
Wet Later
a YTL company

Water industry perspective on the main groundwater management challenges

Luke de Vial

Head of Water Resources and Supply


BRISTOL CHANNEL
Bristol
Bath
Chippenham
Bridgwater
Salisbury
Taunton
Yeovil
Dorchester
Bournemouth
Poole
ENGLISH CHANNEL


Natural
History
Museum
BRISTOL CHANNEL
Bristol
Bath
Chippenham
Bridgwater
Taunton
Salisbury
Yeovil
Dorchester
Bournemouth
Poole
ENGLISH CHANNEL

Advantages of groundwater

- **All being well groundwater provides**
  - **Storage of water**
  - **Clean water**

- **Low cost**
- **Low carbon**

Management of groundwater

- Storage
  - How much storage
  - How do we manage our abstractions
  - Relationship with river flows
- Clean
  - Is it?
  - Can we clean it up?

Groundwater storage

- 1km^2
- 10m thick
- 1% porosity

➢ 100 Ml

- 50km^2
- 10m thick
- 1% porosity

➢ 5,000 Ml

- 10km^2
- 10m thick
- 1% porosity

➢ 1000 Ml

- 1km^2
- 10m deep
- 100% porosity

➢ 10,000 Ml

Groundwater storage

- 1km^2
- 10m thick
- 1% porosity

➢ 100 Ml

- 10km^2
- 10m thick
- 1% porosity

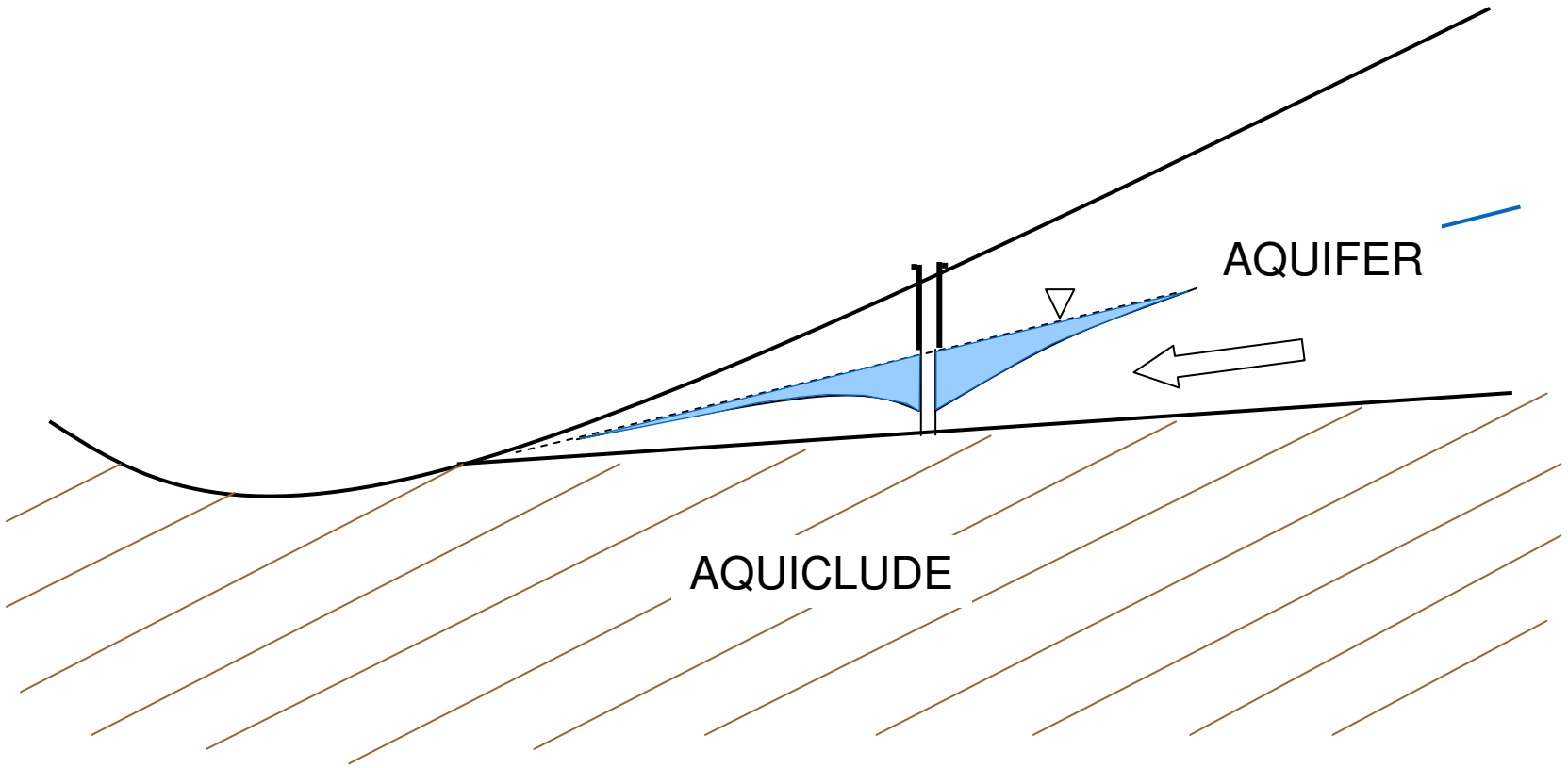
➢ 1000 Ml

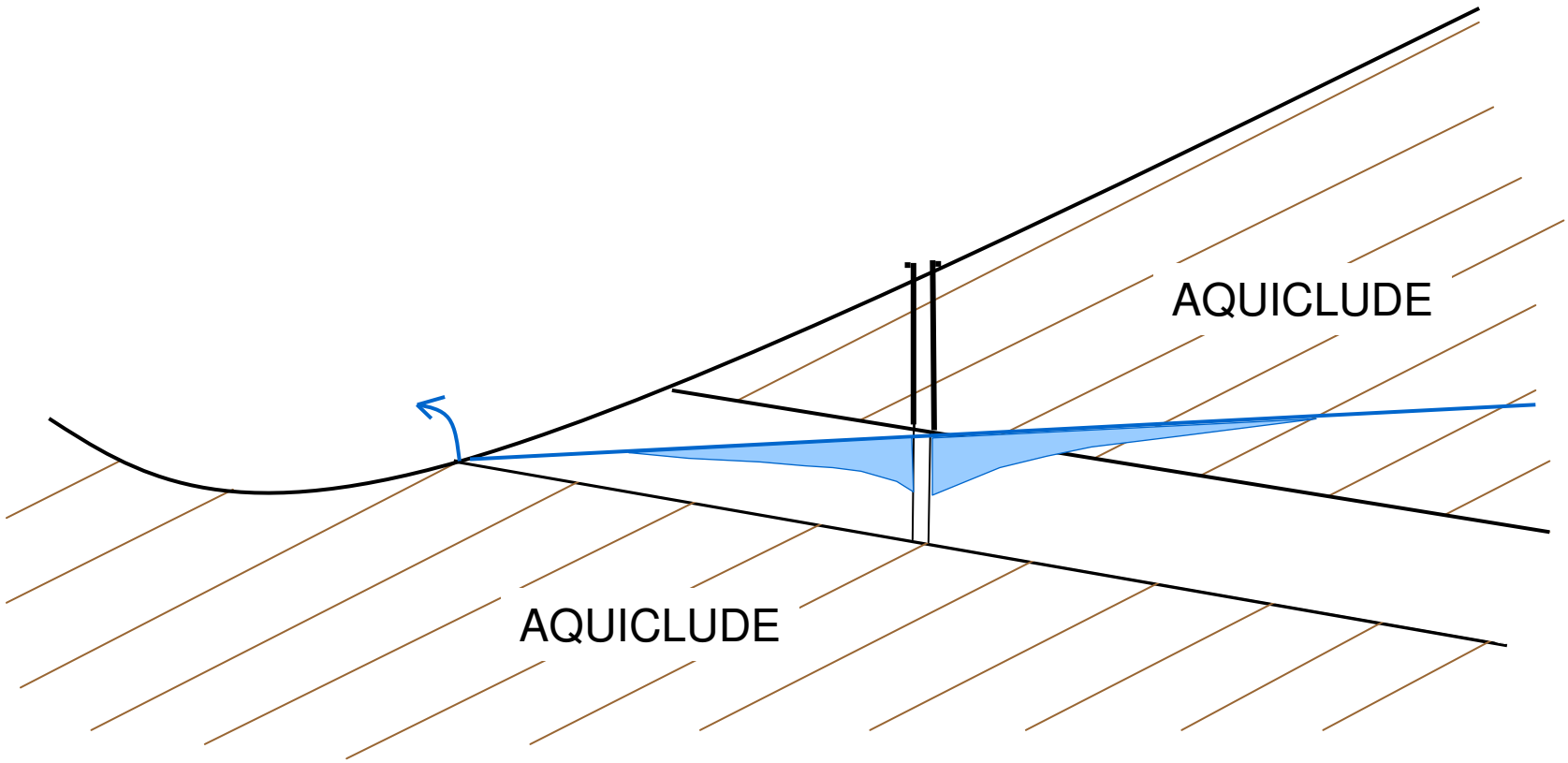
- 50km^2
- 10m thick
