Phosphorus management in a changing world: using models to build a bridge between science and policy

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IPW
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Talk outline

• Setting the stage
• Thames and its catchment
• INCA-P model
• INCA-P simulation of SRP in Thames
• A changing world
• Scenarios
• Conclusions

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Models cannot provide answers, but they can help to frame a dialog about how to best manage in a changing world: EU legislative compliance, climate change, food and water security, legacy environmental issues, etc.
Managing phosphorus in a changing world is not only about agriculture
Thames River and catchment
Pressures on the Thames and its catchment

- WFD Compliance: eutrophication and hydro-morphological alteration
- Can GES be achieved?

- Drinking water supply for greater London (~14M people)
  - Summer low flows similar to abstraction rates
  - Aging, leaky infrastructure; lead pipes
- Food security
  - Agricultural catchment, arable (36%), livestock and pasture
INCA-P Factors affecting surface water P concentrations

• Climate (changing T, P and soil moisture)
• Hydrology
  • storm events & resultant changes in flow pathways affecting P transfer from land to stream
• Land Use and Management
  • sediment availability and transport
  • changes in crop cover
  • changes timing of P additions throughout the year
• Geochemistry
  • sorption and release of P to and from sediment;
  • in-stream P sources and sinks
  • accumulation and depletion of P in soils and groundwater
• Ecology
  • interactions between P and biology.
Dynamic, semi-distributed, daily time step model simulating total dissolved (TDP) and particulate (PP) phosphorus in the land, water column and stream bed. Soluble reactive P (SRP) simulated as a fraction of TDP.
Anthropogenic P sources modelled in INCA-P

INCA-P simulates agricultural, waste water treatment plant (WWTP) and atmospheric P inputs.
INCA-P modelled and observed flow and SRP at Lower Thames (22 - Teddington)
Changing world – UKTAG & WFD classification

| Type (for existing standards) | Annual mean of reactive phosphorus (μg per litre) | | | | |
|-------------------------------|--------------------------------------------------|---|---|---|---|---|---|
|                               | High | Good | Moderate | Poor | | | |
|                               | Existing | New | Existing | New | Existing | New | Existing | New | | | |
| Lowland, low alkalinity       | 30   | 19   | 50        | 40   | 150       | 114   | 500       | 842 (752-918) |
|                               | (13-26) | (28-52) | | | (87-140) | | | | |
| Upland, low alkalinity        | 20   | 13   | 40        | 28   | 150       | 87    | 500       | 752 (752-851) |
|                               | (13-20) | (28-41) | | | (87-117) | | | | |
| Lowland, high alkalinity      | 50   | 36   | 120       | 69   | 250       | 173   | 1000      | 1003 (921-1098) |
|                               | (27-50) | (52-91) | | | (141-215) | | | | |
| Upland, high alkalinity       | 50   | 24   | 120       | 48   | 250       | 132   | 1000      | 898 (829-1012) |
|                               | (18-37) | (28-70) | | | (109-177) | | | | |

New science (Aug 2013) is changing the target SRP concentrations for WFD class boundaries
Changing world - Peak phosphorus

Possible future climate

Warmer temperatures, increased winter rainfall and a likely decline in summer rain (left) may lead to higher winter and lower summer flows (above)
Drinking water demand was equal to river flow in summer 1976; Thames Water proposed a reservoir at Abingdon. The proposal was rejected in 2011; smaller reservoirs may be built.
UK food security

Today, arable agriculture occupies 36% of the catchment. Scenarios increasing % arable to 50 (Landuse 1) and 60% (Landuse 2) were evaluated. It was assumed that present day agricultural practices would be used.
Possible effects of a changing world on mean SRP in lower Thames
Possible P mitigation measures

- Reduce P losses from agricultural land
  - Reduced application rate
  - Use of buffer zones and riparian wetlands
  - Better livestock management

- Tertiary treatment at waste water treatment plants (WWTP)
  - Iron dosing to reduce P to 1 mg/l (required under EU Wastewater Treatment, WFD, Birds & Habitats Directives)
  - Enhanced technology using optimized dosing and ultrafiltration (currently not feasible in UK)

- Source control of P entering WWTP via sources other than natural diet
  - Domestic laundry cleaning products (to be banned by 2015)
  - Automatic dishwashing detergents
  - Tap water dosing for controlling lead in drinking water
  - Use of P in food additives
Mitigation scenarios

• Baseline – present day, business as usual
• 20% Fertiliser reduction, present day arable area
• PR 1 – P removal at WWTP to meet 1 mg/l discharge total P concentration
• PR 2 – P removal at WWTP to meet 0.3 mg/l discharge total P concentration
• 20% fertiliser reduction plus PR2
• Riparian buffer strips
Mitigation effectiveness under different scenarios

![Graph showing mitigation effectiveness under different scenarios.]
## Projected SRP concentrations, Lower Thames

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Baseline</th>
<th>20% Fertiliser Reduction</th>
<th>PR-1</th>
<th>PR-2</th>
<th>PR-2 + 20% Fertiliser Reduction</th>
<th>Riparian</th>
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<td>149</td>
<td>154</td>
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</table>
Conclusions

• SRP concentrations have declined in the Thames
• New science leads to changes in management targets
• Achieving moderate WFD ecological status will be a challenge
• Climate change & reservoir may have limited effects on SRP concentrations
• Trade-offs are needed; lower SRP concentrations in WWTP discharge will allow some agricultural intensification
Key Papers


• Wade et al. 2007. Deliverable No. 185 The Integrated Catchment Model of Phosphorus (INCA-P), a new structure to simulate particulate and soluble phosphorus transport in European catchments