The impact of land management on drinking water quality: A water industry application, East of England

Presented by

Jenny Sandberg, Catchment Modeller, Anglian Water Services

Co-author: Frances Elwell, Water Quality Scientist, Mott MacDonald

2011 International SWAT Conference, Toledo, Spain

Mott MacDonald

anglianwater

Content

- Background
- The Study Area
  - Catchment characteristics
  - Data availability and data processing
- Results
  - Calibration and Validation
  - Land use scenarios
- Conclusion/Discussion
- Time for questions

anglianwater

Background

- The UK Water industry
- Anglian Water
- Anglian Water's Catchment Management Programme

love every drop
anglianwater

The UK Water Industry

- In England and Wales water companies are privately owned
- The water industry is highly regulated:
  - <u>Economic</u>: the Water Services Regulation Authority (OFWAT) and Consumer Council for Water (CCwater)
  - <u>Environmental:</u> the Environment Agency
  - <u>Drinking Water Quality:</u> the Drinking Water Inspectorate (DWI).
- The water industry operates on five-yearly asset management cycles.
- Prices are set by Ofwat at the beginning of each period, following submissions from each company about what it will cost to deliver their business plans.

Anglian Water

- Water and wastewater company supplying water and wastewater services to more than 6 million domestic and business customers in the East of England and Hartlepool.
- ~1,300 Ml/d* raw water abstractions
- 50:50 groundwater and surface water

* Ml/d = Mega-litre per day, one thousand cubic metres (TCM), or one million litres

anglianwater

Catchment Management Programme

- Is catchment management a cost-effective alternative to traditional treatment solutions?

- Stakeholder Liaison:
  - Gain understanding of stakeholders' role, working relationships, influences and interests
  - Raise awareness
  - Build up knowledge of the catchments
- Modelling:
  - What has caused the pollution problem?
  - What land use management practices to promote and where?
  - What impacts on raw water quality would different practices have?
  - How soon would the impacts be seen?
  - Can we do without raw water treatment?

anglianwater

Higher Priority Risk

- Surface Water:
  - 13 water treatment works (25 catchments)
  - Mainly metaldehyde
  - **Modelling tool: The SWAT model**
- Groundwater:
  - 7 water treatment works (15 catchments)
  - Mainly nitrate
  - Modelling tool: Wave/Modflow/MT3D

Drinking Water Standards:

- **Nitrate: 50 mg/l**
- **Individual Pesticides: 0.10 µg/l**
- **Total Pesticides: 0.50 µg/l**

anglianwater

Timeline
– Higher Priority Risk

Scoping phase:
To evaluate and identify modelling options

Pilot Phase: Development of modelling approaches for pesticide and nitrate transport simulations

Roll-out Phase:
The selected modelling approaches to be applied to the remaining catchments

Summer 2010

September 2010 – May 2011

July 2011 – mid 2013

anglianwater

Surface Water Pilot study

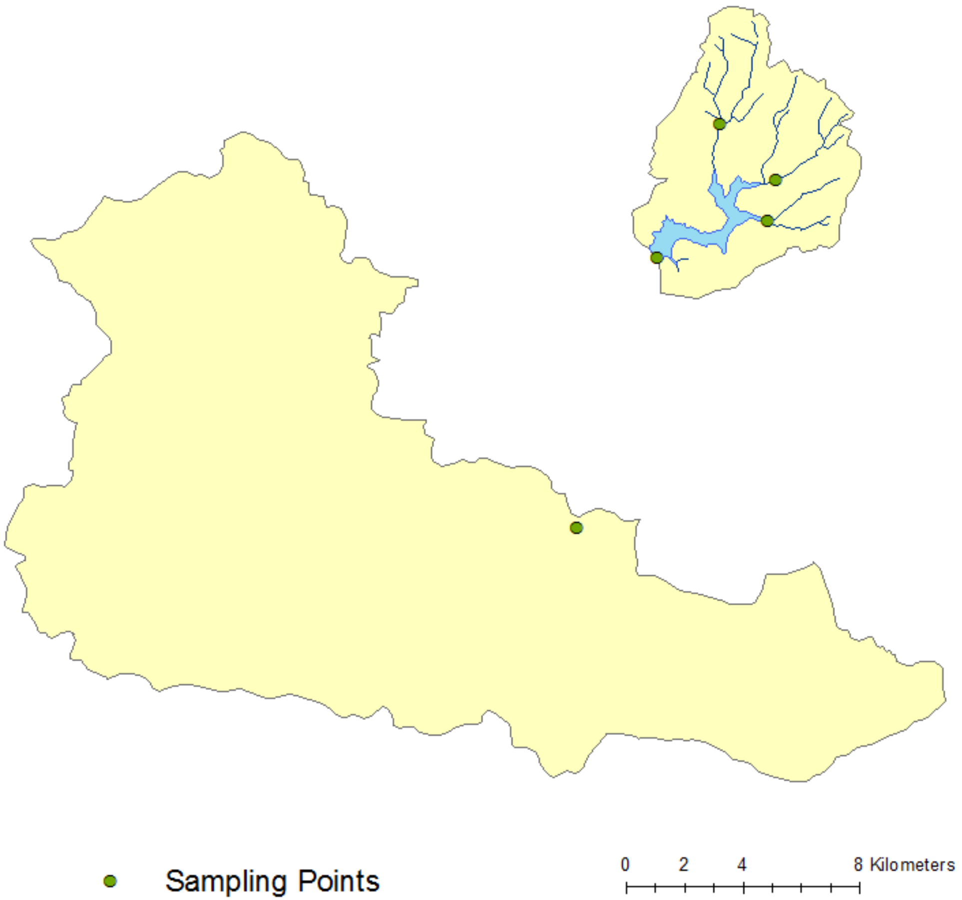
- The Study Area

- Catchment characteristics
- Data Availability

love every drop
anglianwater

The Study Area

- Two SWAT models were built



A raw water storage reservoir fed by two catchments:

