Predicting nitrate levels for Wessex Water's long term water resource planning

Nick Rukin, Associate Director, Entec UK Ltd

Luke de Vial, Head of Water Resources, Wessex Water

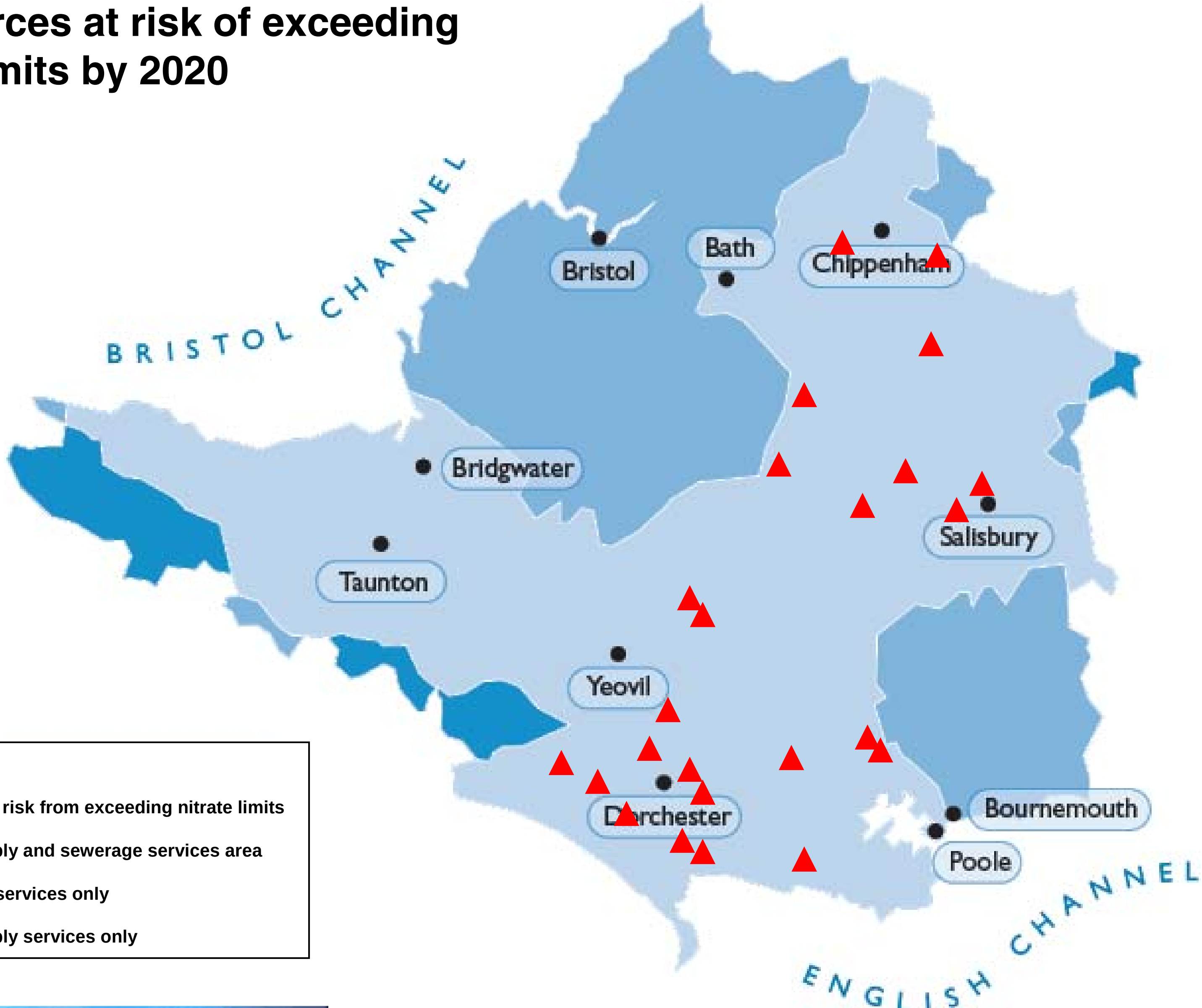
UK Groundwater Forum Conference - 13 May 2008

Creating the environment for business

Background

- **Water quality can limit available water resources as much as recharge, environmental requirements etc**
- **Nitrate is biggest water quality issue affecting Wessex Water**
- **To ensure security of supply, Wessex Water need to:**
  - provide treatment or blending capacity
  - reduce nitrate leaching through catchment management
- **As part of AMP5 submissions, DWI are expecting 'twin track' approach to the nitrate problem of:**
  - preferably blending for short to mid term
  - catchment management for mid to long term
- **Nitrate treatment is DWI's least preferred option**

(24) Sources at risk of exceeding nitrate limits by 2020



Key

- Sources at risk from exceeding nitrate limits
- Water supply and sewerage services area
- Sewerage services only
- Water supply services only

Nitrate Treatment

- **Reliable solution**
- **Costly to build and operate**
- **Waste disposal difficult**
- **Long term energy / carbon footprint issues**
- **Wessex Water**
  - have built 4 so far
  - average cost £4M
  - possible 1 per year for foreseeable future

Wessex Water
a YTL company

Entec

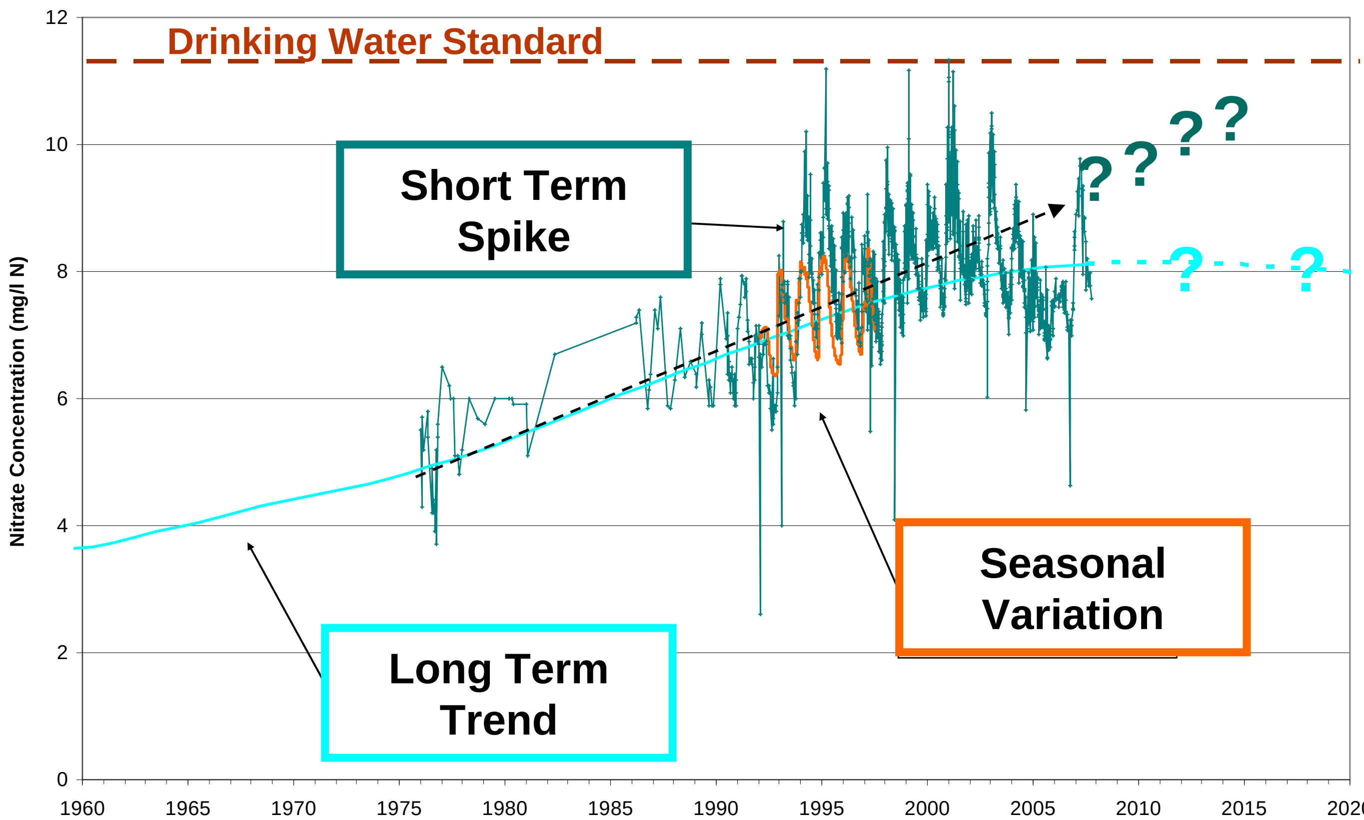
Creating the environment for business

Catchment Management

- Wessex Water have been working with farmers over the last four years in a number of trial catchments
- Collection of samples and farmer liaison
- Dedicated Wessex Water catchment advisors meet farmers each week / month
- Catchments are designated (2002) Nitrate Vulnerable Zones, but Environment Agency have budget for one visit every six years
- Early results look promising but ……….

……..how long until rising nitrate trends can be reversed in the abstractions?

Typical Trend



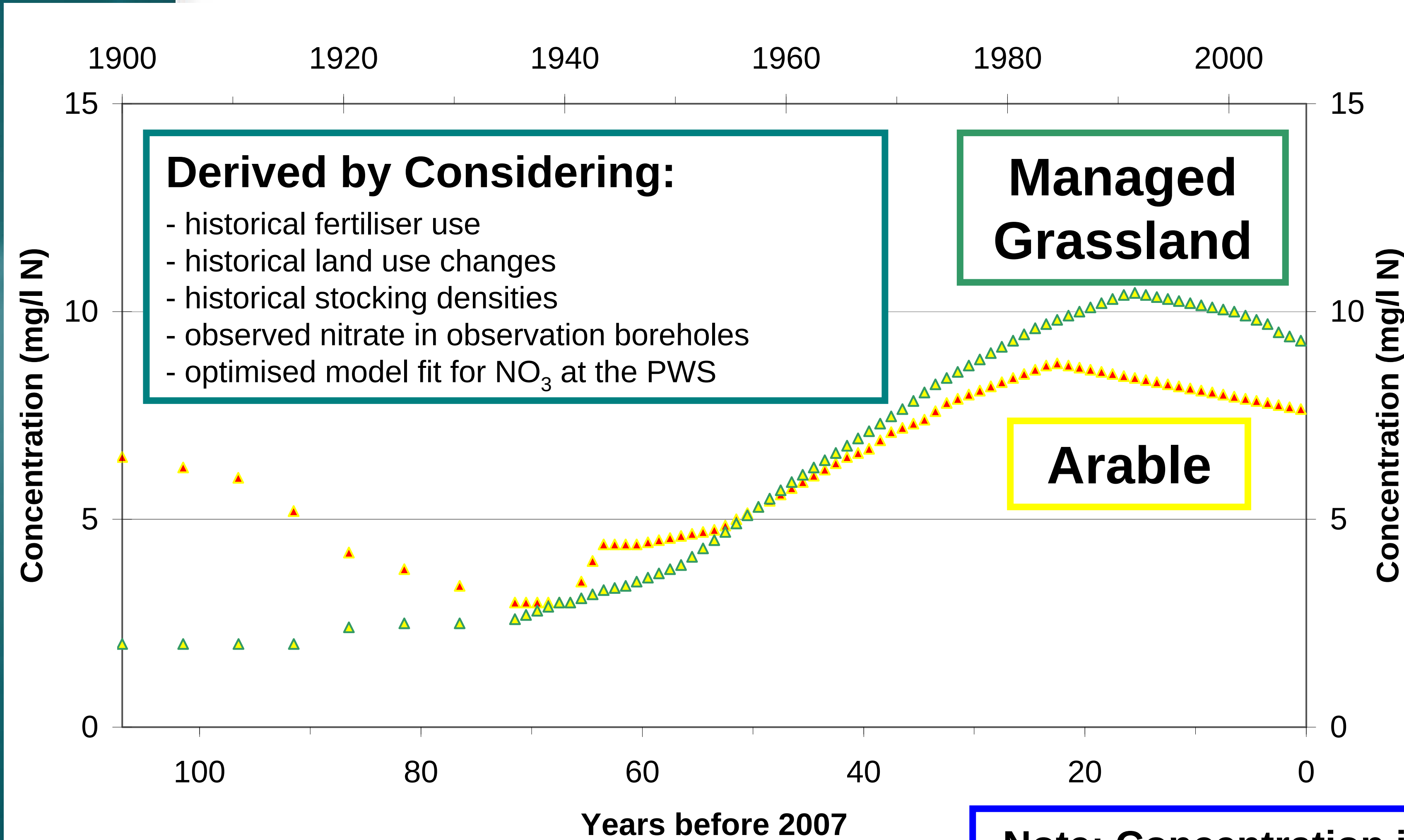
The Big Question

Can the observed trends be simulated to gain confidence in controlling factors and forward predictions?