- 1% porosity

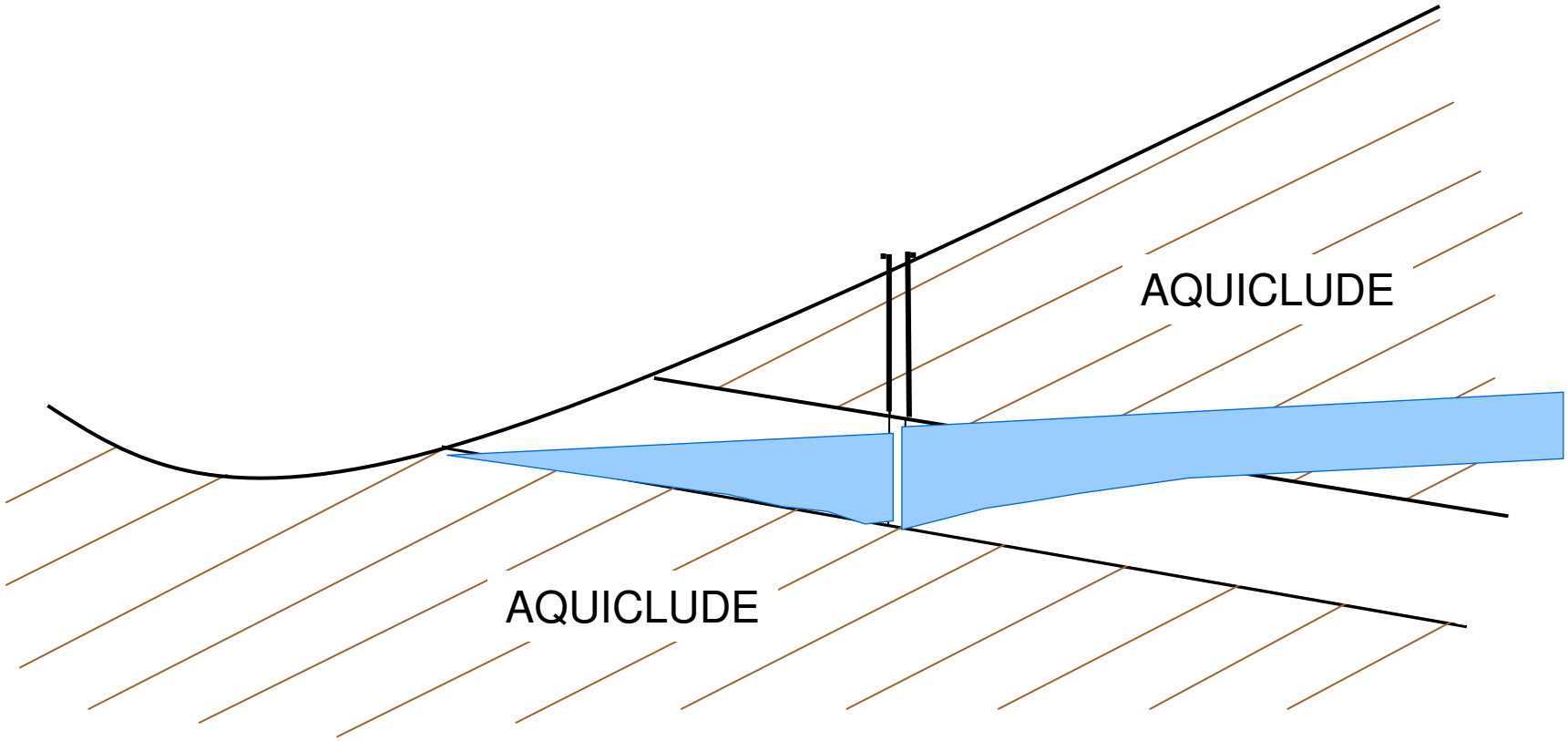
➢ 5,000 Ml

- 1km^2
- 10m deep
- 100% porosity

➢ 10,000 Ml


AQUIFER
AQUICLUDE


AQUICLUDE
AQUICLUDE


AQUICLUDE
AQUICLUDE

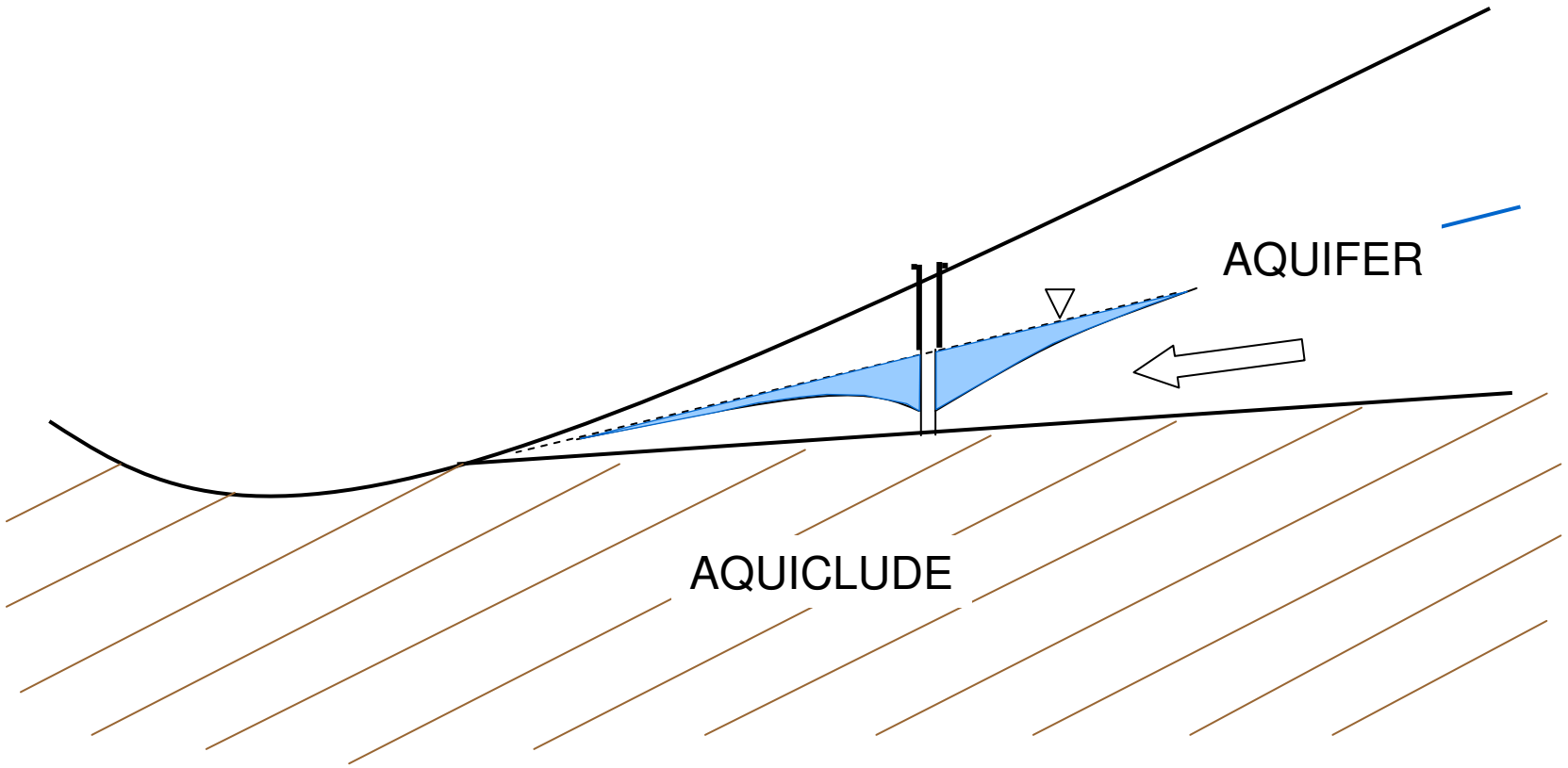
Storage management

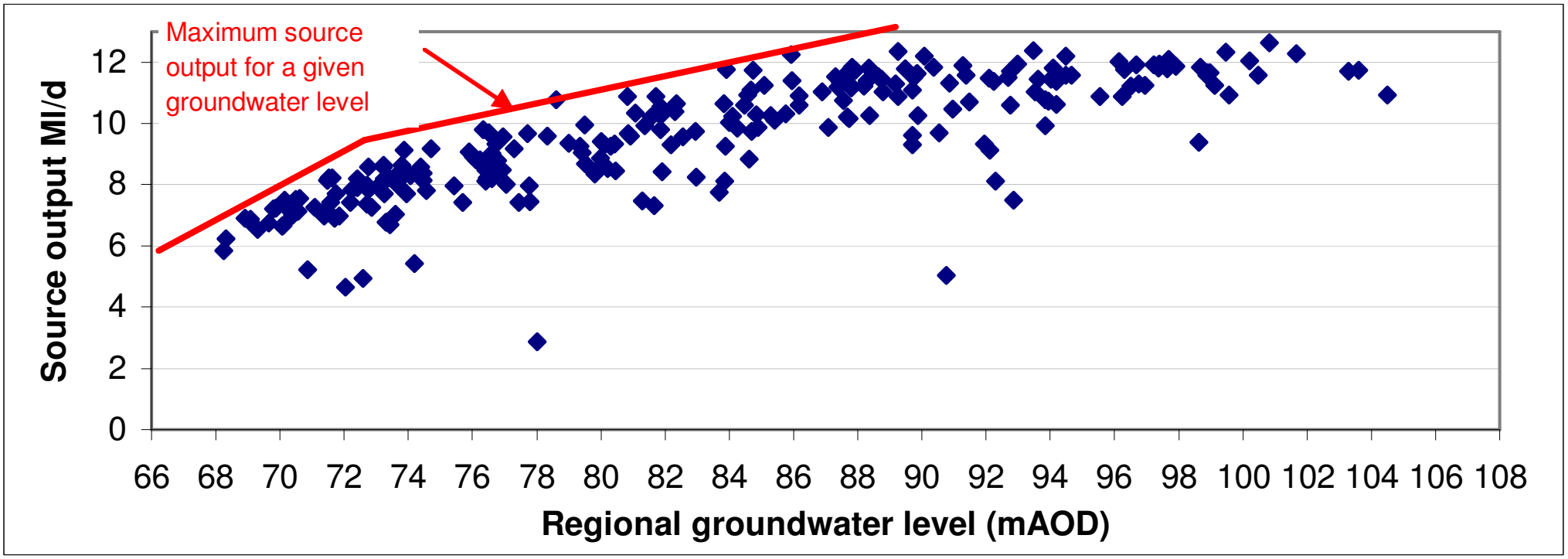
- **Purpose of storage management**
  - **Maximise yield**
  - **Minimise impact on river flows**