- The direct catchment to the reservoir (50 Km2)
- A larger pumped catchment (320 Km2) from which water is being pumped from the River Nene

Metaldehyde has been detected at levels exceeding the drinking water standard of **0.1µg/l.**

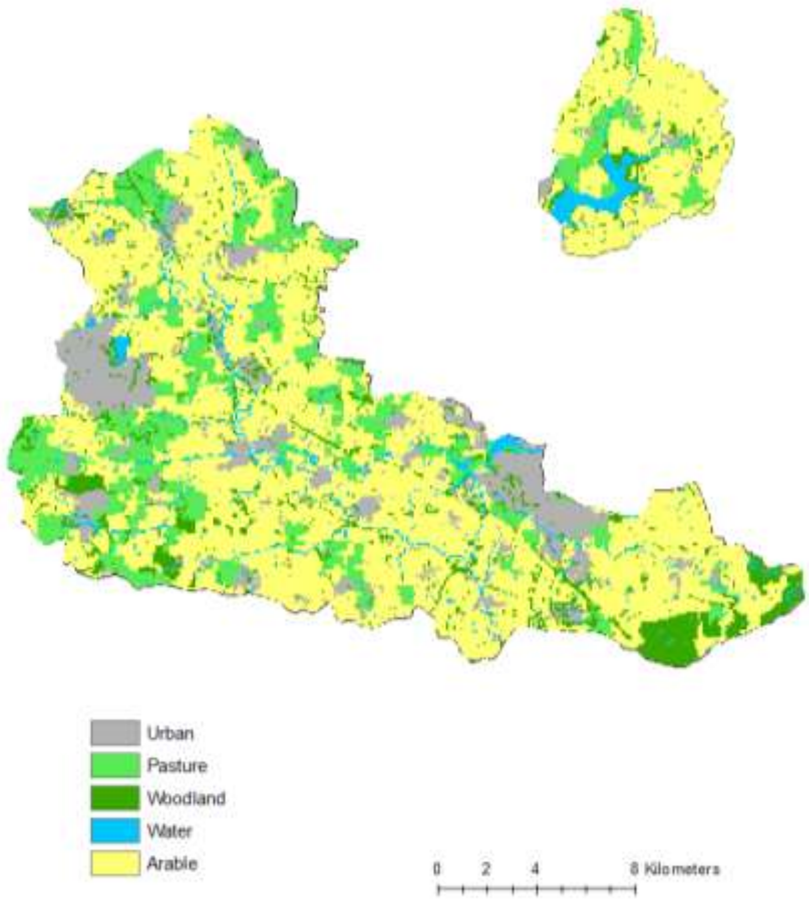
Two SWAT models were built; one for the pumped and one for the direct catchment.