Model Development

- Constrain Historically Leached Nitrate
- Constrain Travel Times from Soil to Abstraction
- Factor in Seasonality and 'Spikiness'

Best Estimate of Historically Leached Nitrate

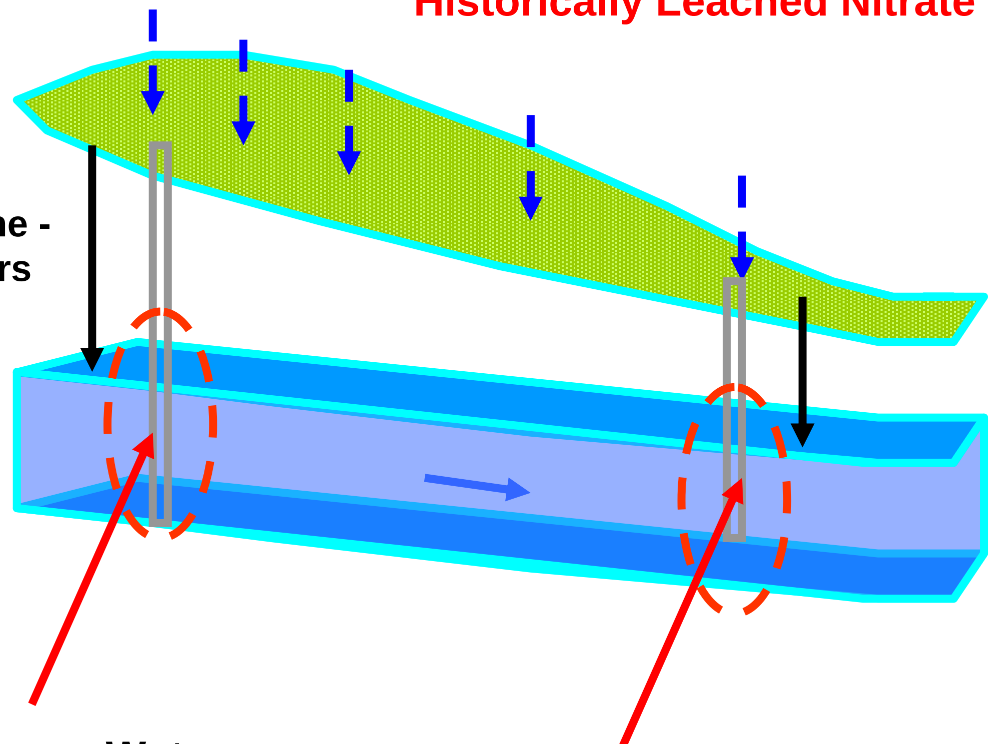


Note: Concentration in 440 mm/yr recharge

Unsaturated Zone Travel Times - Theory

Historically Leached Nitrate

Thick Unsaturated Zone - Travel Time = 30 years



Thin Unsaturated Zone - Travel Time = 10 years

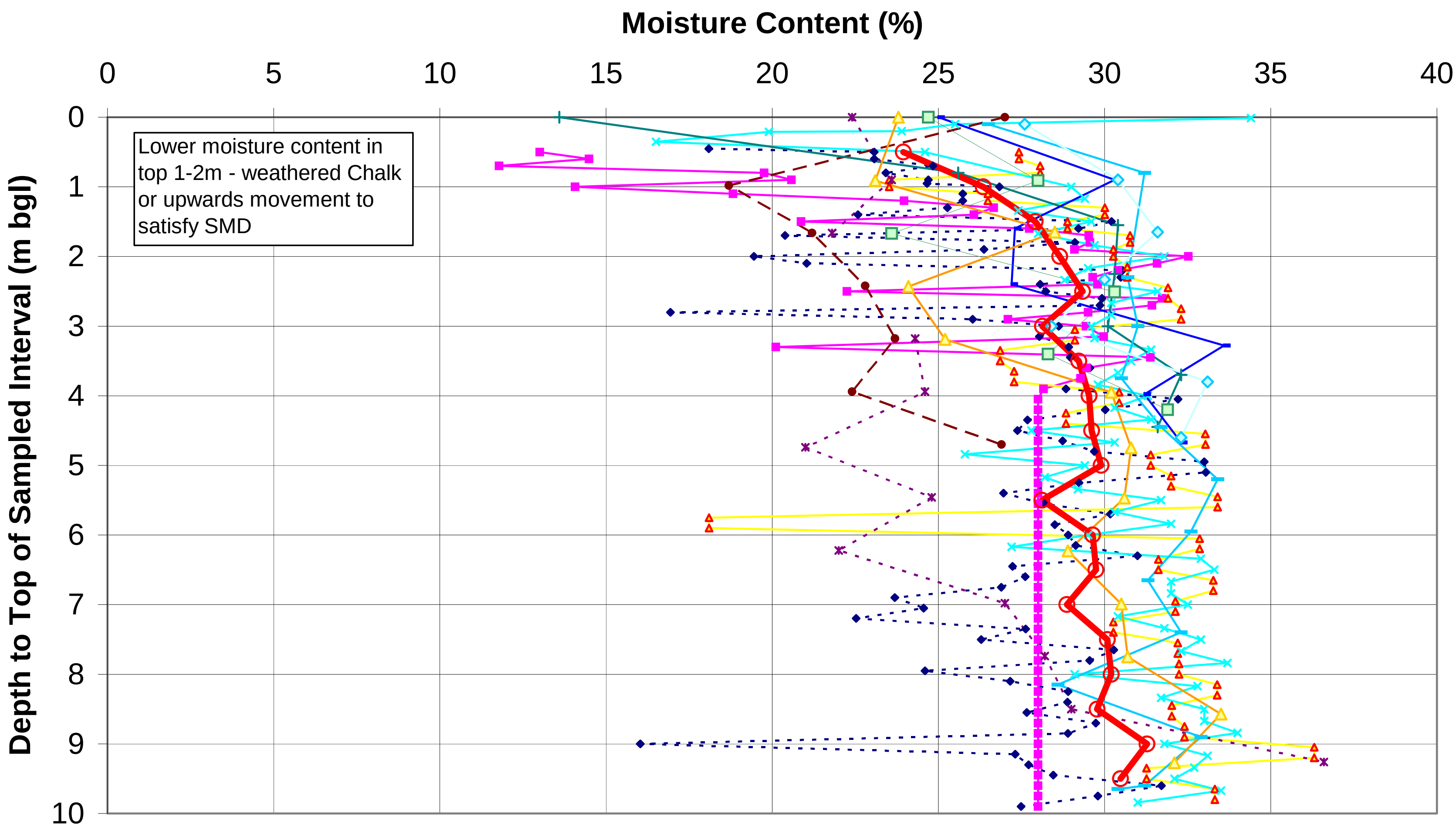
Recharge Water with Nitrate from 30 years ago

Recharge Water with Nitrate from 10 years ago

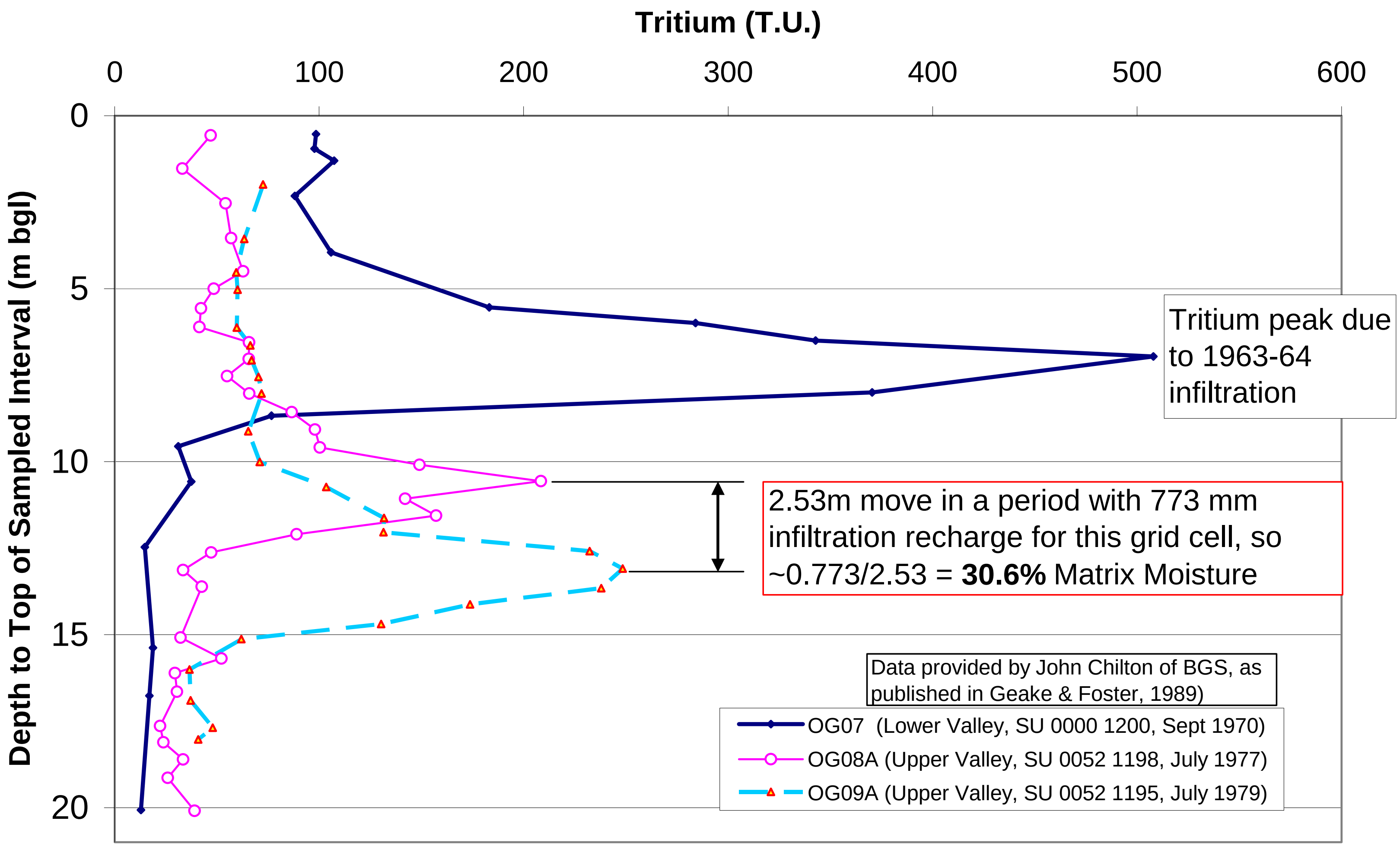
$$\text{Unsat Travel Time} = \frac{\text{Moisture Content x Unsat Thickness}}{\text{Recharge}}$$

Entec

Moisture Content Data from Cores



Tritium Profiles also used to constrain moisture content

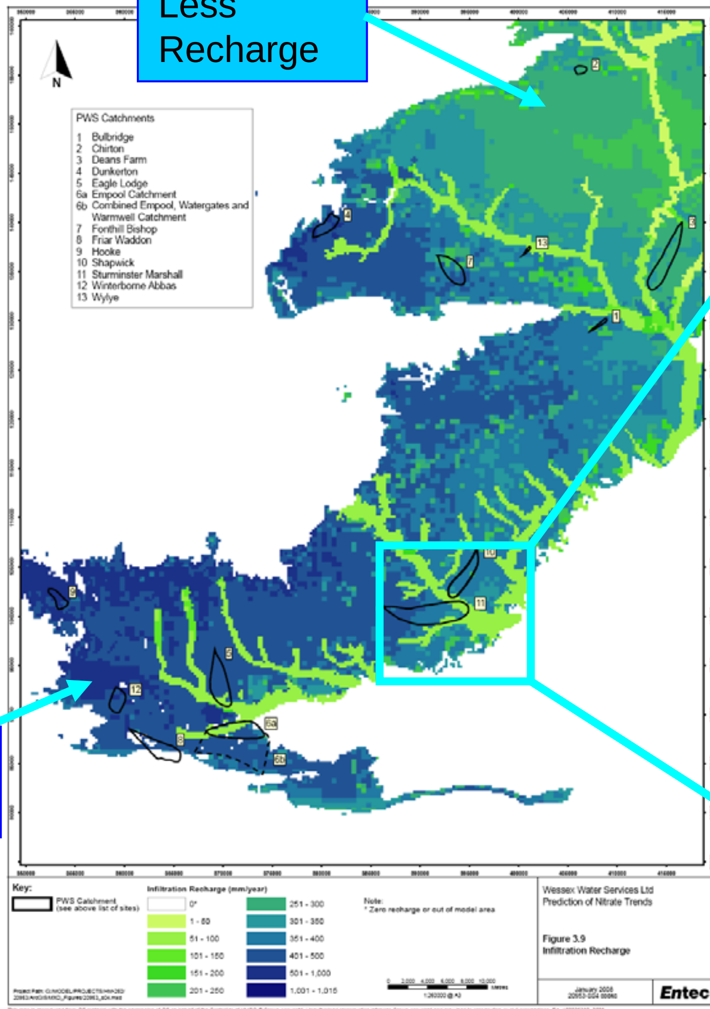


Entec

Creating the environment for business

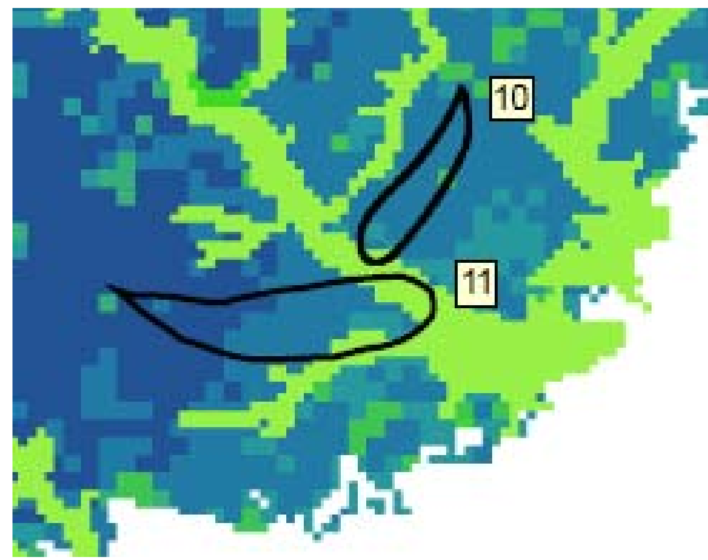
Infiltration Recharge

Less Recharge



More Recharge

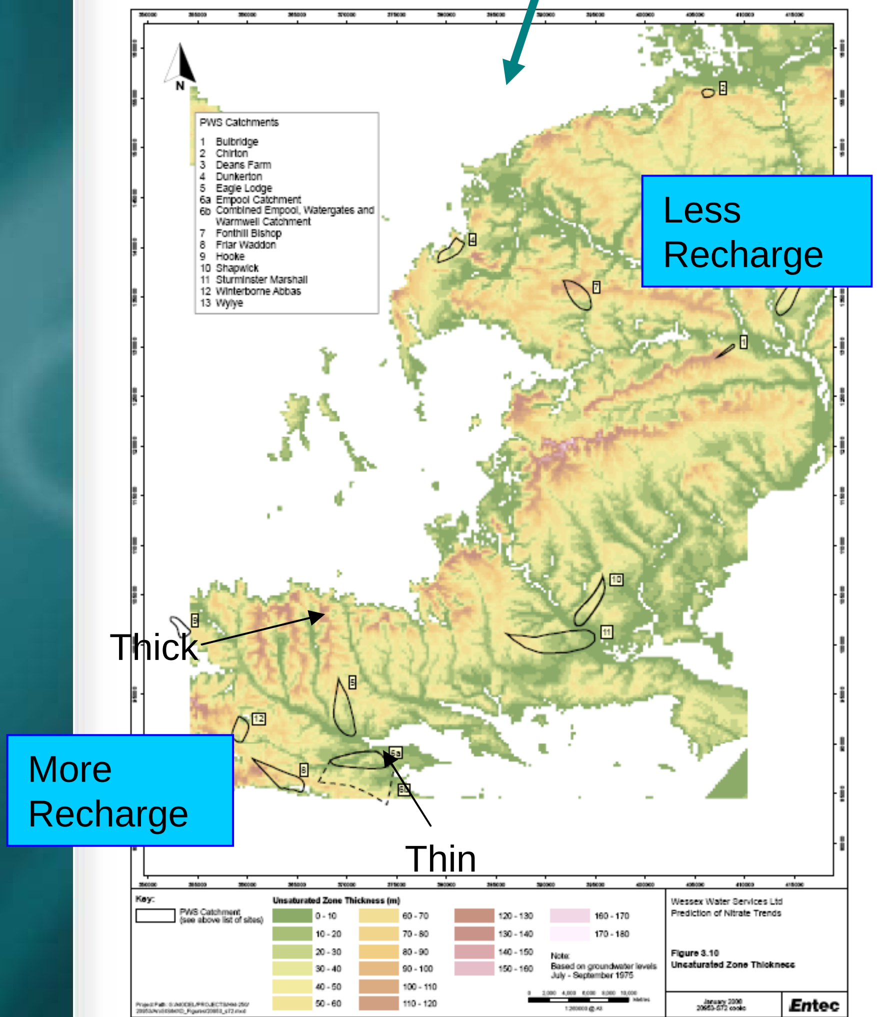
Output from the 4R South Wessex Recharge Model

