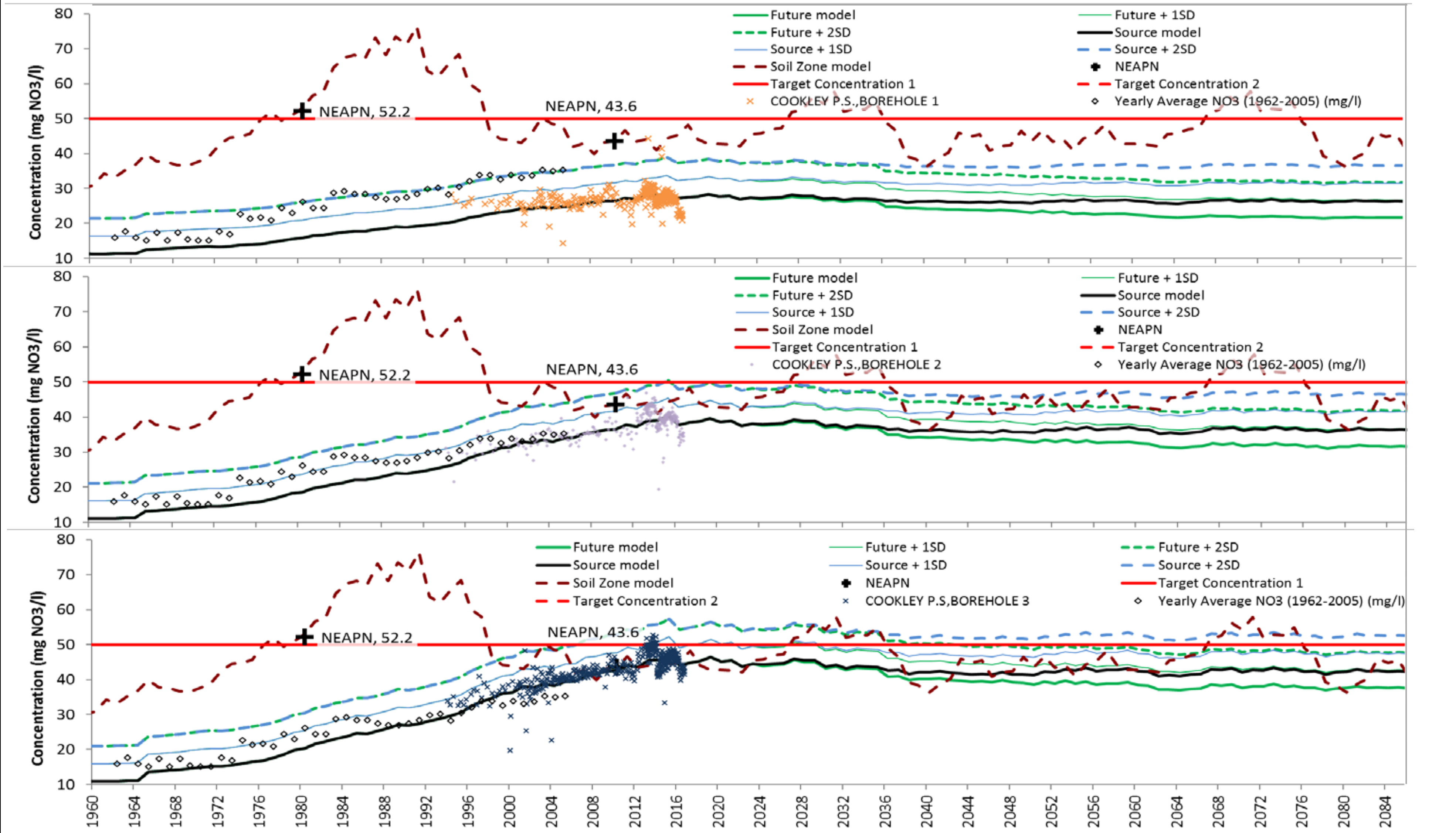

Figure 2

Observed nitrate concentration & modelled trends with justified parameters for CK1, CK2 and CK3

The 'future model' trend shows the estimated impact if catchment management measures targeting agriculture were carried out (equivalent to ~8% reduction in N loading in arable and pasture fields from 2016 onwards).