anglianwater

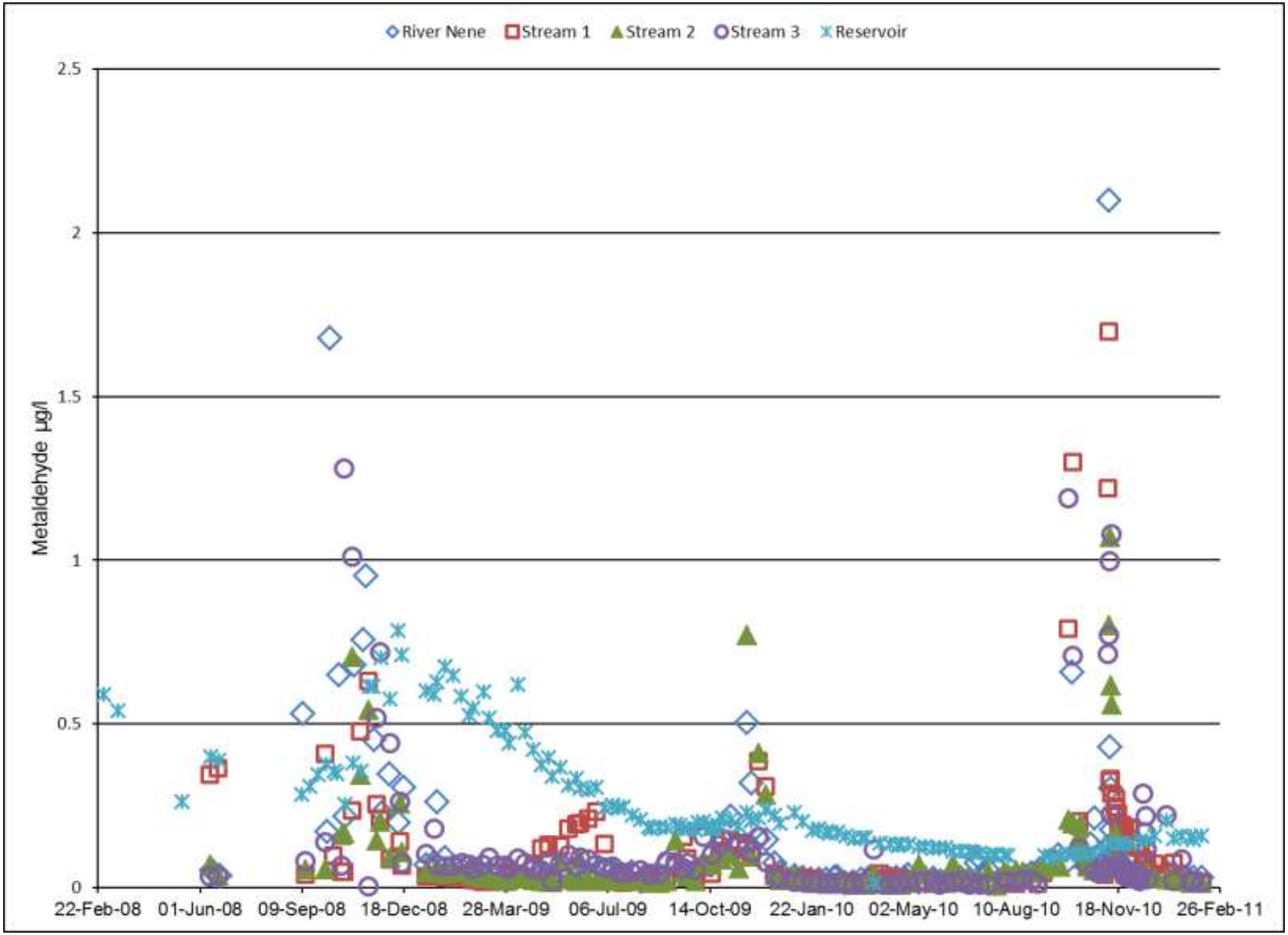
Data Availability

Data Type	Description	Data Source
Topography	Topographic map.	Topographical data from UK Ordnance Survey
Land use	Land use information was obtained from a number of sources of various spatial resolution and level of detail on land use categories.	The European Environment Agency (EEA, 2004), Edina Agcensus data set (The University of Edinburgh, 2004), land use mapping from UK Ordnance Survey (OS, 2011).
Soil	An ArcGIS map layer (1:250 000) outlining the dominant soil types (soil series) in the region, and a number of non-spatial datasets which describe the characteristics of the soil types.	National Soil Resources Institute (NSRI), 2010
Weather	Precipitation, wind speed, solar radiation, relative humidity, temperature.	A local weather station, the UK Met Office and the European Commission Joint Research Centre
Reservoir	Historical water level data, abstraction and operational details.	AWS
River/stream hydrology	Gauging Stations and spot measurements.	The Environment Agency, AWS
Pesticide Management	Monthly pesticide application by region.	The UK Food and Environment Research Agency (FERA)
Water Quality	Pesticide concentrations in raw water (streams, river and reservoir).	AWS, the UK Environment Agency

Catchment characteristics
- Land Use



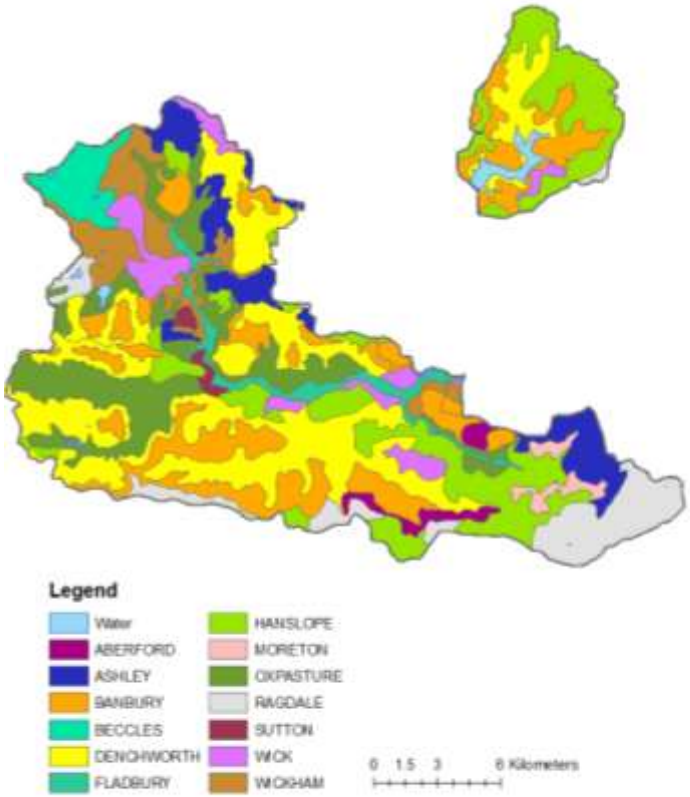
- Dominated by cereal production, where winter wheat and winter oilseed rape are the main crops.
- Hence, metaldehyde is commonly used in the autumn to protect crops against slugs.