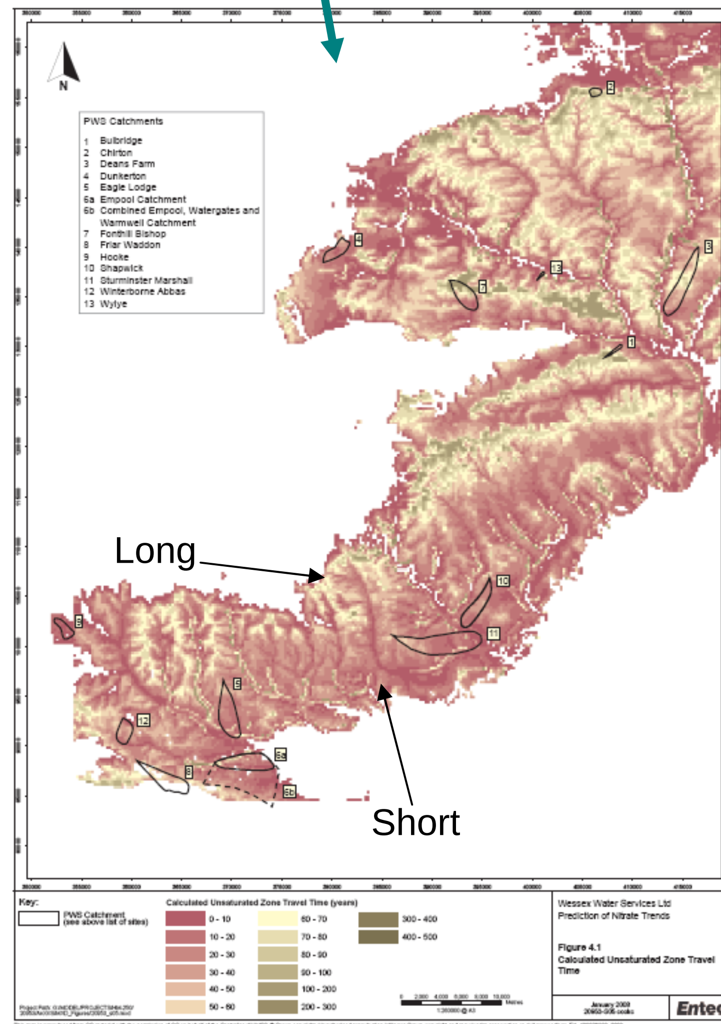


Entec

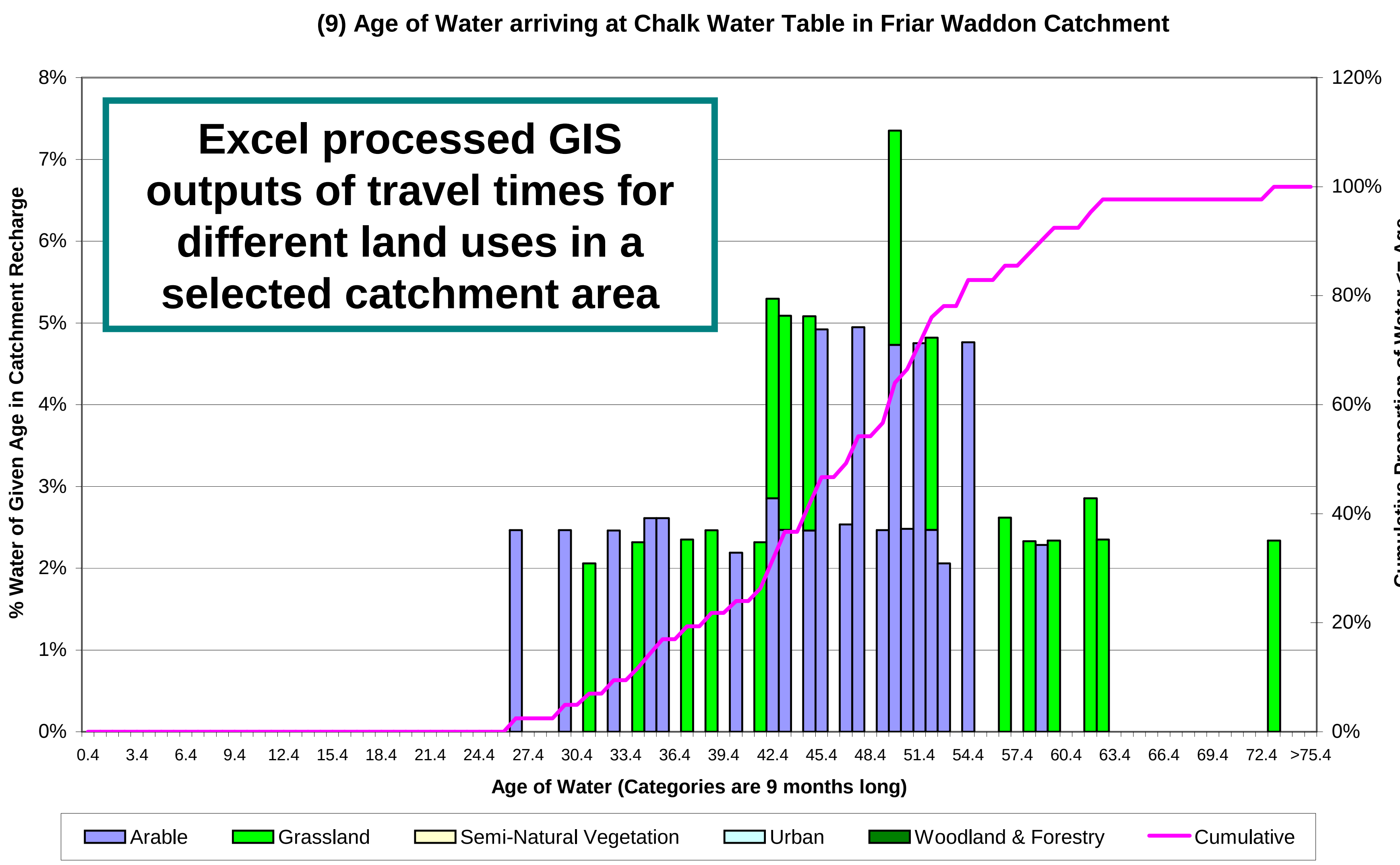
Creating the environment for business

Unsat Zone Thickness & Travel Time





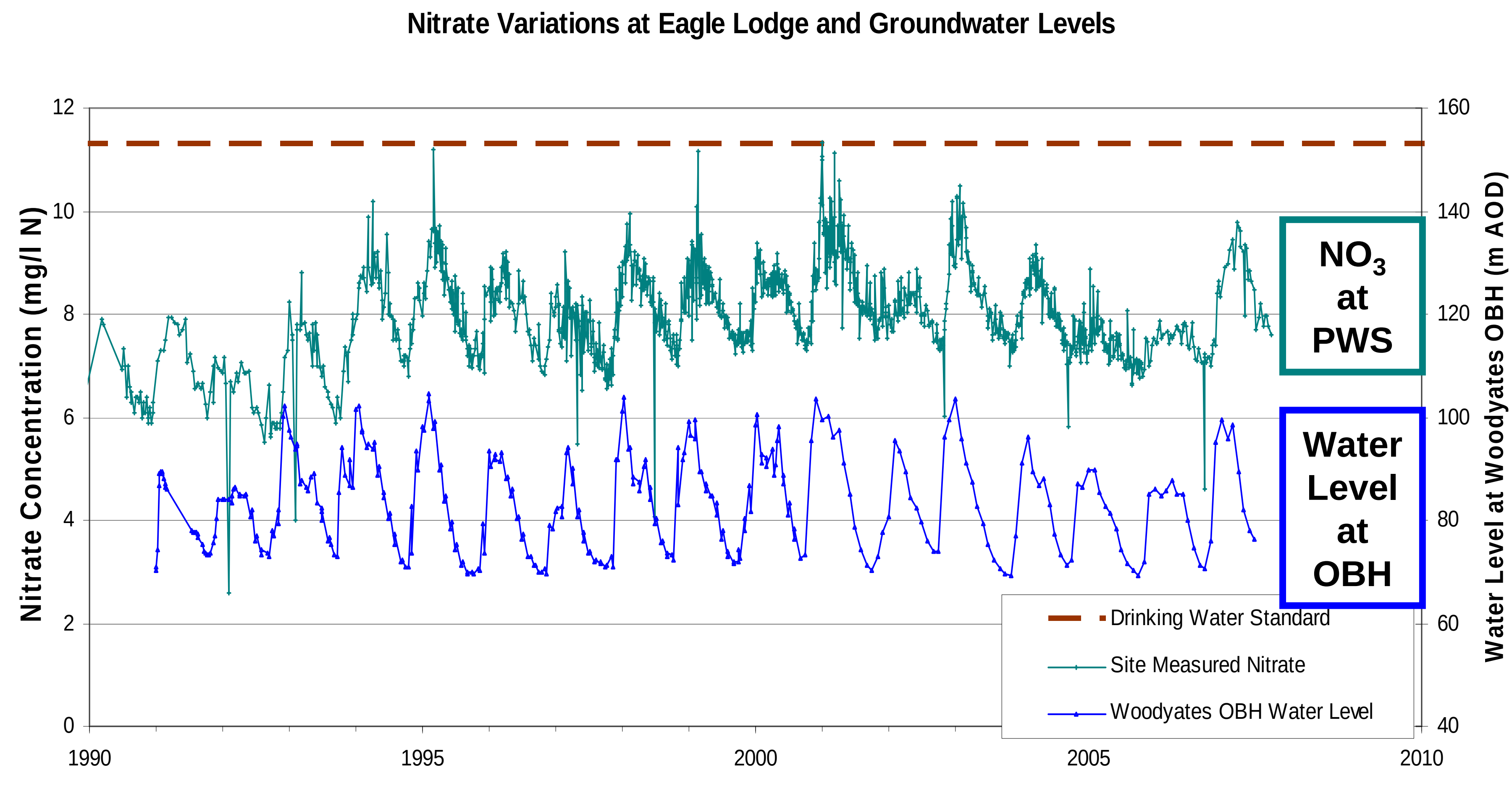
Creating the environment for business



Entec

Creating the environment for business

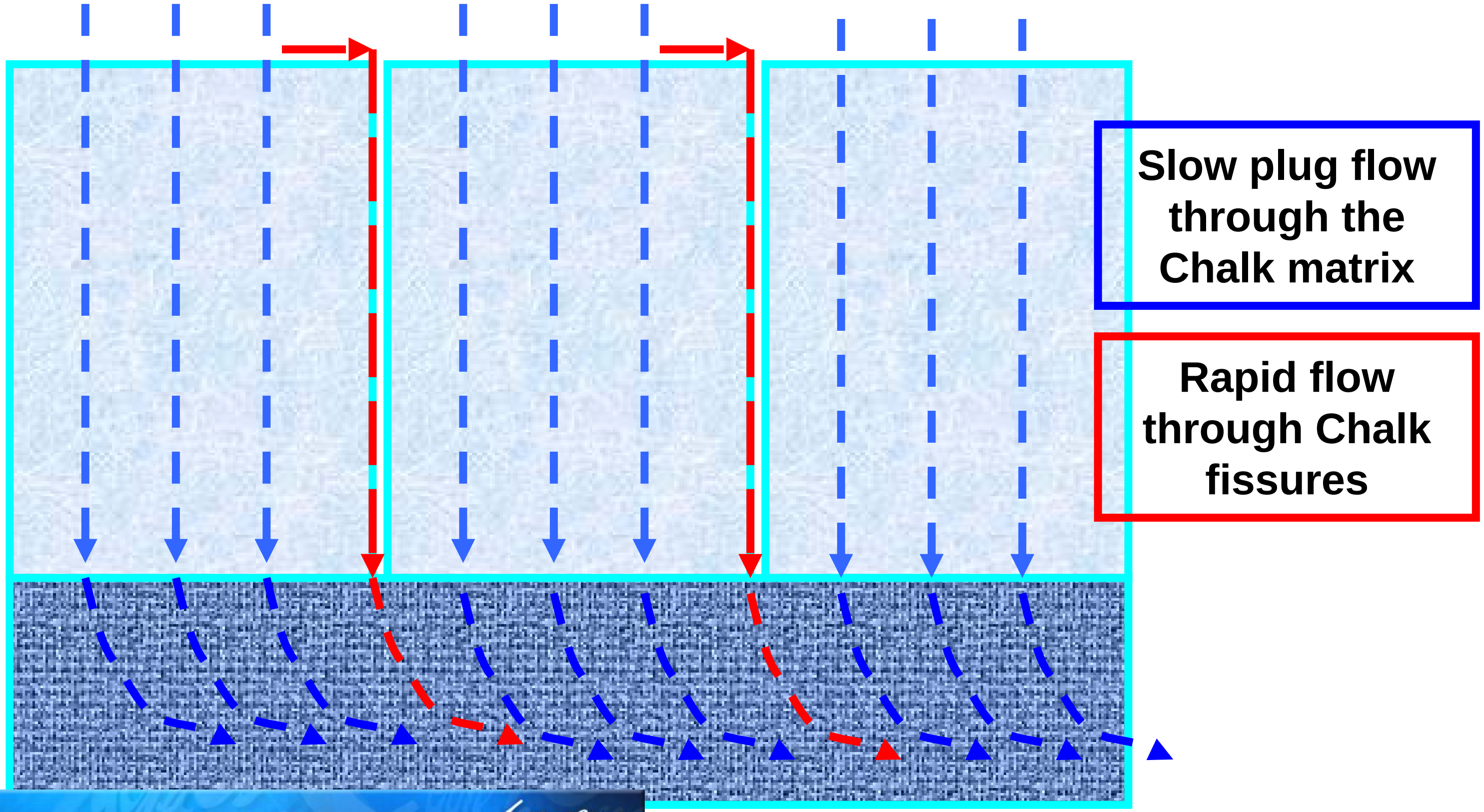
Seasonal Variations in NO_3 Related to Water Level Variation



Spikes – Bypass Recharge is a plausible explanation

Infiltration recharge drives slow movement of historically leached NO_3

Bypass recharge sends through spikes of this months (?) leaching



Nitrate Predictions

Nitrate concentration at time t =

- **Function of historically leached nitrate from appropriate land use, infiltration recharge and delay in unsaturated zone**

  +
- **Function of groundwater level**

  +
- **Function of bypass recharge**

Nitrate Predictions – Long Term Trend

Nitrate level at time t =

- **Function of historically leached nitrate from appropriate land use, infiltration recharge and delay in unsaturated zone**