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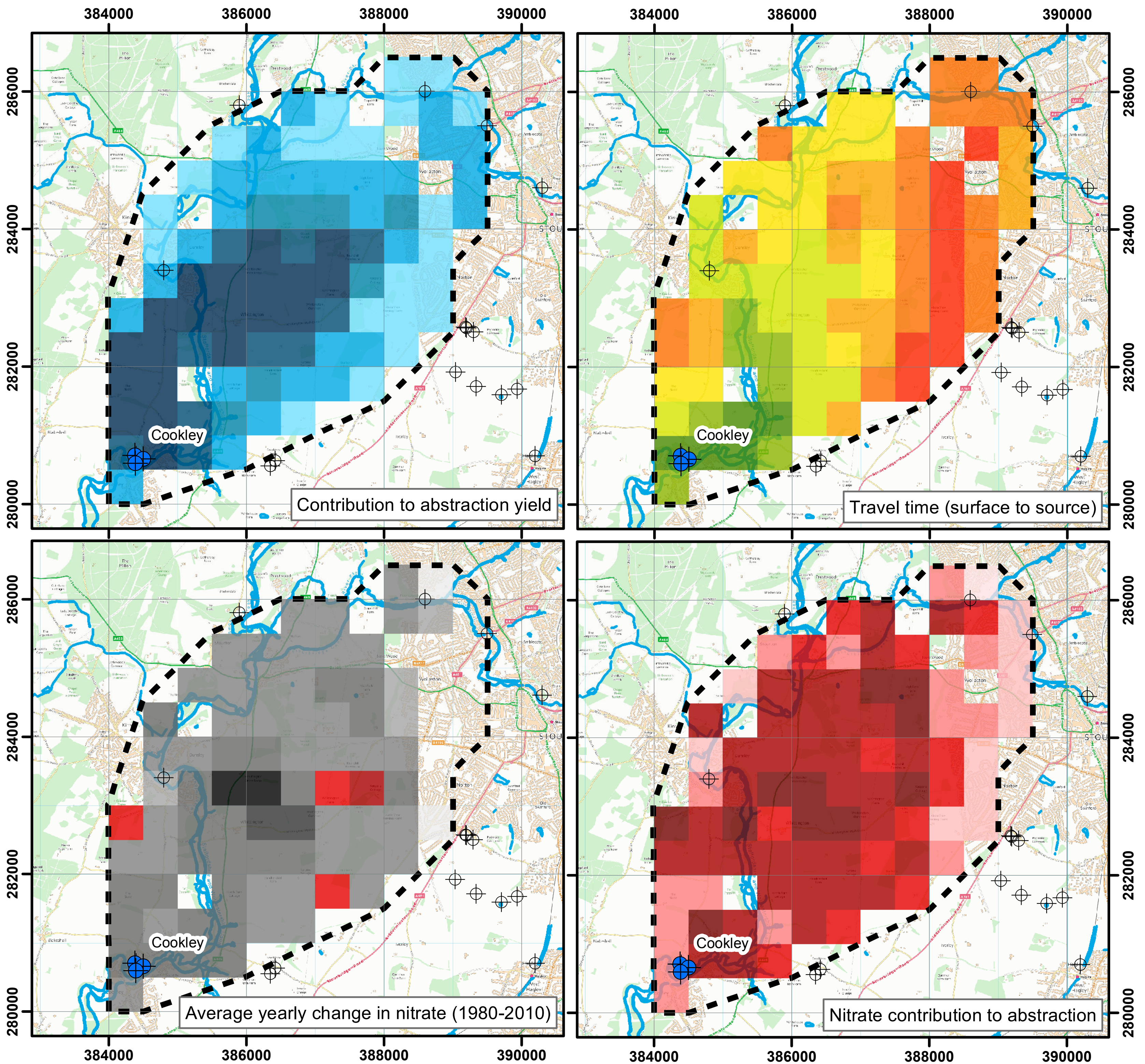

Figure 3
Cookley spatial outputs

Legend

- Abstractions
- Other PWS groundwater abstractions
- Historical catchment
- Surface Water

Abstraction Yield (%)
- 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 3

Travel Time (years)
- 0
- 1 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 80
- 81 - 100

Change in N loading per year (kg/ha)
- <-20
- -20 - -10
- -10 - -2.5
- -2.5 - -1
- -1 - -0.5
- -0.5 - -0.25
- -0.25 - 0
- 0
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 10
- 10 - 20

N contribution (%)
- 0
- < 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- 2 - 5

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File Reference
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