anglianwater

Catchment characteristics
- Soil Type

Heavy Clay soils/loamy soils

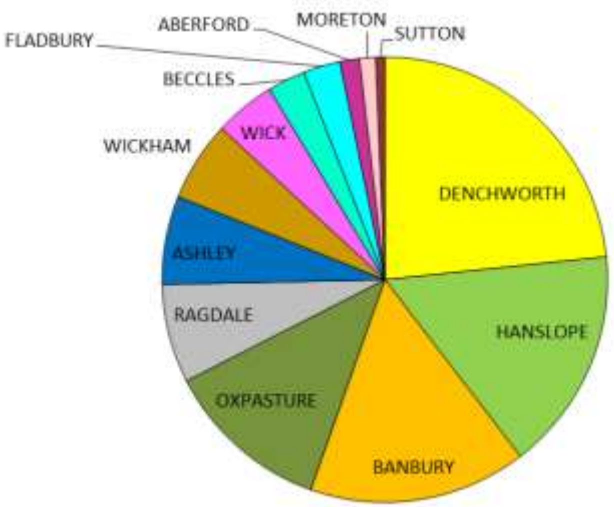


Soil Texture

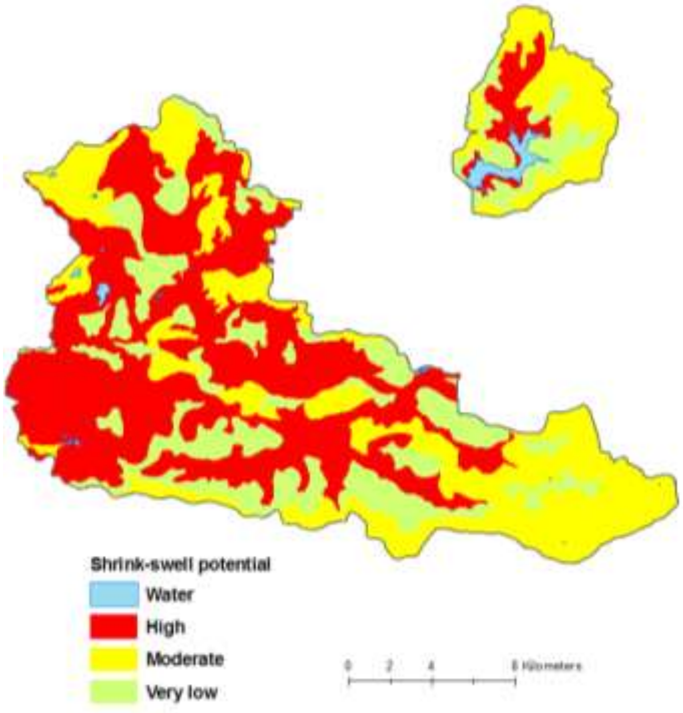
Denchworth: Clay *(clay 57%, silt 35%, sand 8%)*

Hanslope: Clay/clay loam *(42% clay, 37% silt, 21% sand)*

Banbury: Loam *(Clay 23%, silt 28%, sand 49%)*



SWAT user soil database



- Based on national soil maps (NSRI, 2010) and associated datasets describing physical and hydrological properties of the dominant soil types.

- The hydrological soil group and maximum crack volume was estimated based on the shrink-swell potential of each soil.

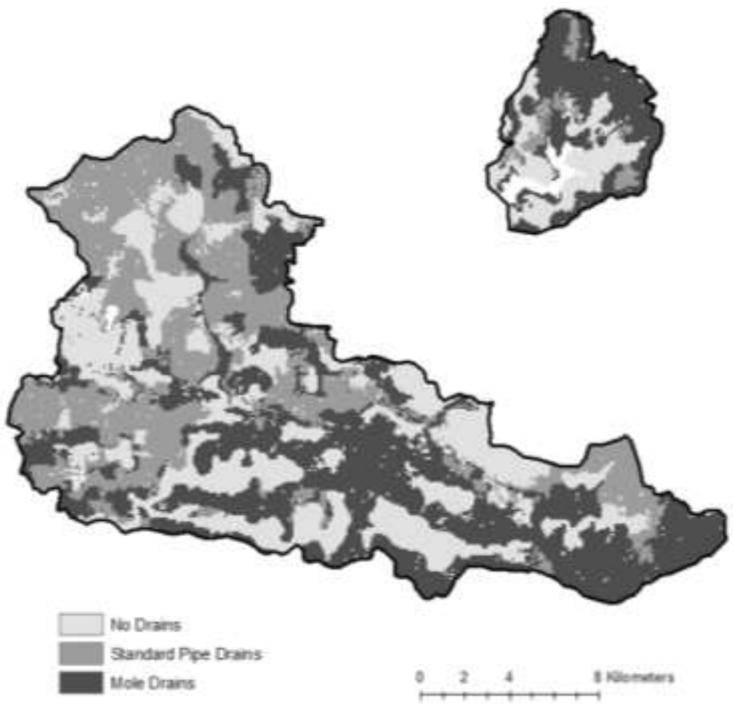
Shrink-swell Potential*	Hydrological Soil Group	Crack volume
Very Low	A	0
Low	B	0
Moderate	C	0.1
High - very high	D	0.25

*NSRI, 2010

Drainage system

- The location and design of drainage systems were estimated based on soil hydrology, soil texture (clay content) and land use.
- Low permeability soils were identified based on the Hydrology of Soil Types* (HOST) classification system.