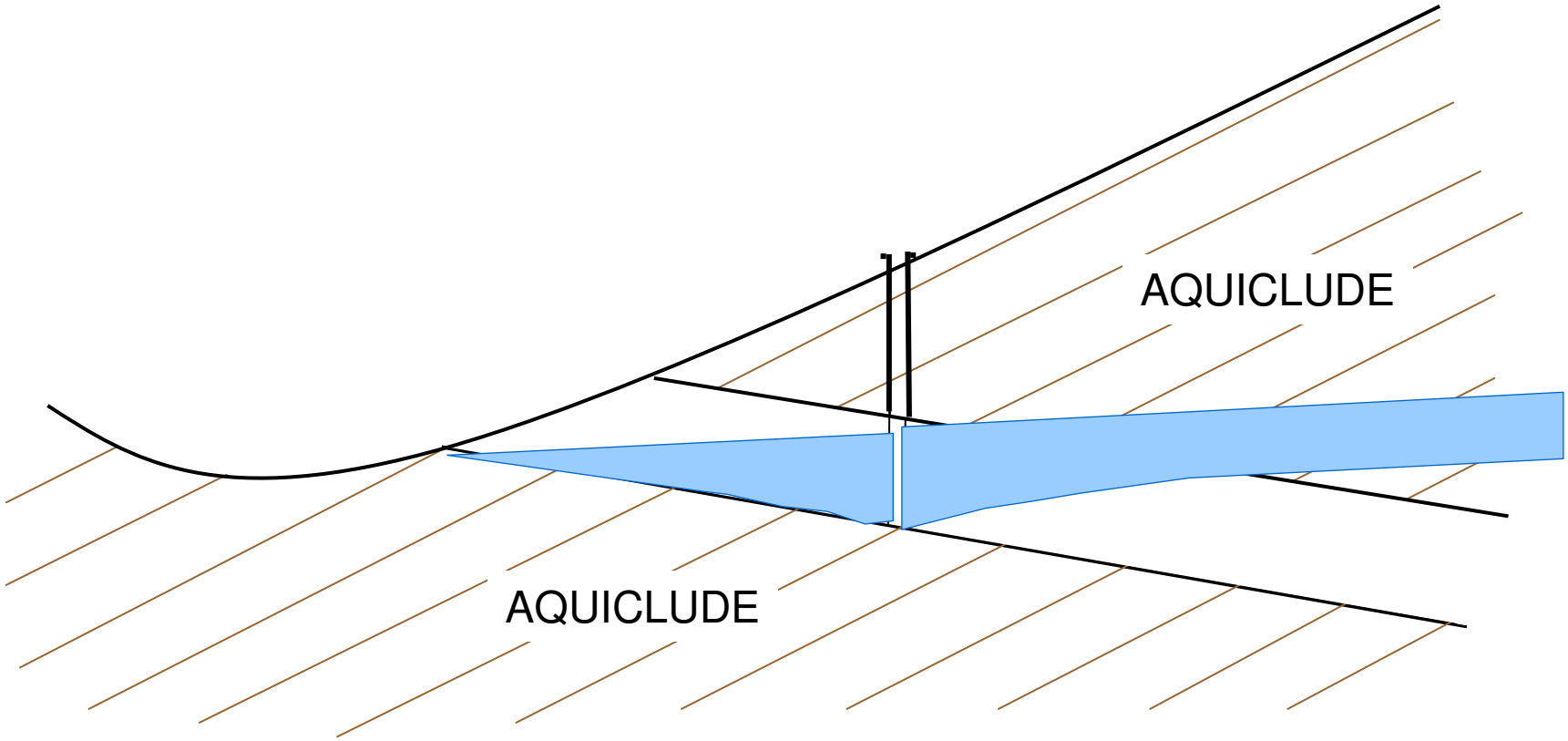
Maximise groundwater yield

