Projecting uncertain impacts of climate change on wetlands: a risk-based tool for England and Wales

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Background

- The Wetland Vision
  - restoration and management of wetlands throughout England over the next 50 years
  - little information on climate change

- www.wetlandvision.org.uk
Project aim

• Produce a set of tools to assess impacts of climate change

• Assumption - hydrology is the key characteristic of a wetland that will be directly impacted
Risk-based tool-kit

Rapid assessment in hours

Tier 1 tool
CEH web site

Results pre-defined for a few generic wetland types for 2050

Intermediate assessment in weeks

Tier 2 tool
Agency technical experts or CEH service, general data

General results tailored to specific site

Detailed assessment in months

Tier 3 tool
Specialist consultants, detailed site data

Detailed site results, management options
Tier 1 tool approach – regional impacts

Climate change (Geographical location)

Catchment response (Water source)

Wetland eco-hydrology model

Ecosystem sensitivity (Interest feature)

Selected wetland plant communities
Tier 1 climate inputs

- UKCP09 climate projections
- 2050s timeslice (2040-2069)
- ‘Medium’ greenhouse gases and aerosols emissions scenario
- IPCC SRES A1B
- 12 river basin regions for England and Wales
- 10,000 projections per region
## Tier 1 wetland modelling

<table>
<thead>
<tr>
<th>Water supply mechanism end members</th>
<th>Rain-fed</th>
<th>River-fed (SW/GW)</th>
<th>Groundwater-fed (various aquifers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKCP09 rainfall and temperature</td>
<td>River flows typical catchments (CEH: FFGWL)</td>
<td>Groundwater levels representative boreholes (BGS: FFGWL)</td>
<td></td>
</tr>
</tbody>
</table>

### Diagram Description

- **OF**: Outflow from the river.
- **OB**: Outflow from the wetland.
- **P**: Precipitation.
- **E**: Evapotranspiration.

- **DL**: Low permeability soils.
- **GD**: Floodplain wetland.
- **GR**: Aquifer.
- **P**: Precipitation.
- **E**: Evapotranspiration.
Tier 1 groundwater-fed wetland modelling

- 15 region-aquifer combinations
- 4 vegetation communities
- 600,000 climate change simulations
- Simple (efficient) wetland models
  - applicable at regional scale
- Hypothetical wetlands
  - calibrated to be sustainable under baseline climate conditions
- Approach follows that developed for rain-fed and river-fed wetlands*

Tier 1 GW-fed modelling approach

- Simple conceptual understanding
  - groundwater discharge and recharge
  - lateral groundwater seepage
  - no precipitation or evaporation
  - no surface runoff
  - no downslope outflow
Tier 1 GW-fed model equation

\[ WL_{WET,t} = WL_{WET,t-1} + k(WL_{GW,t} - WL_{WET,t-1}) \]

- WL _WET_ water level / hydraulic head (m)
- WET wetland
- GW groundwater
- t timestep
- k ‘hydraulic head transfer rate’ factor (m/m)

- ‘k’ (basically a scaling factor) combines
  - wetland, aquifer (and any aquitard) permeabilities
  - relative specific yields and scales of wetland and aquifer

- Wetland surface elevation (mAOD) parameter
- No horizontal dimensions – not modelling water volumes
- No lag term – wetland scale minor relative to aquifer
Tier 1 GW-fed model baseline calibration

- Monthly groundwater level data (BGS)
- 1980 – 1990 baseline
- Initial conditions - end winter optimum
- 9 month run-in
- Semi-automatic wetland calibration - optimise parameters - ecohydrological water level requirements - deviation consistent between regions
Tier 1 GW-fed model climate change

- We now have 60 calibrated baseline models for each region-aquifer-vegetation community combination...
- ...but we plan to run 10,000 climate change projections for each model...
- ...it isn’t practical to store/interpret 600,000 sets of monthly wetland water level data!?
Tier 1 climate change impact metrics

- Hydrology
  - water levels
  - water balance
- Plant communities
  - ecohydrological water level requirements
- Historic environment
  - soil saturation depths
- Birds
  - flooding in winter and spring
Tier 1 visualising uncertainty

- Impact metric histograms
  - 10,000 projections
  - impact boundaries defined by expert judgement

- Basic block plot
Tier 1 wetlands and climate change tool

• Open access
• Rain-fed and river-fed wetland results currently online
• [http://www.ceh.ac.uk/sci_programmes/Water/Wetlands/ClimateChangeAssessmentToolforWetlands.html](http://www.ceh.ac.uk/sci_programmes/Water/Wetlands/ClimateChangeAssessmentToolforWetlands.html)
• Google ‘CEH wetlands climate change’!
• Revised website and groundwater-fed wetland results online by end March 2013
• A preview of the groundwater-fed Tier 1 tool...
Wetlands and Climate Change
Tool for assessing wetland sensitivity to climate change

1. Select region
   - Anglian
   - Dee
   - Humber
   - Northumbria
   - North West England
   - South East England
   - Severn
   - Solway
   - South West England
   - Thames
   - Tweed
   - Western Wales

2. Select water source / National Vegetation Classification
   - Groundwater-fed
   - Permo-Triassic Sandstone

3. Select feature of interest and metric
   - Hydrology (water balance)

4. Select result type
Tier 1 tool limitations

• It provides a generalised regional indication of potential impacts suitable for risk screening and investigating uncertainty.

• It is not a detailed prediction for a particular wetland.

• Other UKCP09 climate change timeslices and emissions scenarios.

• Multiple water sources not considered - assess separately then consider results in combination using site understanding.

• Water quality/nutrients not explicitly considered - use site understanding, e.g. increasing chalk groundwater water balance likely to increase base-richness.
Tier 3 GW-fed wetland case study

- Testing the Tier 1 tool
- Great Cressingham Fen (GCF), Norfolk
  - calcareous valley-fen
  - groundwater-fed by springs and seepages from the Chalk via granular alluvial deposits
  - surface inputs from rainfall and limited rainfall-runoff
- Existing calibrated Tier 3 model (EA/Entec)

(Whiteman et al., 2004)
Tier 3 GW-fed wetland case study

- Great Cressingham Fen
  - single 200 x 200 m grid cell
  - 70 x 70 km Ely Ouse
  - regional groundwater model
  - MODFLOW and 4R

- Detailed distributed groundwater modelling by Entec (2011)
  - naturalised GW levels
  - baseline (1961 to 1990)
  - 2050s (2040 to 2069)
  - three RCM representations

(Entec, 2011)
Tier 3 GW-fed wetland case study

• Calculated impact metrics for Tier 3 wetland water levels
• Standardised results to Tier 1 baseline (as Tier 3 RCM is a simulated baseline climate, Tier 1 uses observed climate)
• M13 *Schoenus nigricans-Juncus subnodulosus* mire
Tier 3 GW-fed wetland case study

• Some consistency between the Tier 1 and Tier 3 models

• Caveats
  - different baseline climate data
  - Tier 3 GCF grid cell groundwater levels represent several vegetation communities therefore average response
  - natural vs naturalisation
Tier 2 tool

- Simple Tier 1 models
- Groundwater levels for a specific wetland
  - other FFGWL project results
  - generate climate change results from an existing groundwater model
  - develop a new model (baseline and climate change)
Future developments

• Modelling wetland water levels and nutrients under climate change - linking Tier 1 river-fed wetlands and INCA river models

• Considering model uncertainty as well as climate uncertainty - improved calibration objective function - parameter equifinality

• Other UKCP09 timeslices and emissions scenarios?

(Gowing, 2004)
Thank you

Any questions / discussion welcome