Hydrology of Soil Types (HOST)* is a categorisation of the British soils based on their soil hydrology.



Spatial distribution and drainage design estimated based on soil type and land use.

*Boorman et al., 1995

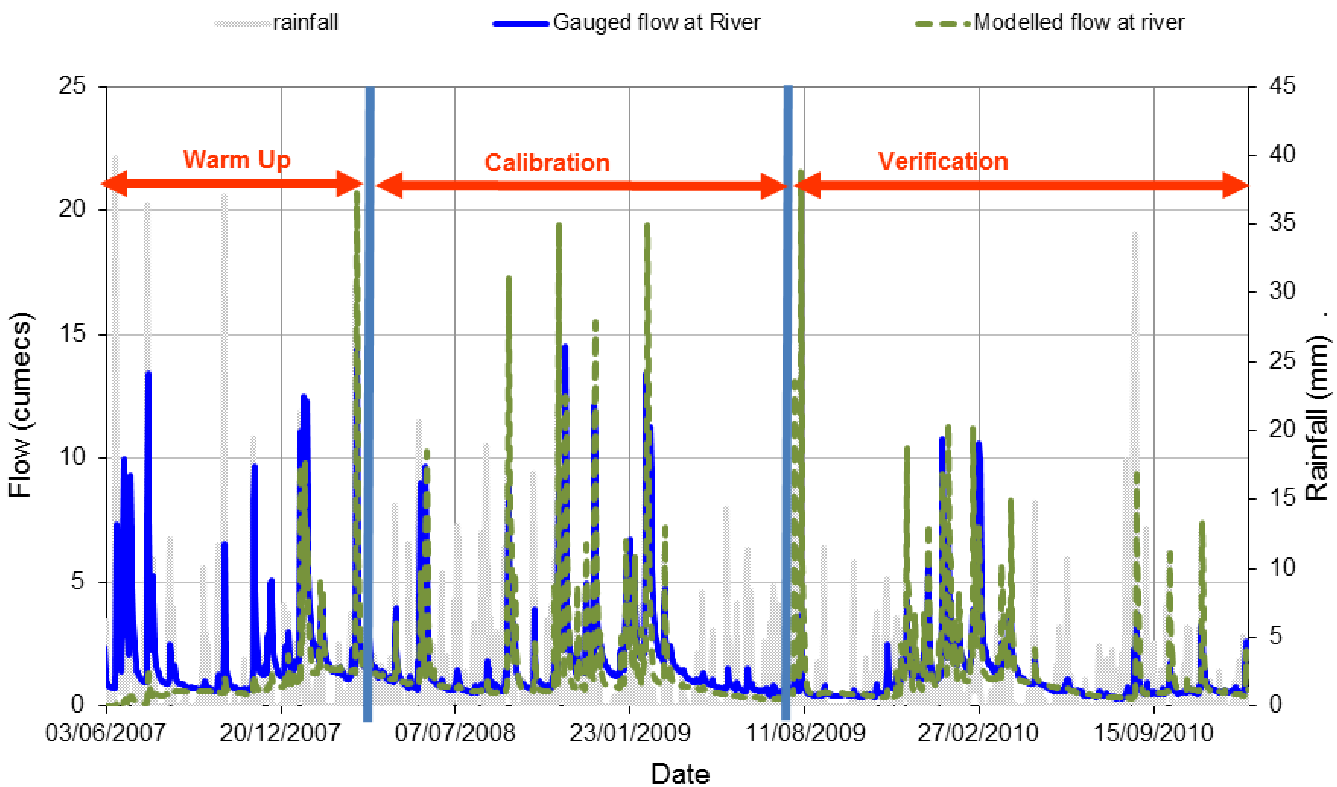
Results

love every drop
anglianwater

Model Calibration and Validation
- The hydrological model

<u>The pumped catchment</u>

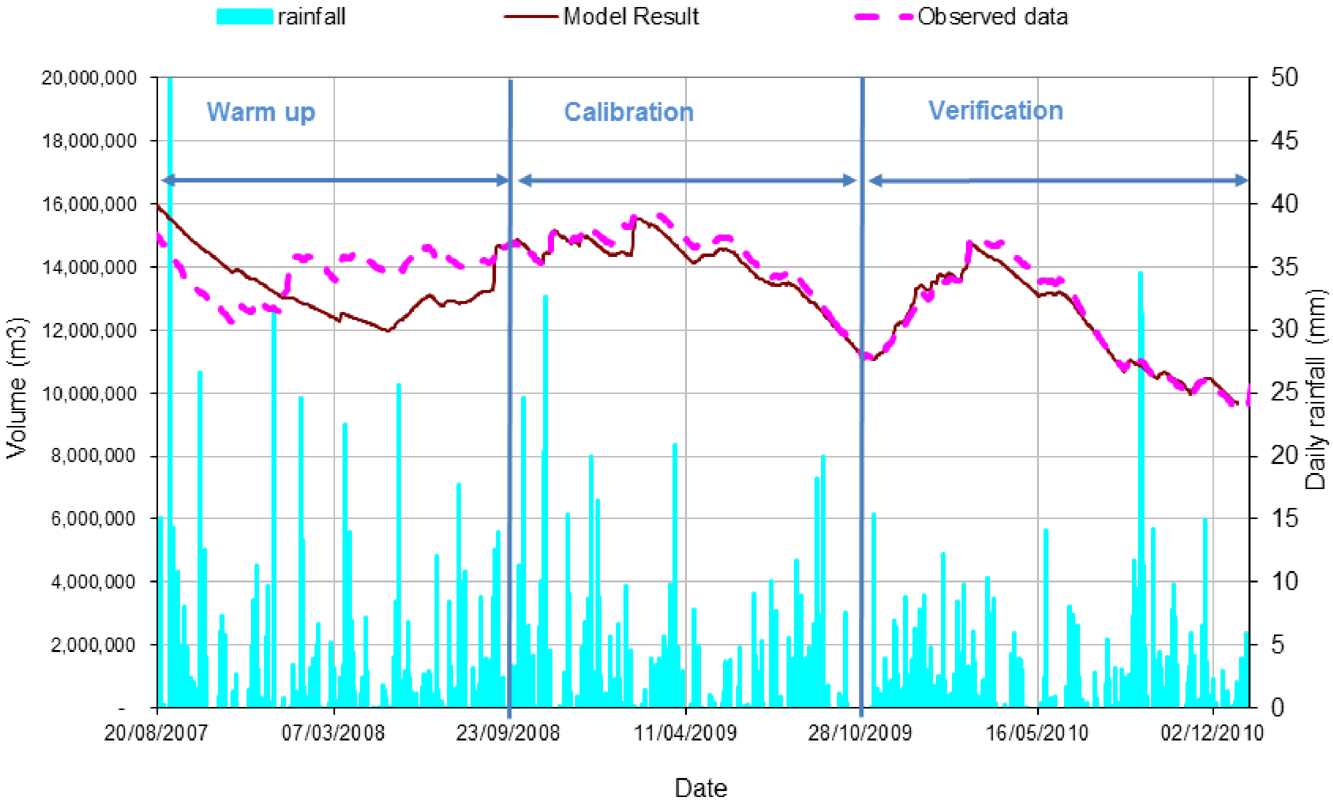
- Gauged flows