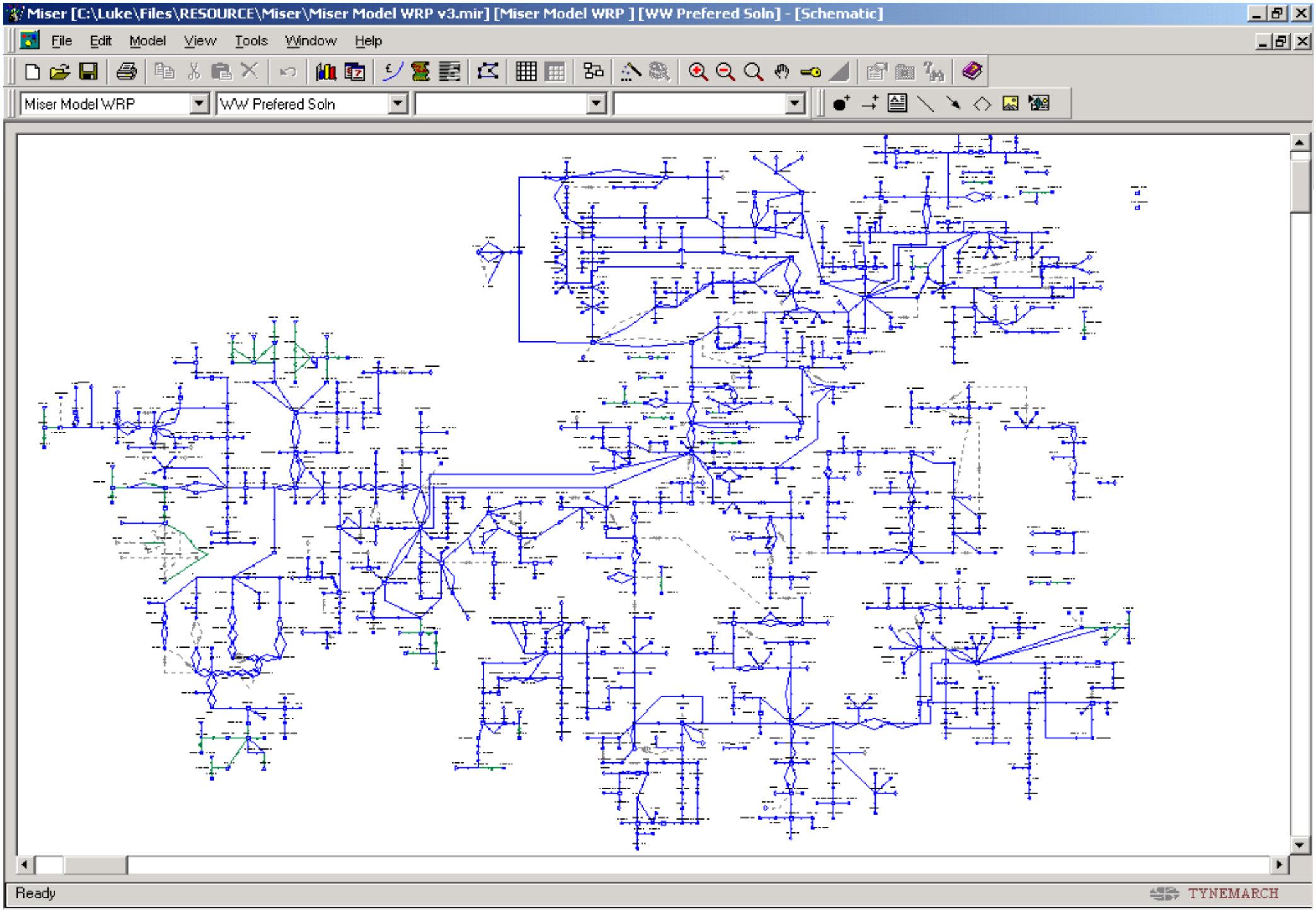
- **Use it or loose it**
- **A reservoir**