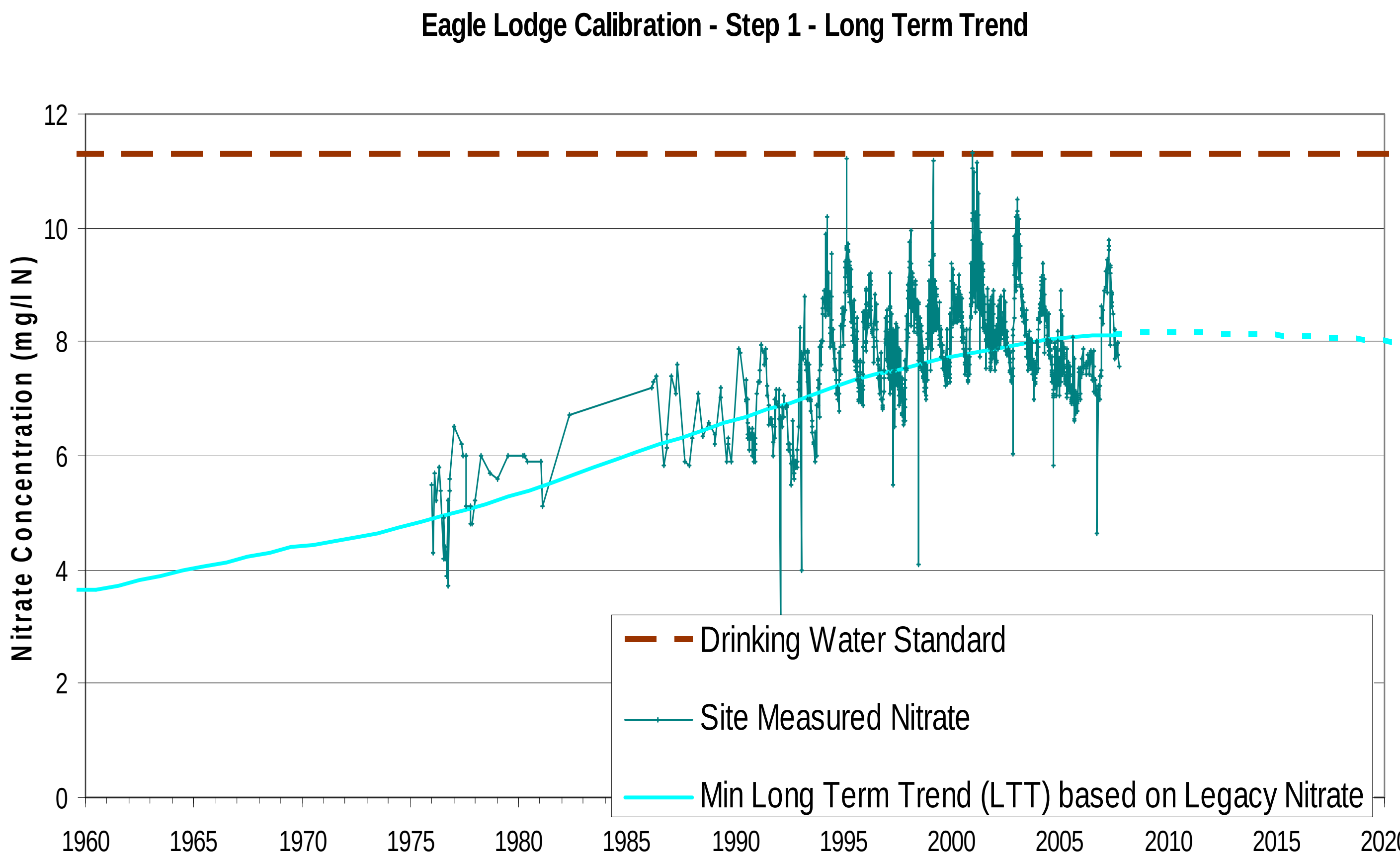
  +

- **Function of groundwater level**

  +

- **Function of bypass recharge**

Model Calibration Step 1 – Long Term Trend



Entec

Creating the environment for business

Nitrate Predictions – Adding Seasonality

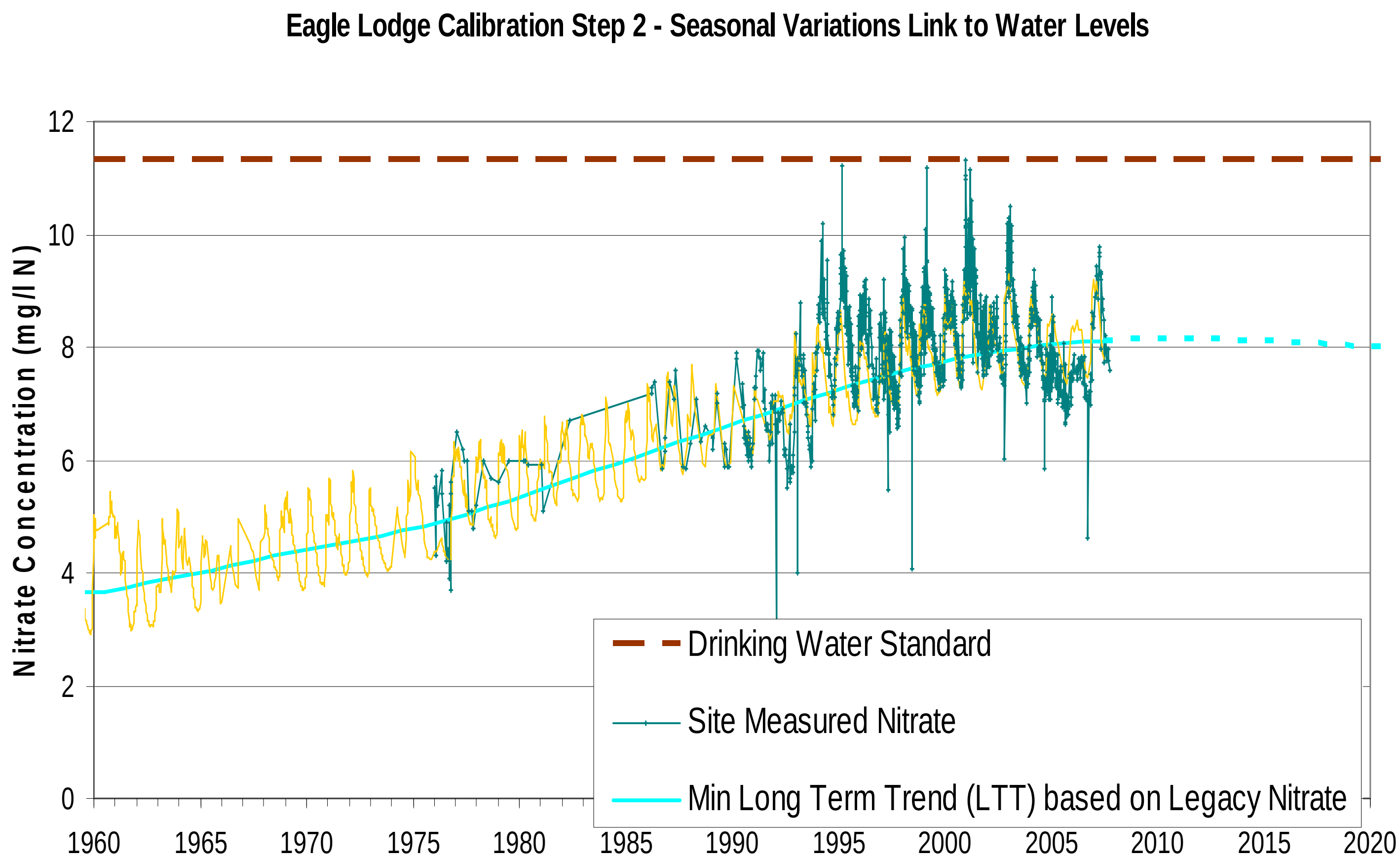
Nitrate level at time t =

- Function of historic application of nitrate / thickness of the unsaturated zone

  +
- **Function of groundwater level**

  +
- Function of bypass recharge

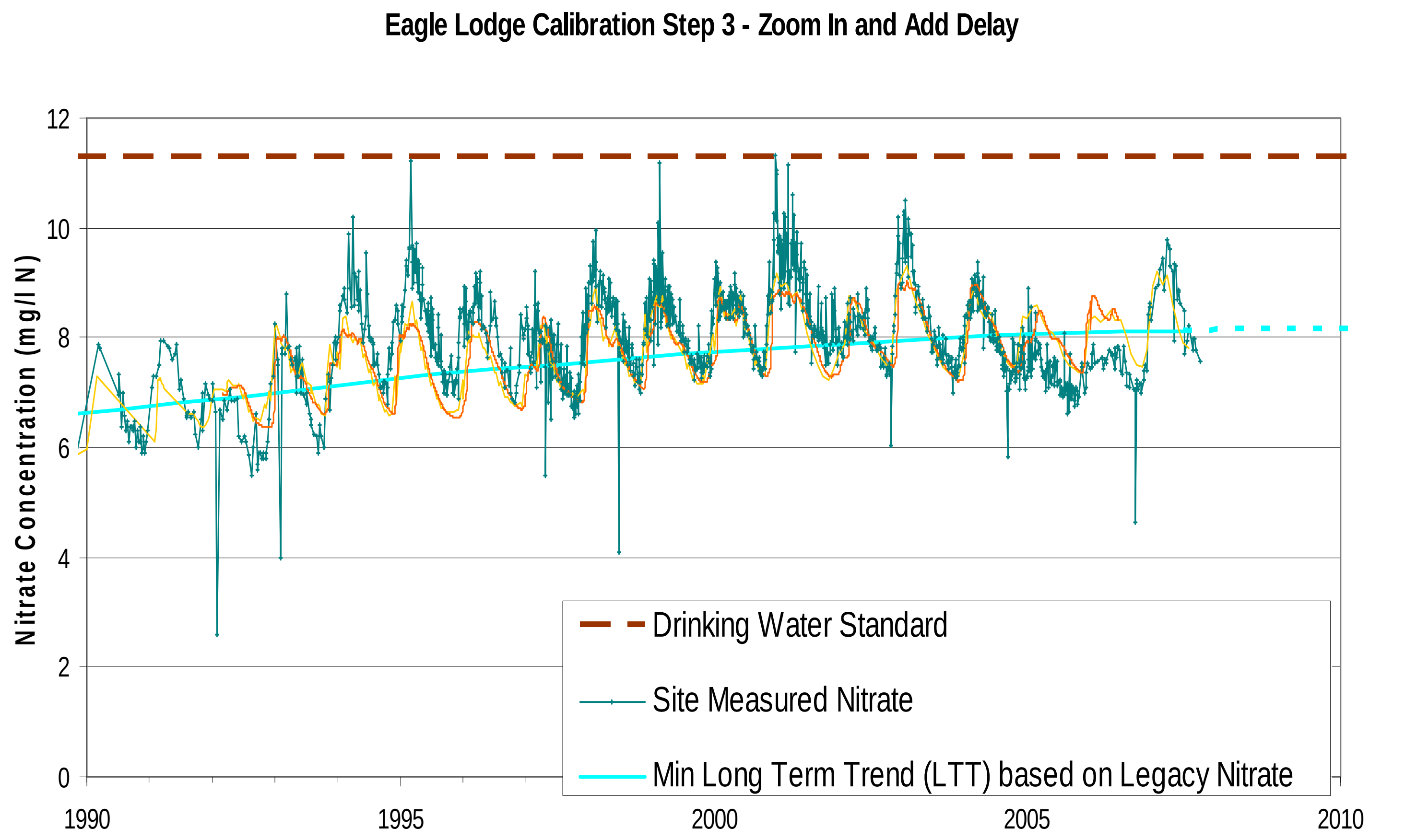
Model Calibration Step 2 – Seasonal Variations Link to Water Levels



Entec

Creating the environment for business

Model Calibration Step 3 – Zoom in and Add Delay



Nitrate Predictions – adding the spikes

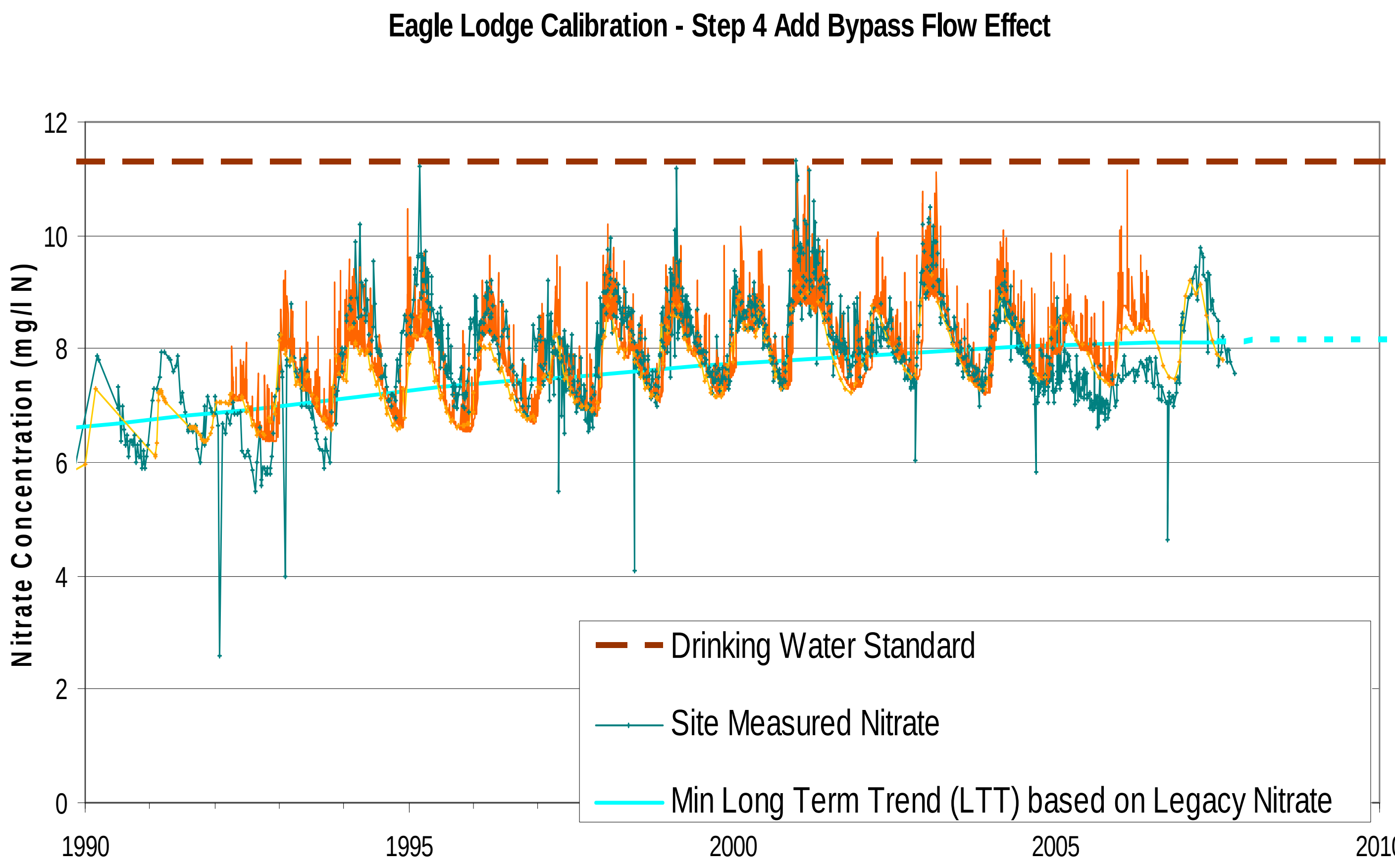
Nitrate level at time t =

- Function of historic application of nitrate / thickness of the unsaturated zone