Model Calibration and Validation
- The hydrological model

<u>The direct catchment</u>

- Reservoir volumes

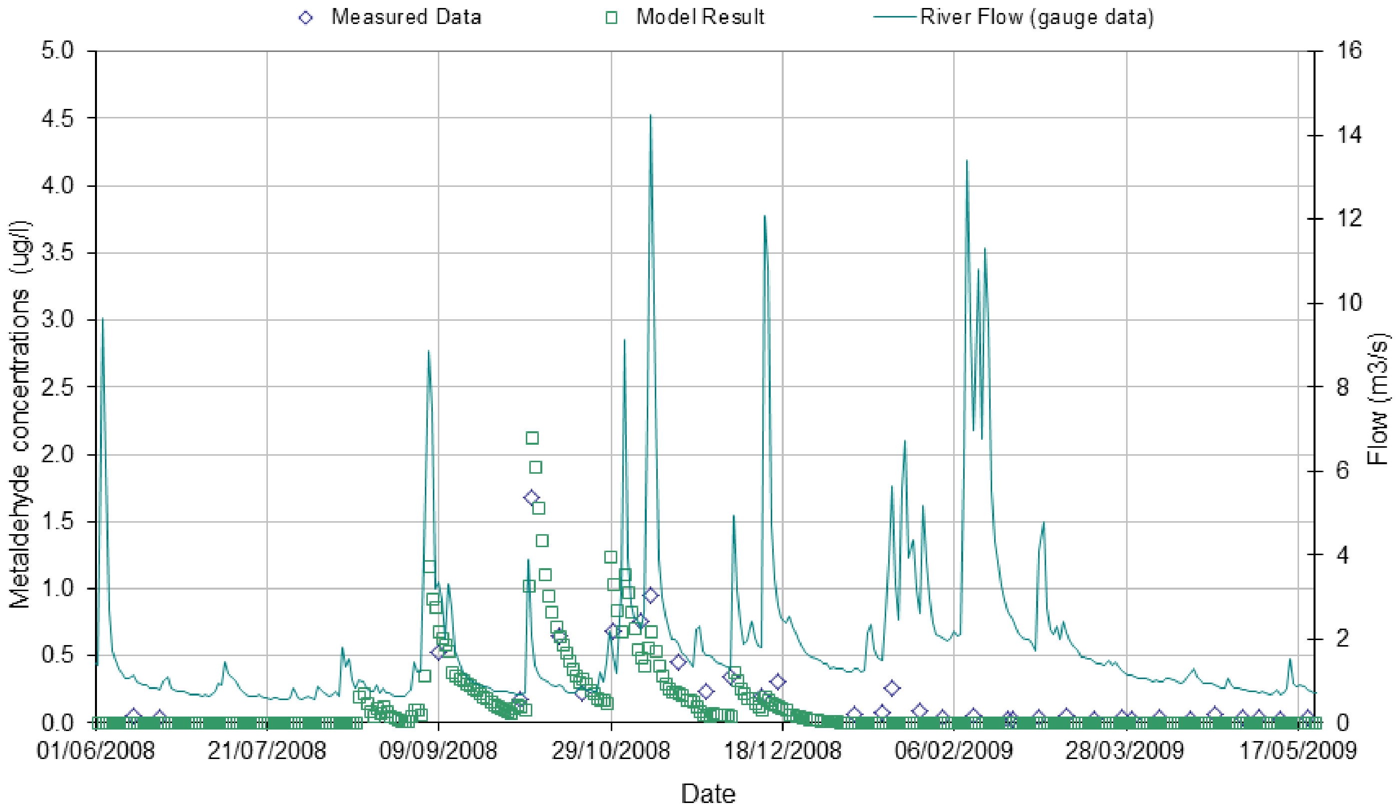


Model Calibration and Validation

- The water quality model

<u>The pumped catchment</u>

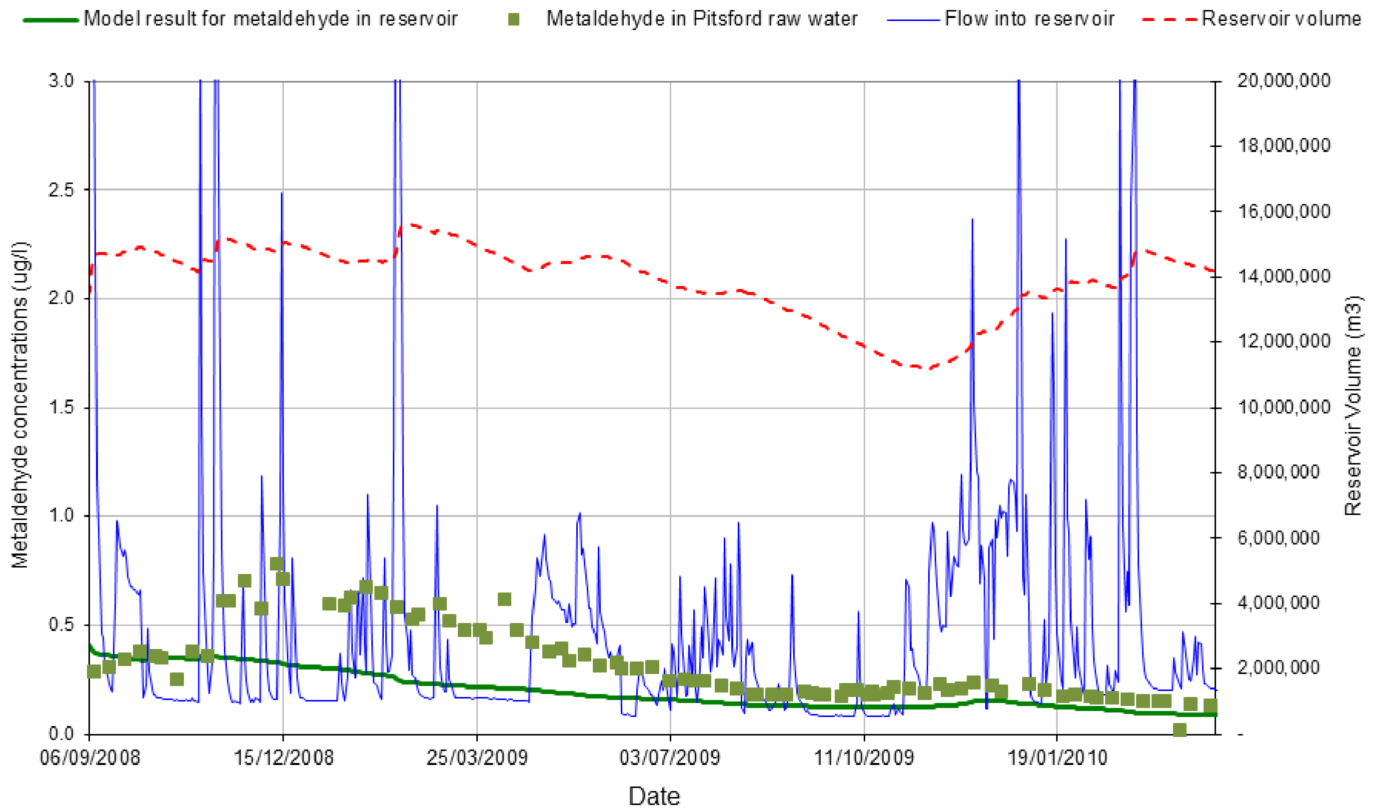
- River abstraction point



Model Calibration and Validation
- The water quality model

<u>The direct catchment</u>

- Metaldehyde concentrations in the reservoir