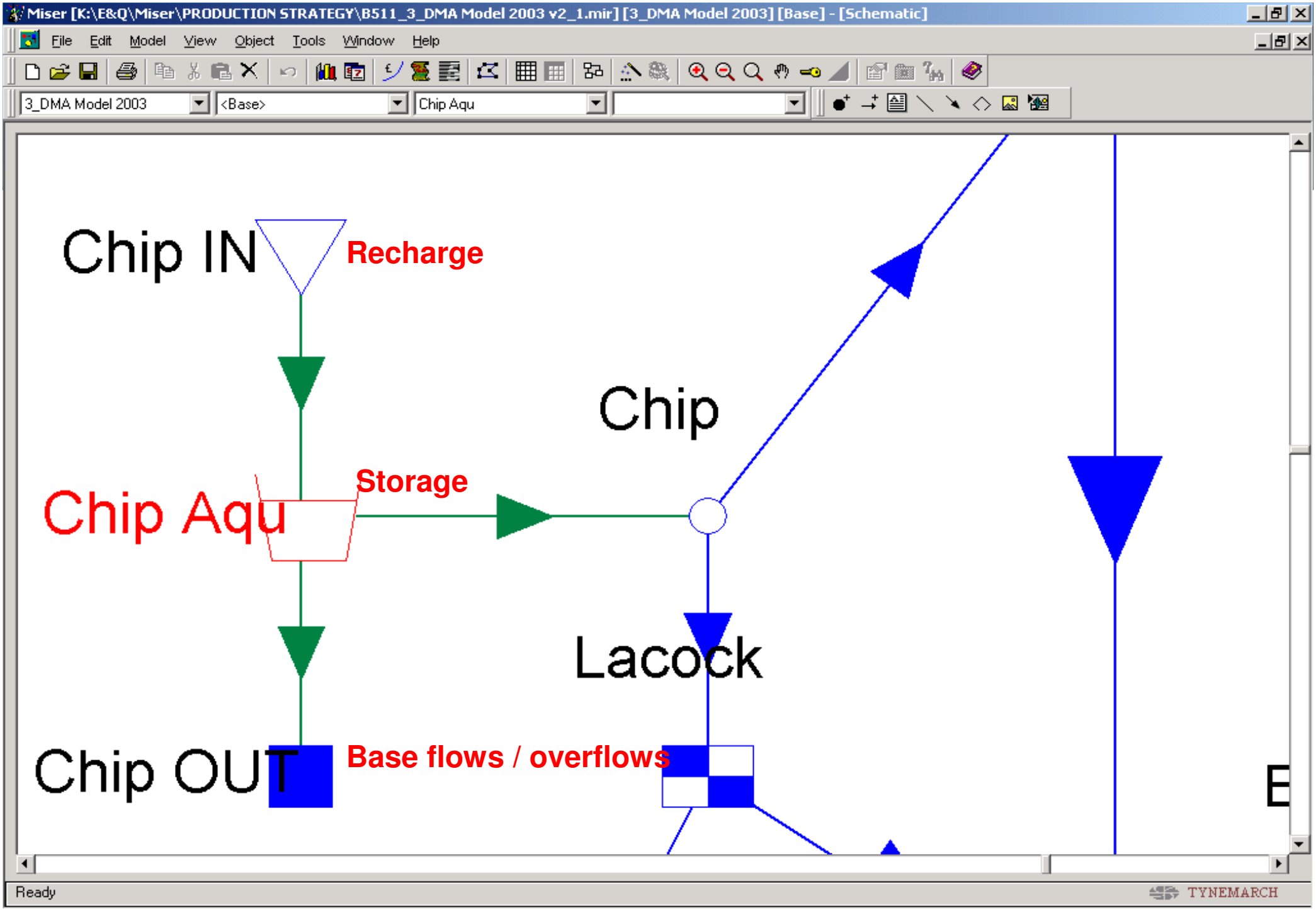
Use it or lose it




Maximum source output for a given groundwater level
Source output Ml/d
0
2
4
6
8
10
12
66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108
Regional groundwater level (mAOD)


AQUICLUDE
AQUICLUDE


Miser [C:\Luke\Files\RESOURCE\Miser\Miser Model WRP v3.mir] [Miser Model WRP] [WW Prefered Soln] - [Schematic]
File Edit Model View Tools Window Help
Miser Model WRP
WW Prefered Soln
Ready
TYNEMARCH


Miser [K:\E&Q\Miser\PRODUCTION STRATEGY\B511_3_DMA Model 2003 v2_1.mir] [3_DMA Model 2003] [Base] - [Schematic]
File Edit Model View Object Tools Window Help
3_DMA Model 2003
<Base>
Chip Aqu
Chip IN
Recharge
Chip
Storage
Chip Aqu
Lacock
Chip OUT
Base flows / overflows
Ready
TYNEMARCH

Edit Node [Chip Aqu]

General | Limits | Reservoir | Control Rules

Storage

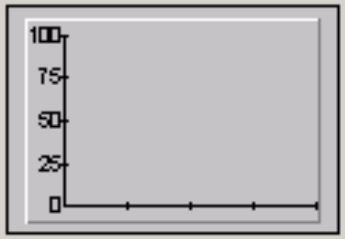
Capacity: 7,006.00 Ml

Upper Operating Limit: 100.00 % 7,006.00 Ml

Lower Operating Limit: 15.00 % 1,050.90 Ml

Target

Target Profile (%): <No preference>



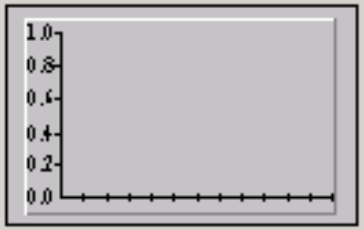
Final Target: % Ml As Initial Volume

(applied to each sequential step)