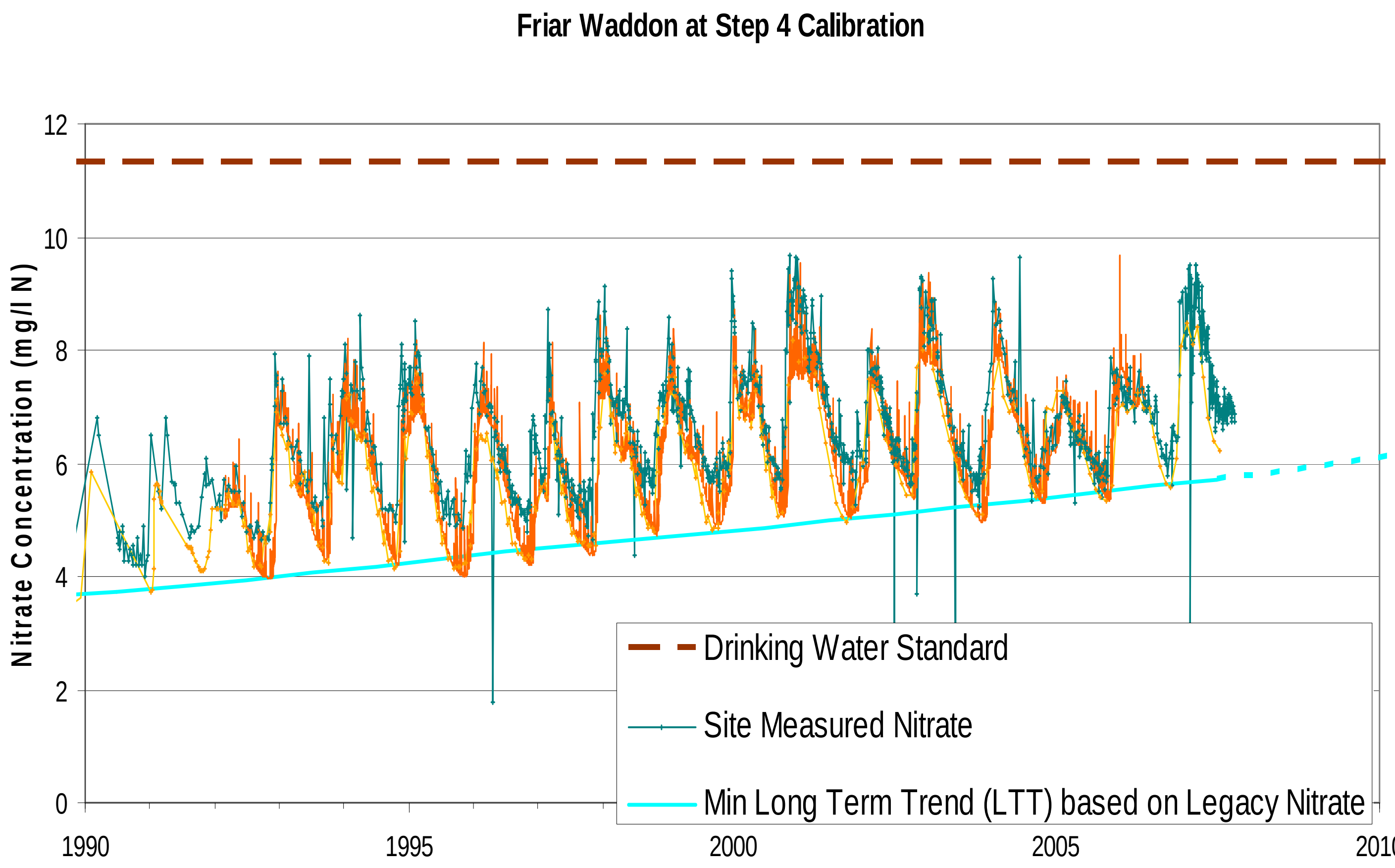
  +
- Function of groundwater level

  +
- **Function of bypass recharge (4R Model Output)**

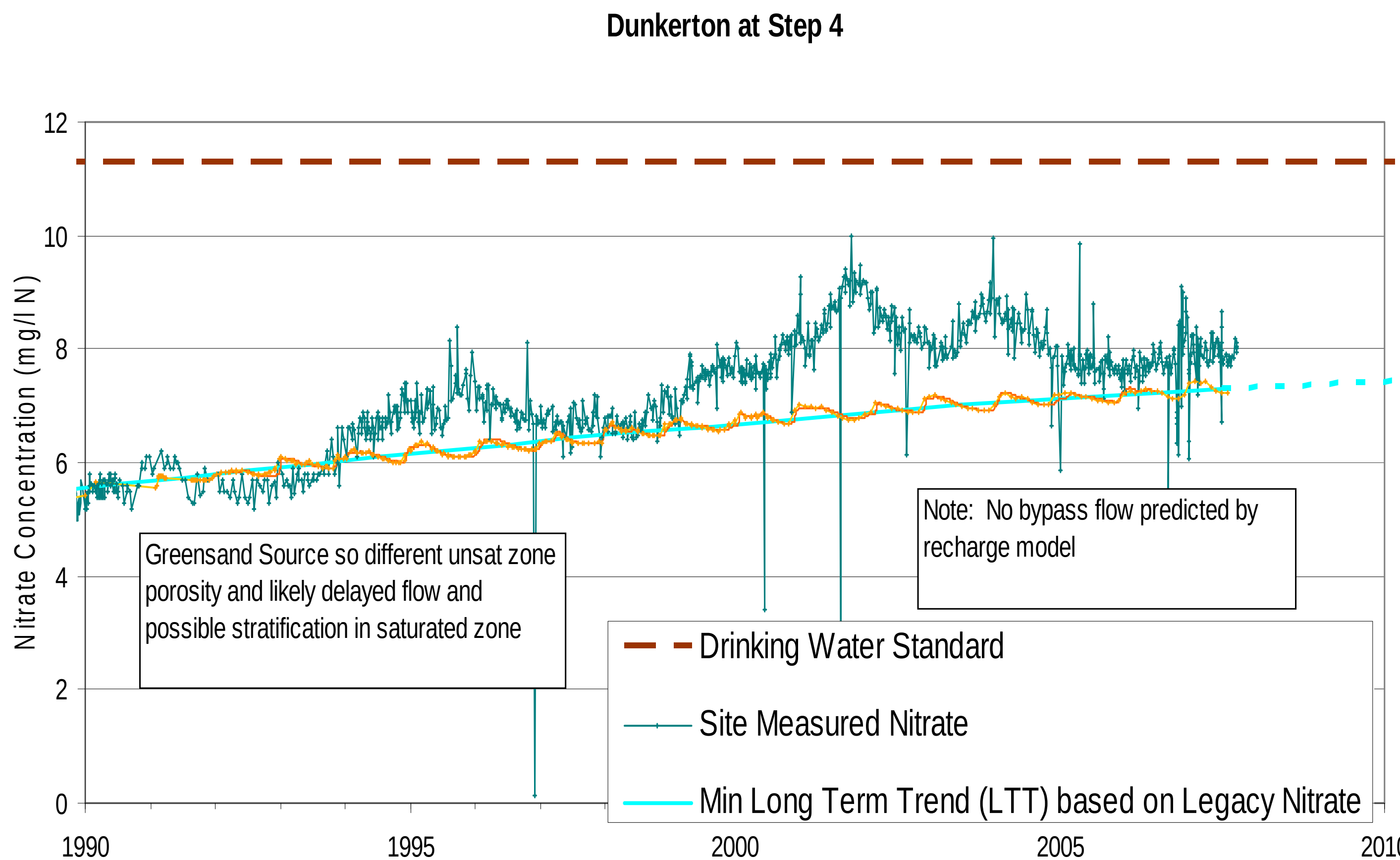
Model Calibration Step 4 –
Add Bypass Recharge Effect



Good Calibration with a Number of Sites



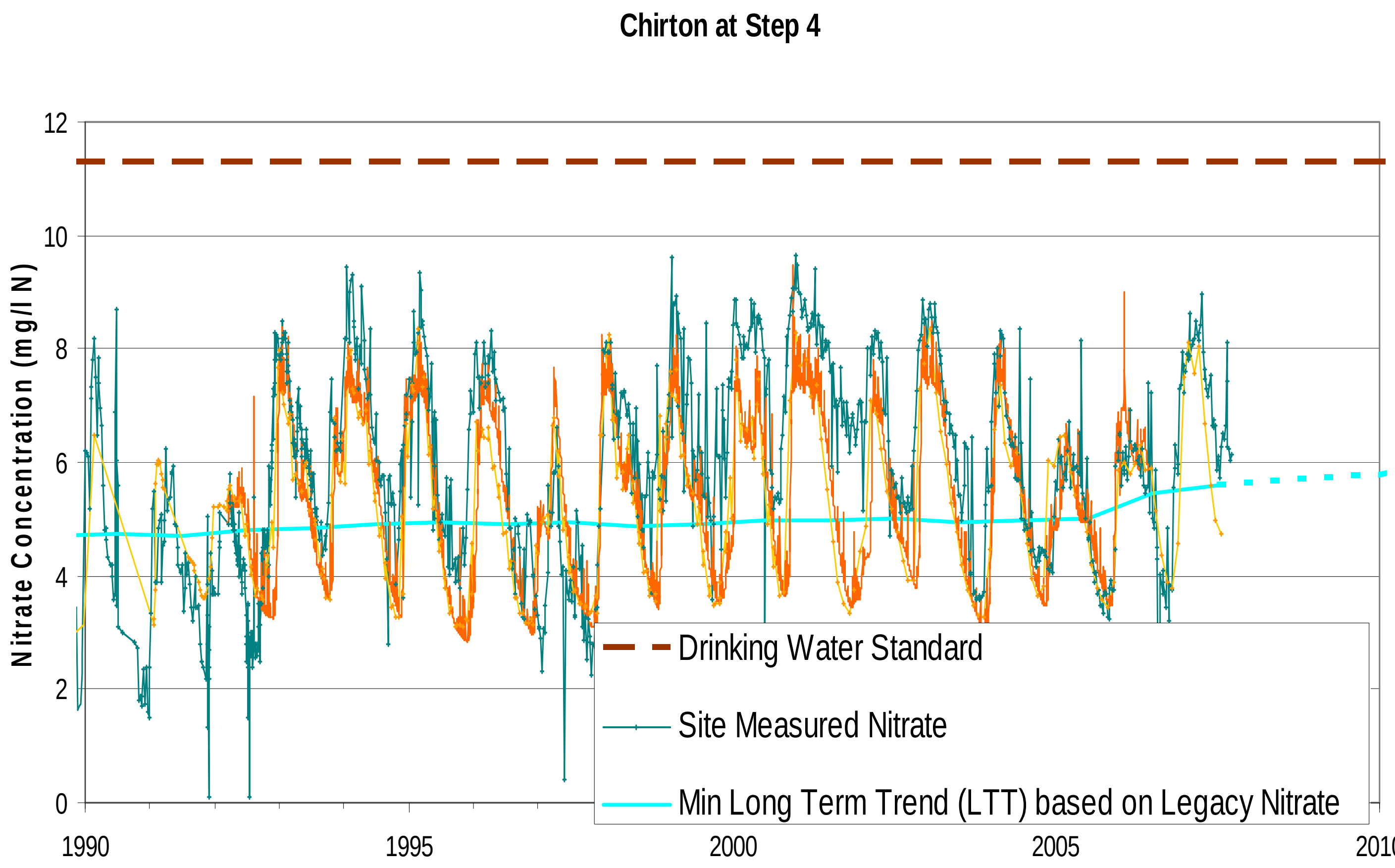
Poor for Upper Greensand Source



Entec

Creating the environment for business

But Generally Good for Chalk Sources



Entec

Creating the environment for business

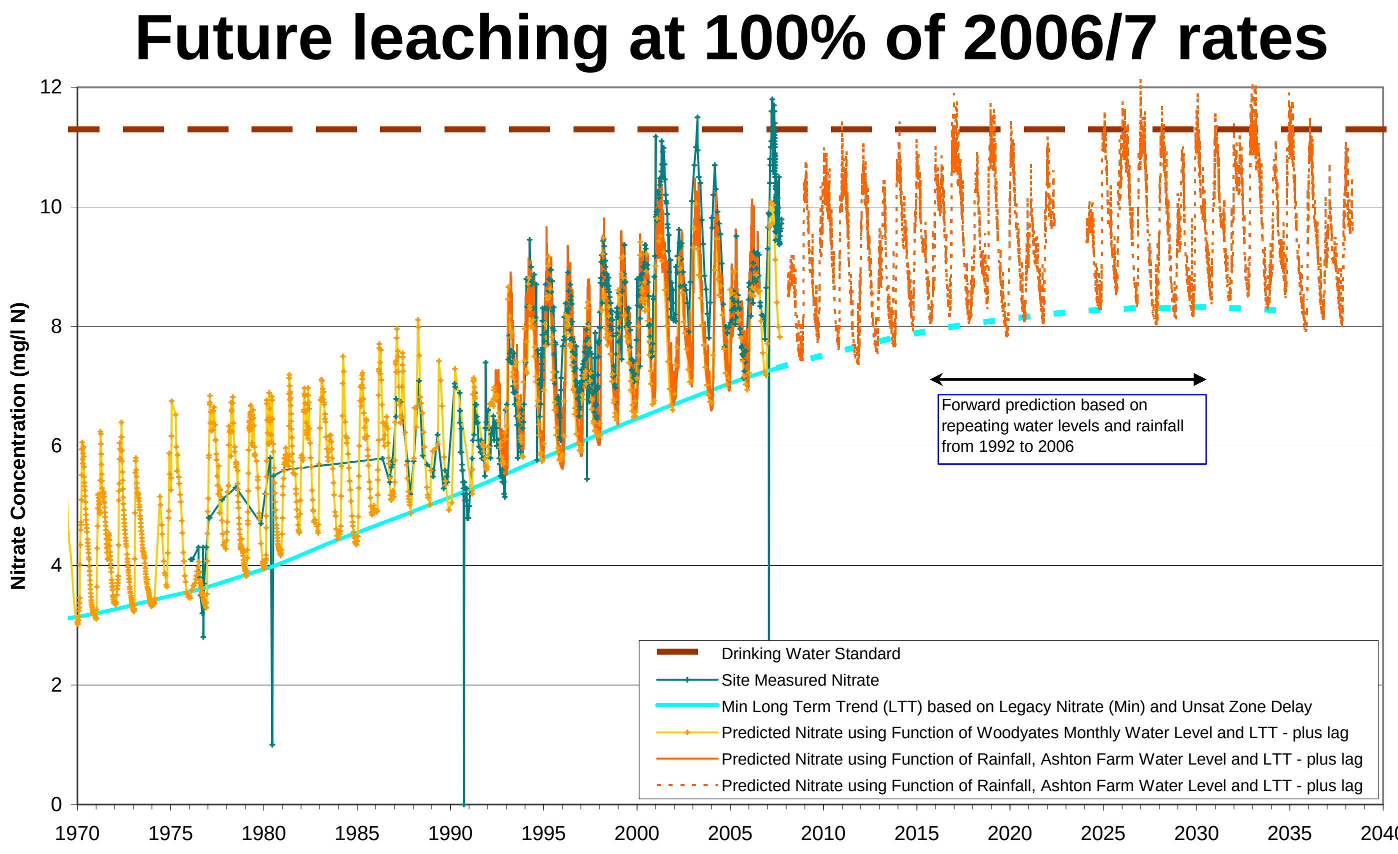
Modelled Scenarios

- With good model fit future leaching scenarios can be assessed:
  - Scenario 1 – nitrate leaching at 2006/7 rates
  - Scenario 2 – nitrate leaching reduced to zero*
  - Scenario 3 – nitrate leaching reduced to 50% of 2006/7 rates