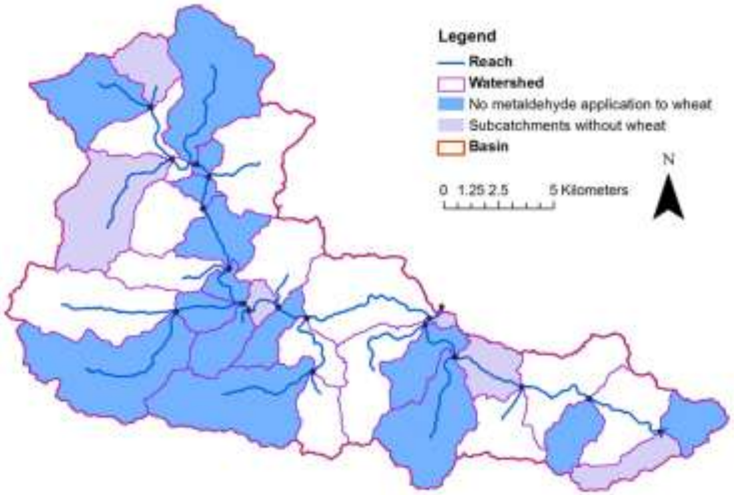


anglianwater

Land Use Scenarios

Initial Scenario Runs

- Filter strips
  - Baseline: 3 m
  - Scenario 1: 0 m – the peak concentrations almost doubled.
  - Scenario 2: 6 m – reduction of approximately 1/3 of the peak in-stream concentrations.
- Excluding metaldehyde application in over half of the area under wheat production
  - 40 % reduction in peak metaldehyde levels at the river abstraction point