(Note: *zero leaching is unrealistic for farmland but demonstrates the best that could be achieved)

(Forward predictions replicate water levels and bypass recharge data from period 1992-2006 twice)

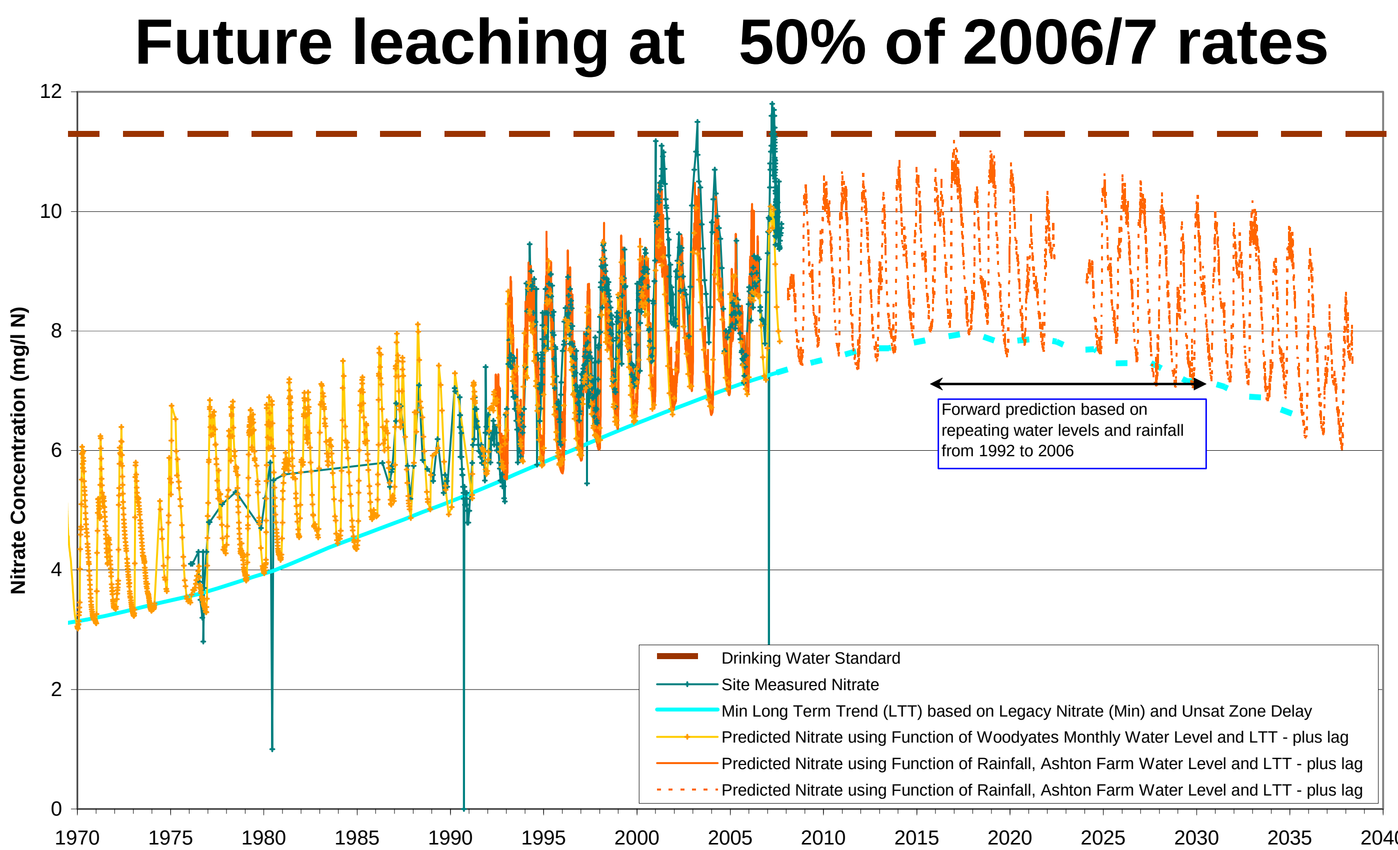
Winterbourne Abbas Scenario 1 Forward Prediction of Nitrate at PWS



Entec

Creating the environment for business

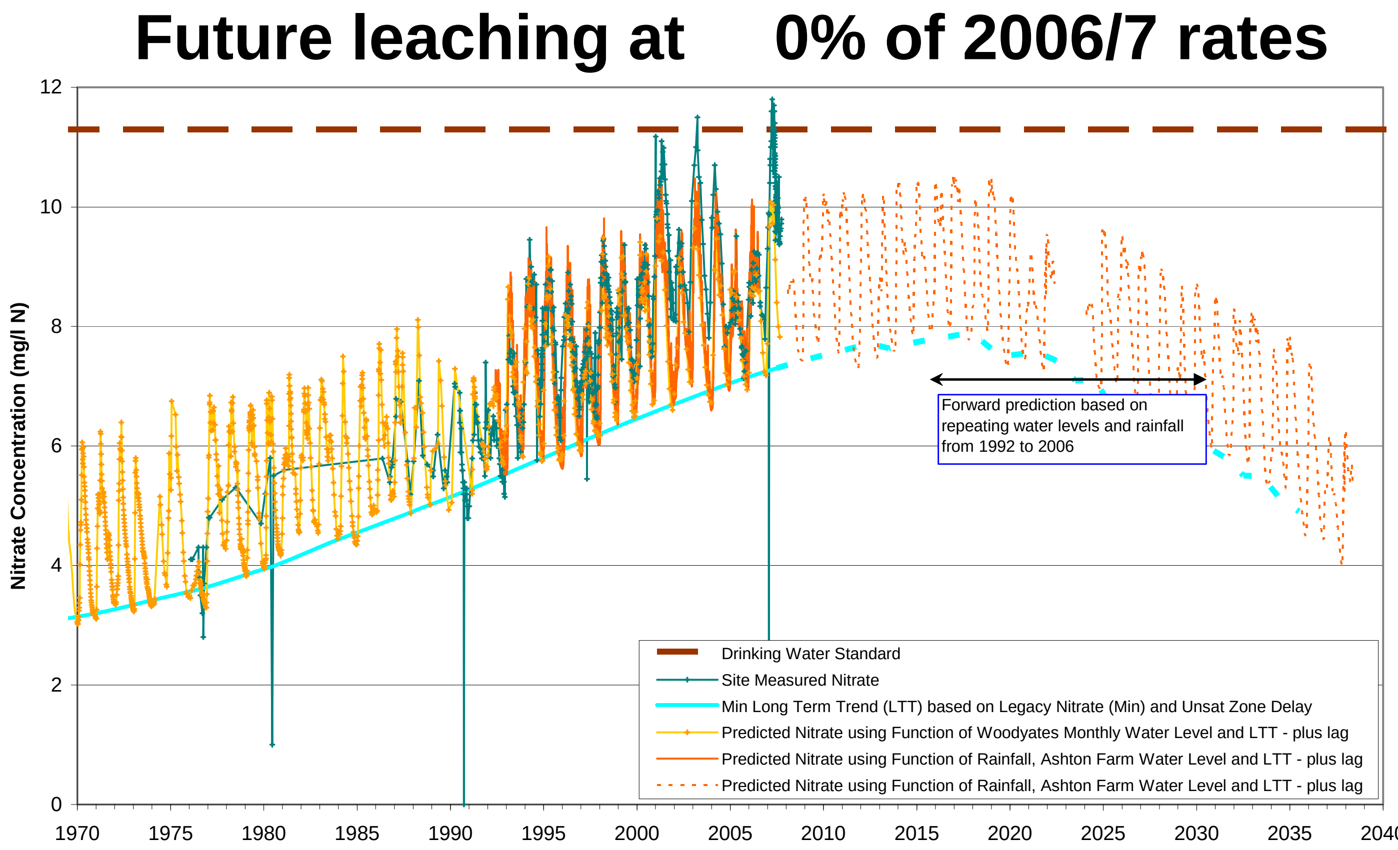
Winterbourne Abbas Scenario 3 Forward Prediction of Nitrate at PWS



Entec

Creating the environment for business

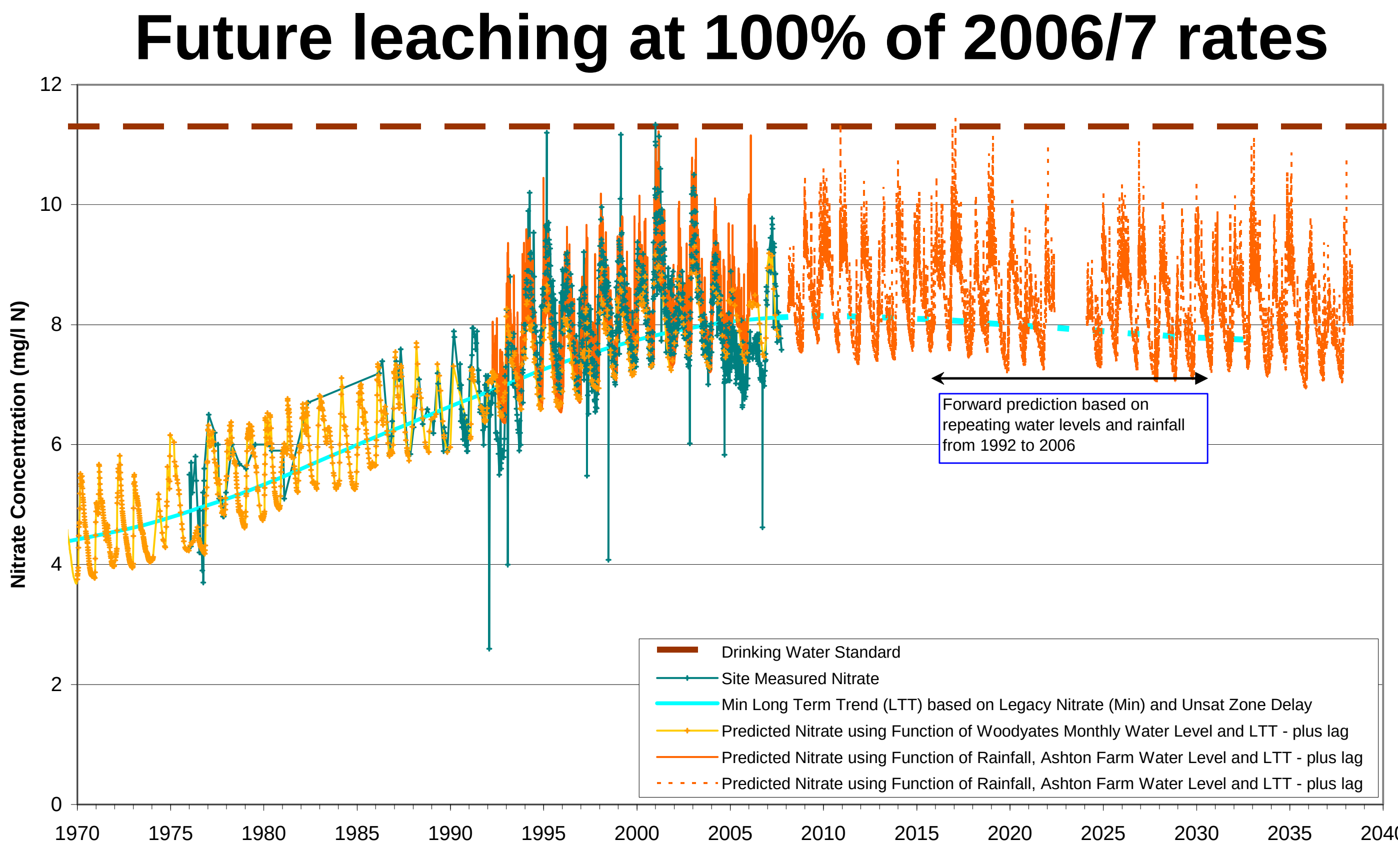
Winterbourne Abbas Scenario 2 Forward Prediction of Nitrate at PWS



Entec

Creating the environment for business

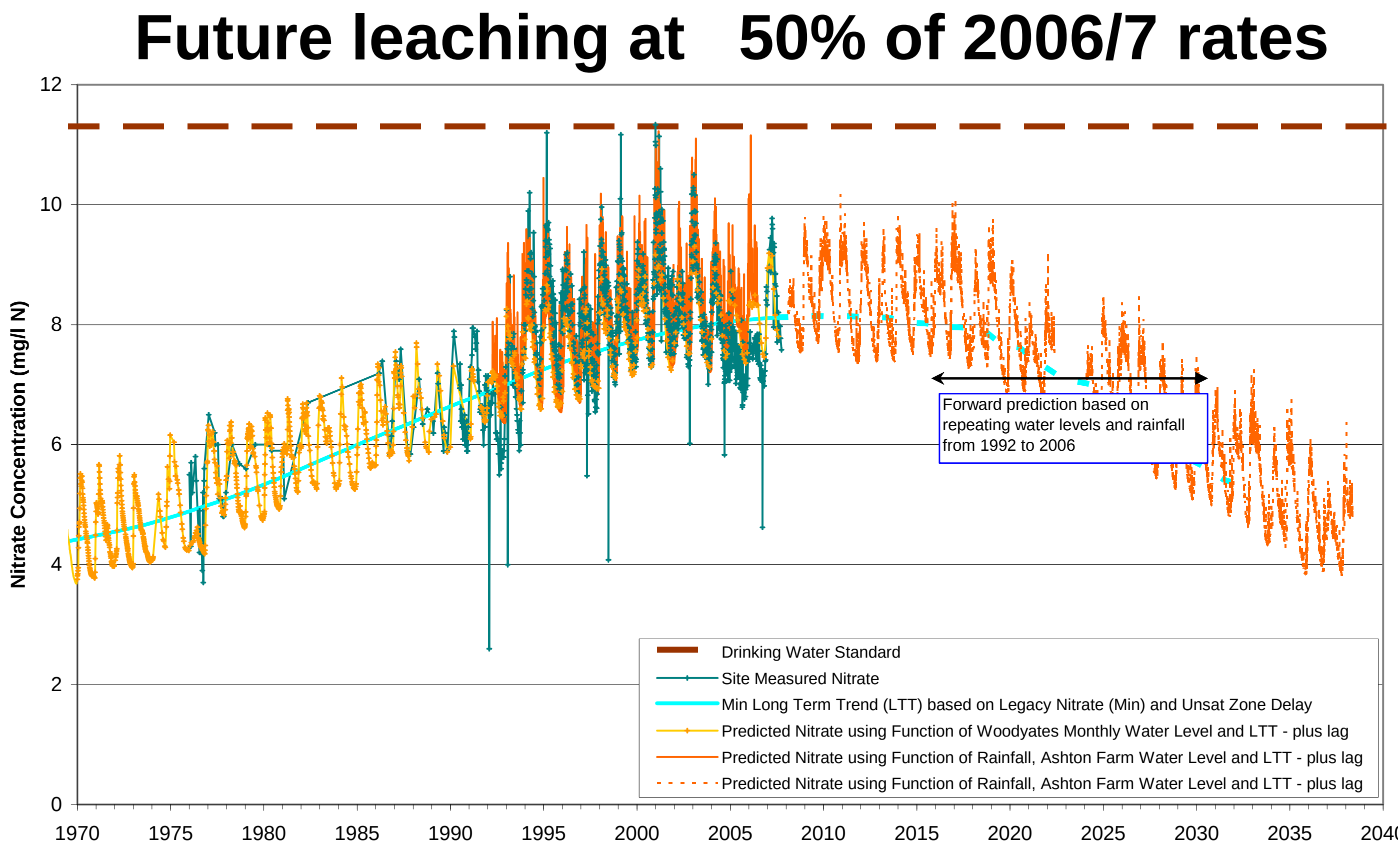
Eagle Lodge Scenario 1
Forward Prediction of Nitrate at PWS



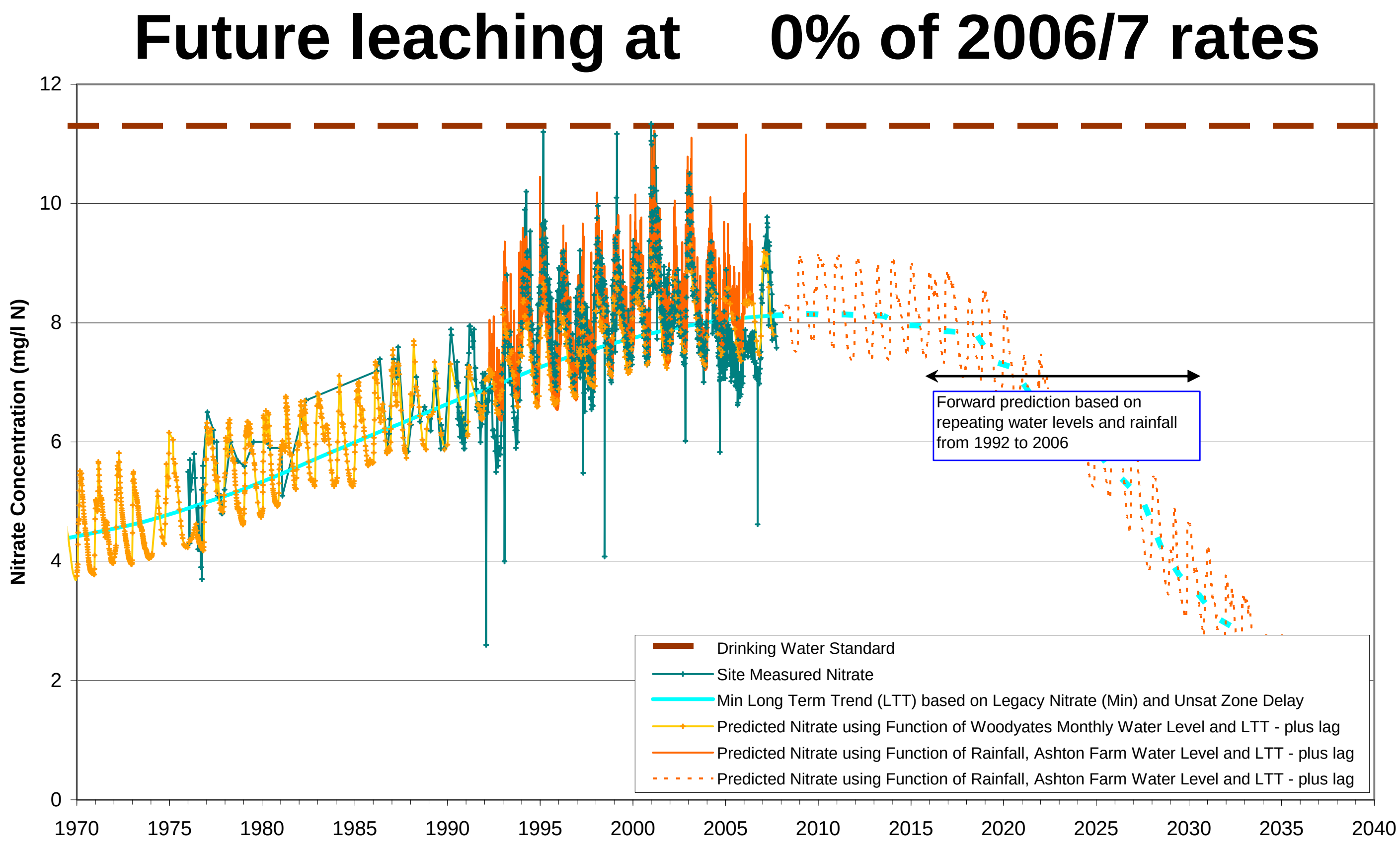
Entec

Creating the environment for business

Eagle Lodge Scenario 3
Forward Prediction of Nitrate at PWS



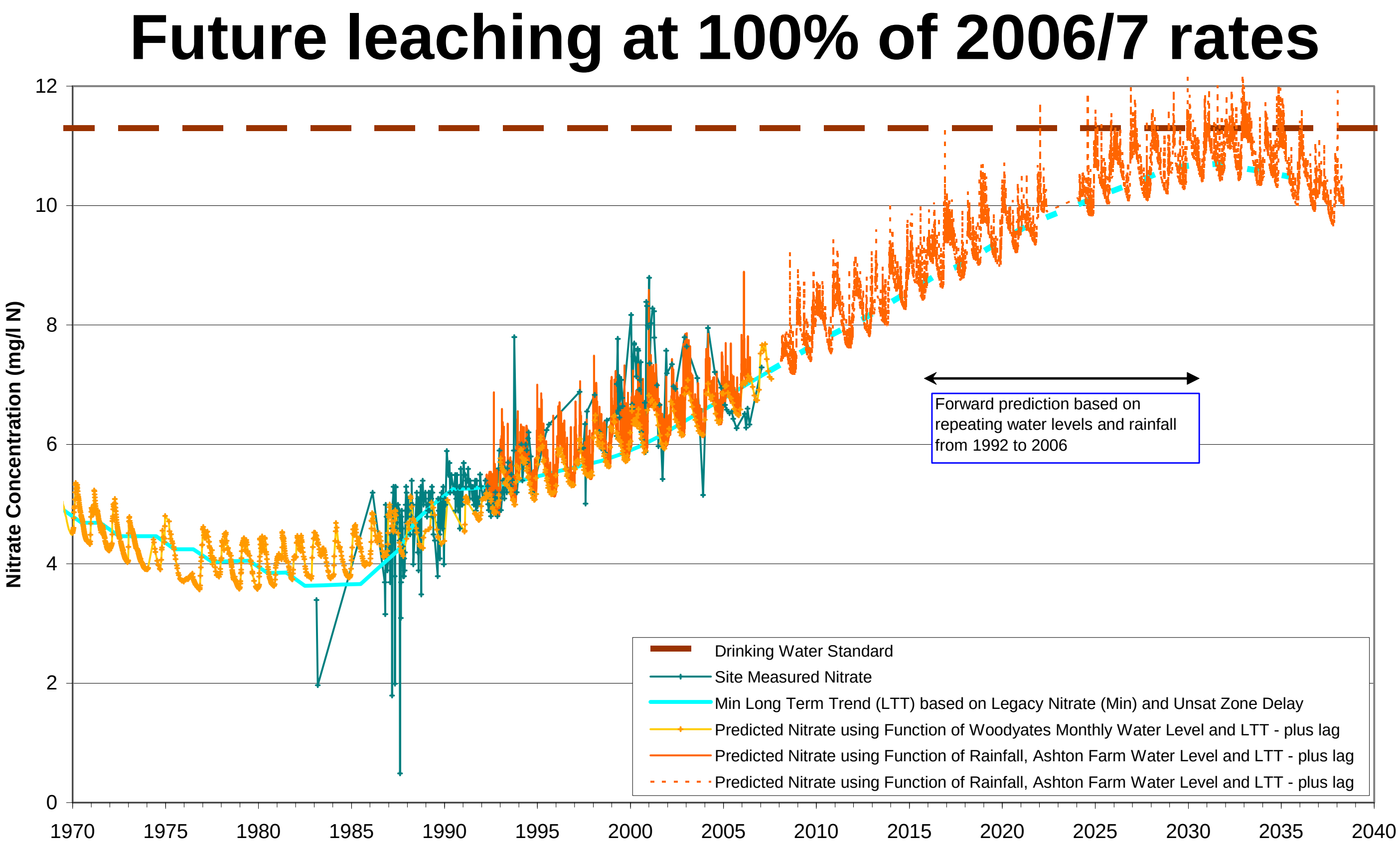
Eagle Lodge Scenario 2 Forward Prediction of Nitrate at PWS



Entec

Creating the environment for business

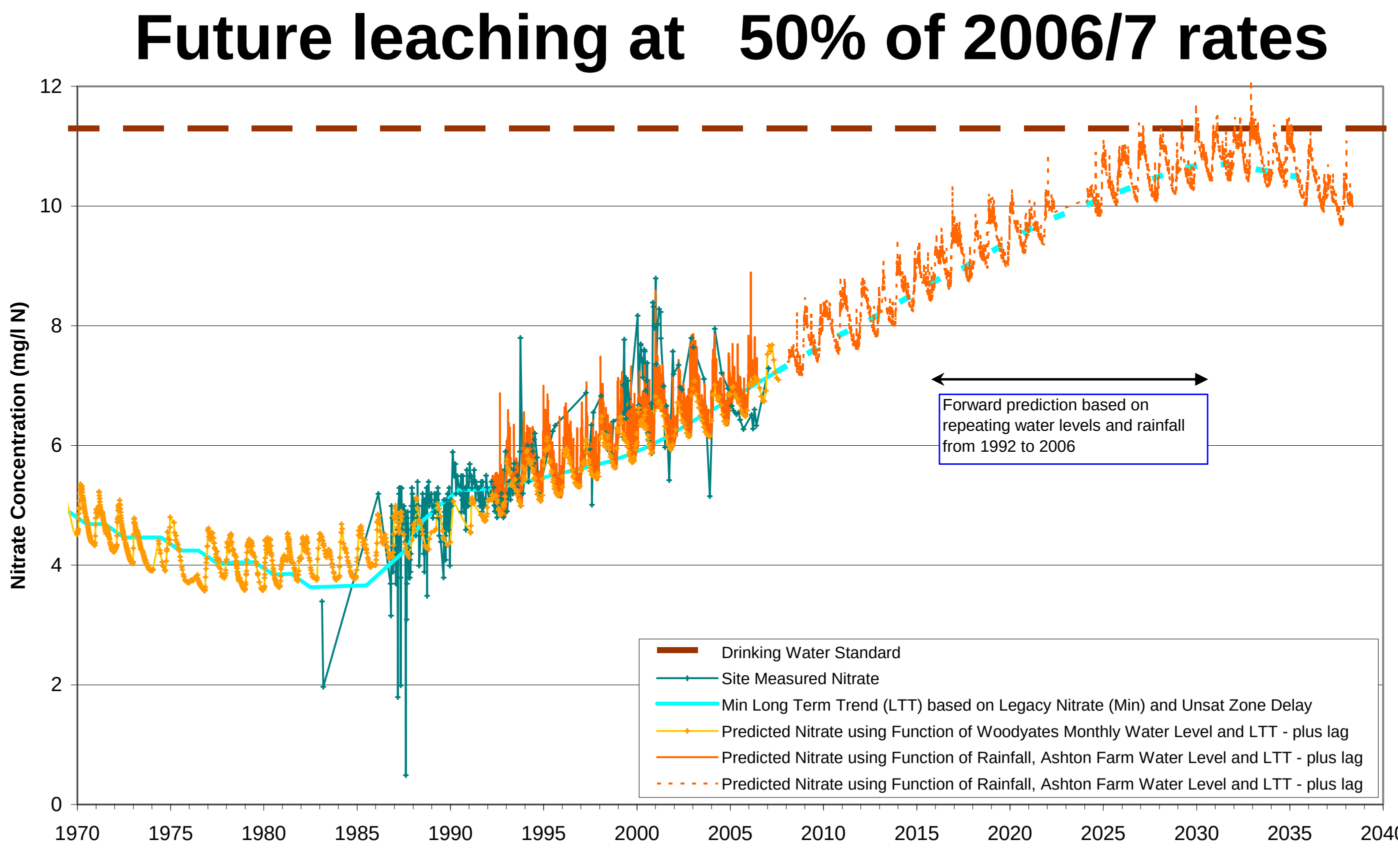
Wylye Scenario 1
Forward Prediction of Nitrate at PWS