anglianwater

Concluding Remarks

Conclusions

- Overall the SWAT model has proved to perform well in the two catchments and will be a useful tool for our future work.
- For the reservoir, the model slightly underestimates metaldehyde concentrations and is not able to replicate peaks. Two potential explanations were identified:
  - Local source in the catchment close to the reservoir abstraction point; and
  - Pesticide accumulation.

  To assess this we would need to run the scenarios using a 2D reservoir model to take into account spatial variability within the reservoir.
- Due to the importance of accurately predicting surface runoff and infiltration when assessing the impacts of land management measures (particularly filter strips) on water quality, it is recommended that, in the future, detailed sensitivity runs of parameters controlling bypass flow and drain flow, are carried out.
- In this pilot study, the feature of dual hydrological soil groups was not applied. This resulted in the need for significantly reducing the curve number (CN) in the calibration process. In the future, it is recommended that the hydrological soil groups are reviewed for the two catchments and dual hydrological soil groups are applied where applicable.

anglianwater

Any Questions?

anglianwater

Acknowledgements

The authors would like to thank the following people who have contributed to the work of this project at various stages:

Anna Chivers, Mike Cook, Jane Dottridge, Peter Ede, Simon Eyre, Louisa Peaver, and Gerry Spraggs.

The views expressed in this presentation are those of the authors only.

Mott MacDonald

love every drop

anglianwater

References

- Boorman, D.B., Hollis, J.M and Lilly, A. 1995. Hydrology of soil types: a hydrologically-based classification of the soils of the United Kingdom. Institute of Hydrology Report No.126. Institute of Hydrology, Wallingford.
- European Environment Agency (EEA). 2010. Corine Land Cover 2000 (CLC 2000) Map. Available at: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster. Accessed 15.05.2011.
- National Soil Resources Institute (NSRI). 2010. Land Information System (LandIS) Digital soil dataset.
- Neitsch, S.L., Arnold, J.G., Kiniry, J.R., and Williams, J.R. 2005. Soil and Water Assessment Tool. Theoretical Documentation. Grassland, Soil and Water Research Laboratory, Agricultural Research Service, Temple, Texas.
- Novák, V. 1999. Soil-Crack Characteristics—Estimation Methods Applied to Heavy Soils in the NOPEX Area. *Agricultural and Forest Meteorology. 98: 501-507.*
- Olsen, P.A., and Haugen, L.E. 1998. A new model to of the shrinkage characteristics applied to some Norwegian soils. *Geoderma. 83(1-2):67-81.*
- The UK Ordnance Survey (OS). 2011. UK Ordnance Survey VectorMap District. Available at: http://www.ordnancesurvey.co.uk/oswebsite/products/os-vectormap-district/index.html. Accessed 16.05.2011.
- The University of Edinburgh. 2004. Edina Agcensus for 2004. Available at: http://edina.ac.uk/agcensus/. Accessed on 16.05.11.

Primary SWAT model hydrological parameters adjusted during calibration

Parameter	Description	Calibration
CH_N	Manning's "n" (roughness coefficient) in channel	Set to 0.08
OV_N	Manning's "n" for overland flow	Set to 0.5
CN	Curve number – controls the amount of rainfall runoff	Initial values were selected based on the SWAT user guide. These were reduced to 70% of initial estimates.
CH_L	Channel length – estimated by SWAT based on topography but details of meandering can be lost due to resolution	Increase by 20% to account for meandering.
GWLAG	Groundwater lag – controls response time of baseflow to rainfall	Set to 150 days
CNCOEFF	Plant ET curve number coefficient – allows the model to adjust the curve number based on the plant evapotranspiration	Set to 2
ESCO	Soil evaporation compensation factor	Default value reduced to 0.7 to account for some cracking.
FFCB	Initial soil water storage	Set to 0.8 for the pumped catchment and 1.0 for the direct reservoir catchment.

anglianwater

Primary SWAT model pesticide parameters adjusted during calibration

Parameter	Description	Calibration
AP_EF	Application efficiency, i.e. fraction of pesticide applied that is deposited on soil or foliage.	0.5
FILTERW	Width of filter strips at edge of fields	3 m
CHPST_REA	Reaction rate of pesticides in stream, calculated from information on half-life in water.	0.07
HLIFE_S	Half-life in soil	10
HLIFE_F	Half-life on foliage	5
SKOC	Soil adsorption coefficient	120

SWAT drain inputs

Type of drain	TDRAIN (hr)	DDRAIN (mm)	GDRAIN (hr)
Standard pipe drains	48	1000	25
Mole drains	30	500	25

anglianwater