Entec

Creating the environment for business

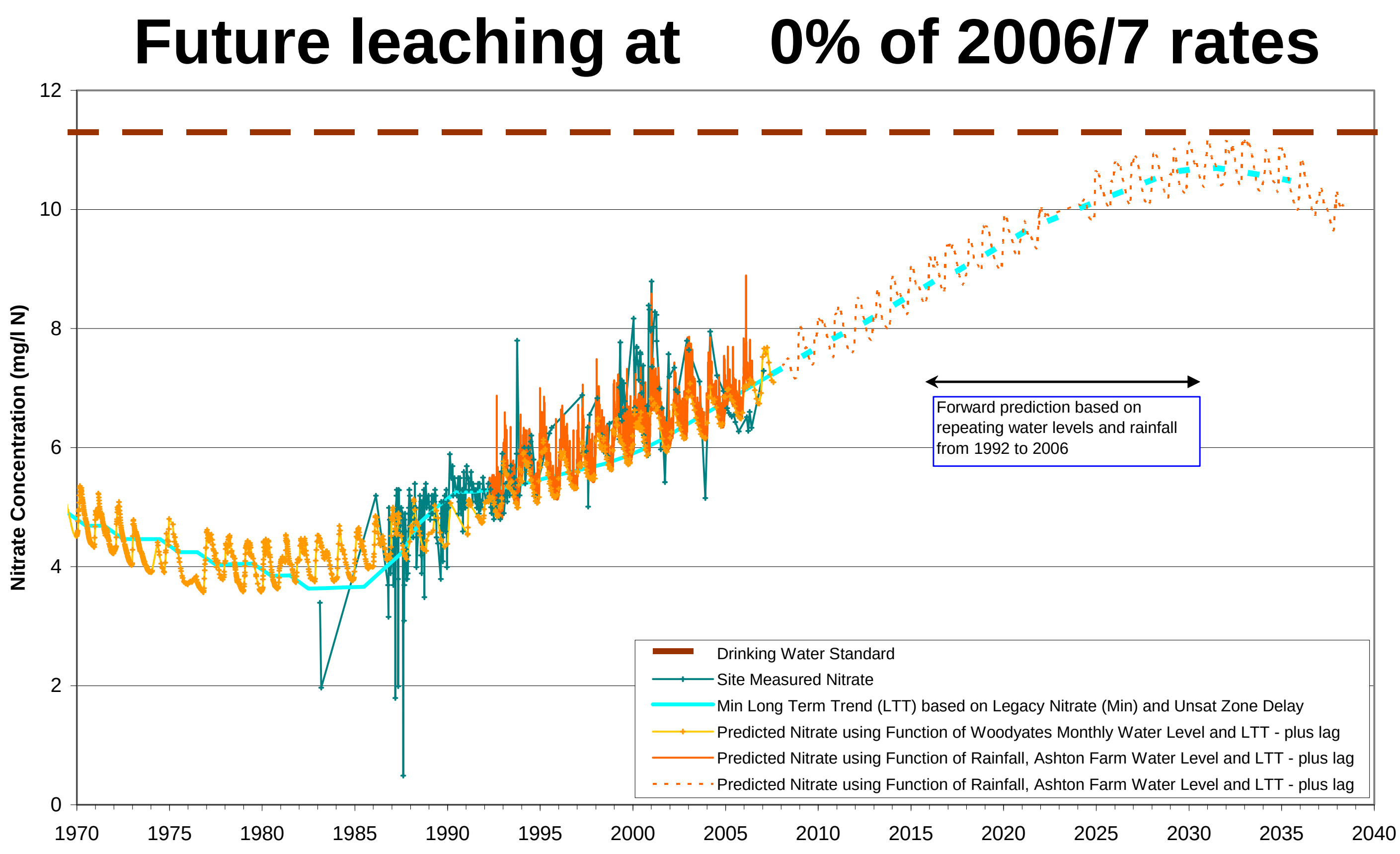
Wylye Scenario 3
Forward Prediction of Nitrate at PWS



Entec

Creating the environment for business

Wylye Scenario 2
Forward Prediction of Nitrate at PWS



Lessons / Conclusions

- Historically leached nitrate difficult to constrain, but use of one arable and one managed grassland trend has been successfully applied to 10 Chalk catchments
- Leached concentrations are lower where recharge is higher so would anticipate higher nitrate concentrations moving more slowly further east on the Chalk
- Source Protection Zones do not typically match the likely catchments – so may manage the wrong fields!
- Good model fit gives basis for making forward predictions
- Provides a tool to help decide how soon catchment management could make a difference – supports AMP5 funding application
- Additional value of recharge model realised

Predicting nitrate levels for Wessex Water's long term water resource planning

Nick Rukin, Associate Director, Entec UK Ltd

Luke de Vial, Head of Water Resources, Wessex Water

UK Groundwater Forum Conference – 13 May 2008

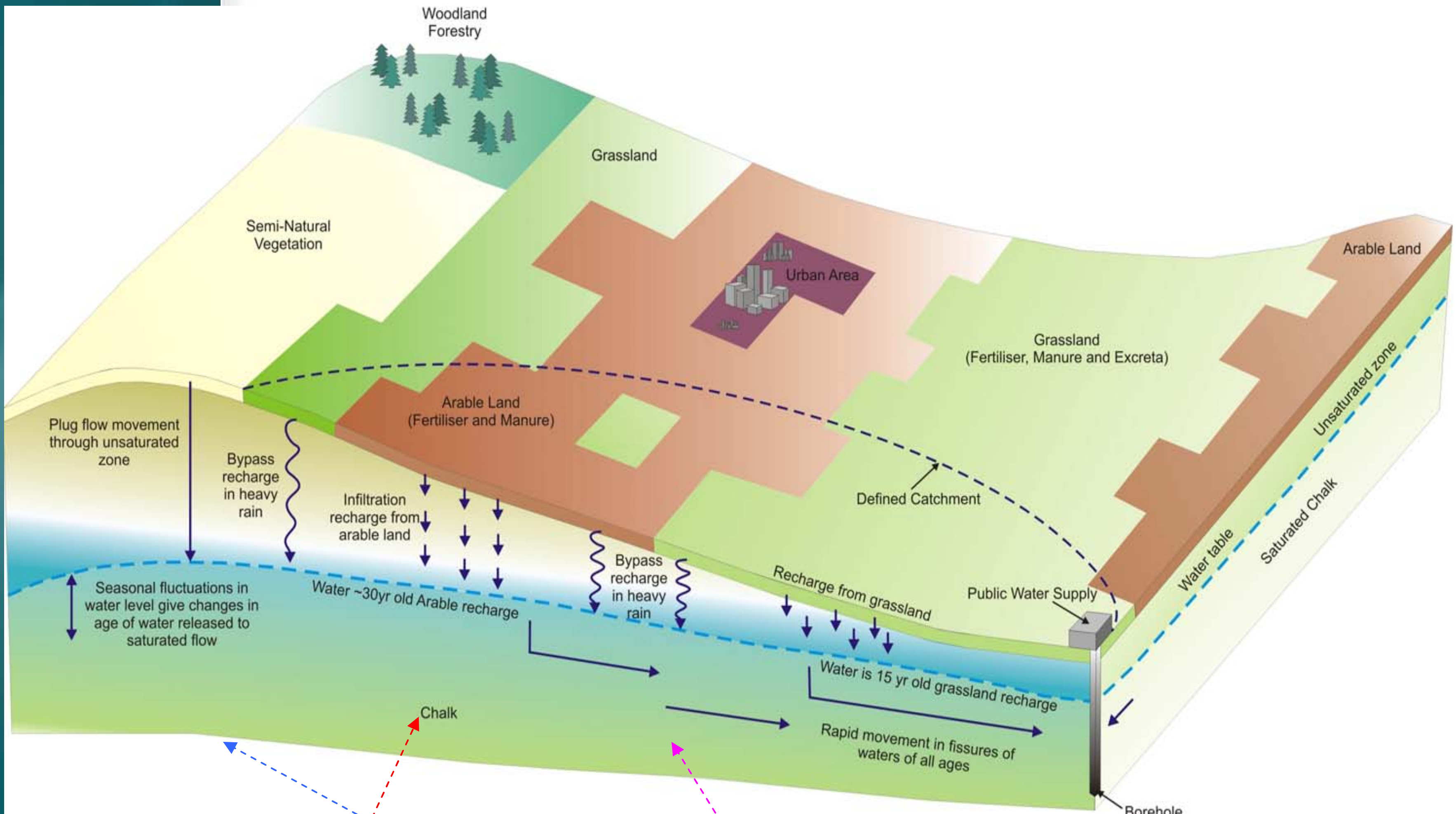
Time for Questions ?

Entec

Creating the environment for business

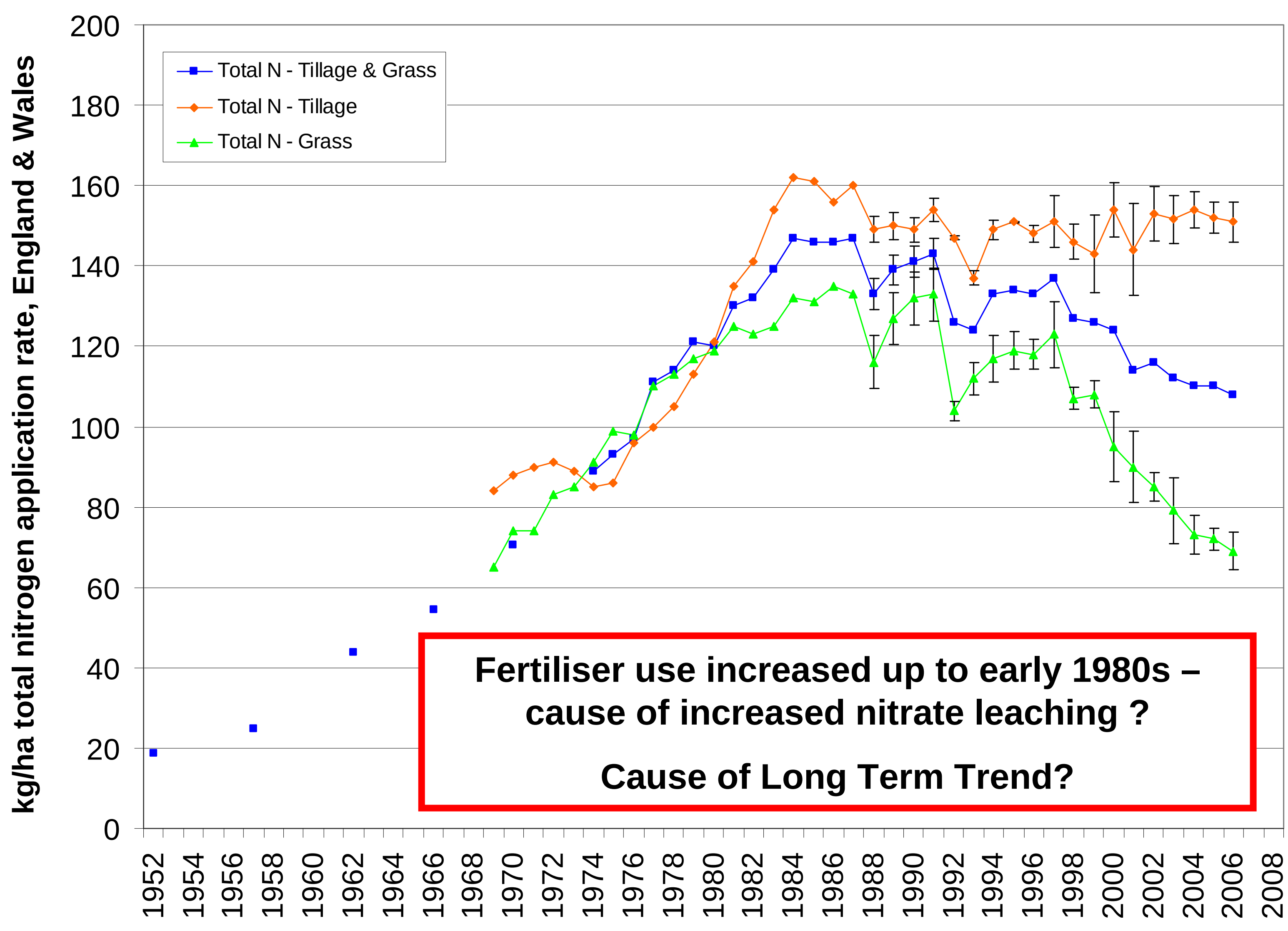
a YTL company

Conceptual Model For Nitrate Trend Prediction

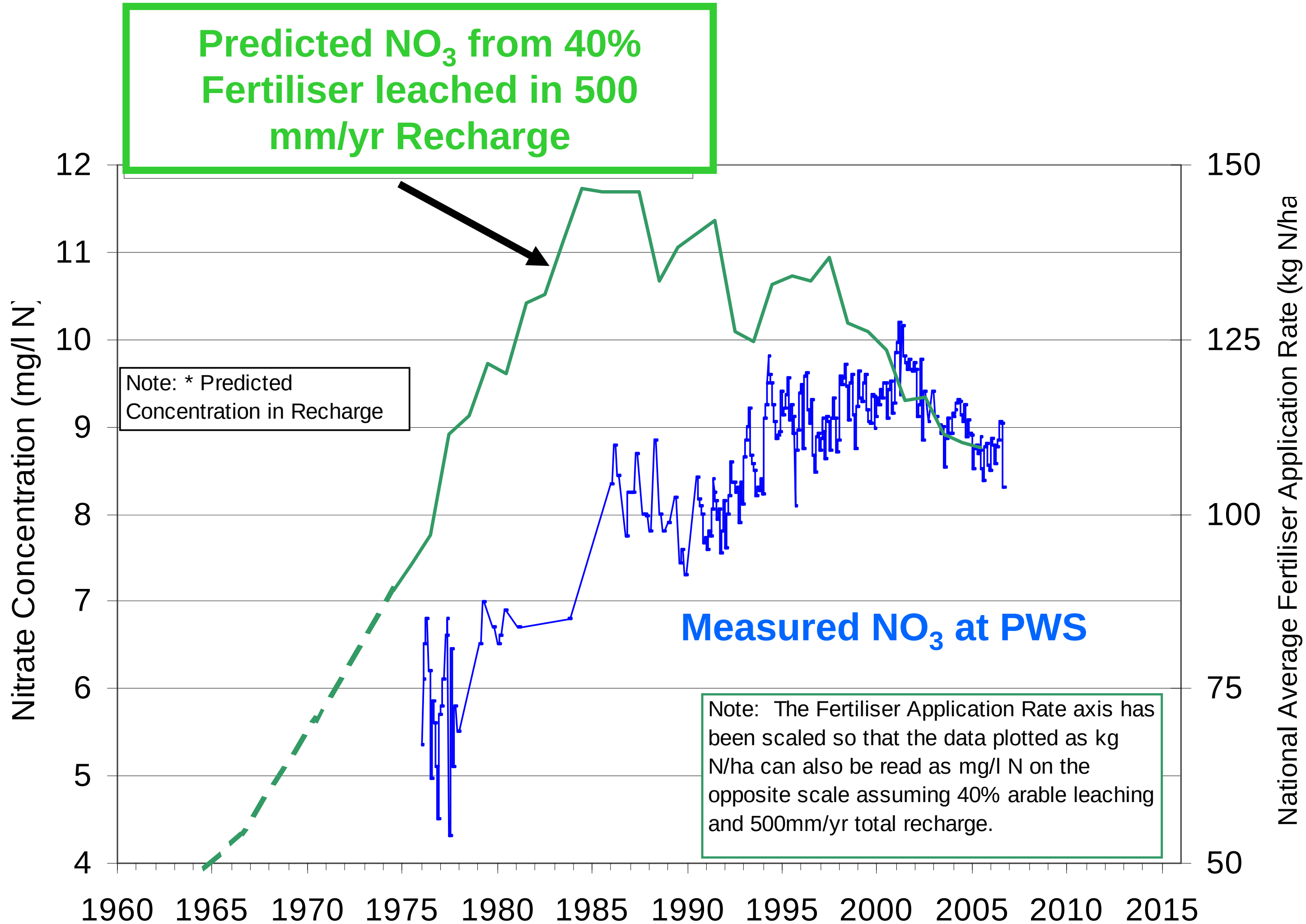


NO_3 at borehole = Long term trend + seasonal trend + bypass spike

Inorganic Fertiliser Use (1952 – 2006)



Observed NO_3 = Delayed Leached Fertiliser?



Entec

Creating the environment for business