Initial Volume

Constant 58.69 % 4,112.00 Ml

Seguence <No data>



Fixed Reservoir Volume

Optimised

Evaporation

Evaporation: Ml/d

Evaporation Profile: <Flat>

Normalised

MiniMax

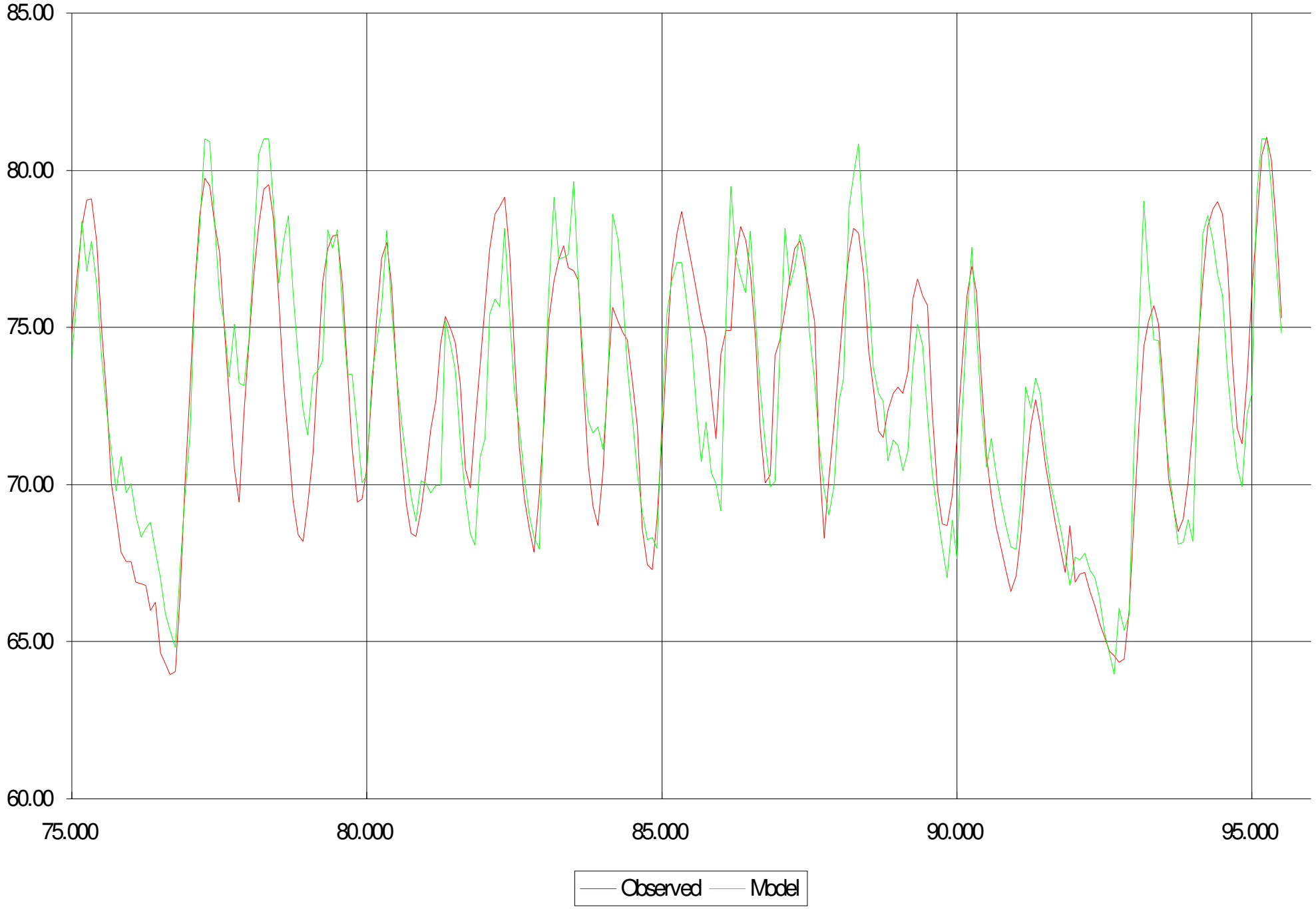
Minimise the Maximum Storage Level Across the Timesteps (Ml)

Maximise the Minimum Storage Level Across the Timesteps (Ml)

Effect of Change in Capacity

% values do not change Ml values do not change

OK Cancel Help


85.00
80.00
75.00
70.00
65.00
60.00
75.000
80.000
85.000
90.000
95.000
Observed
Model

Manage the groundwater

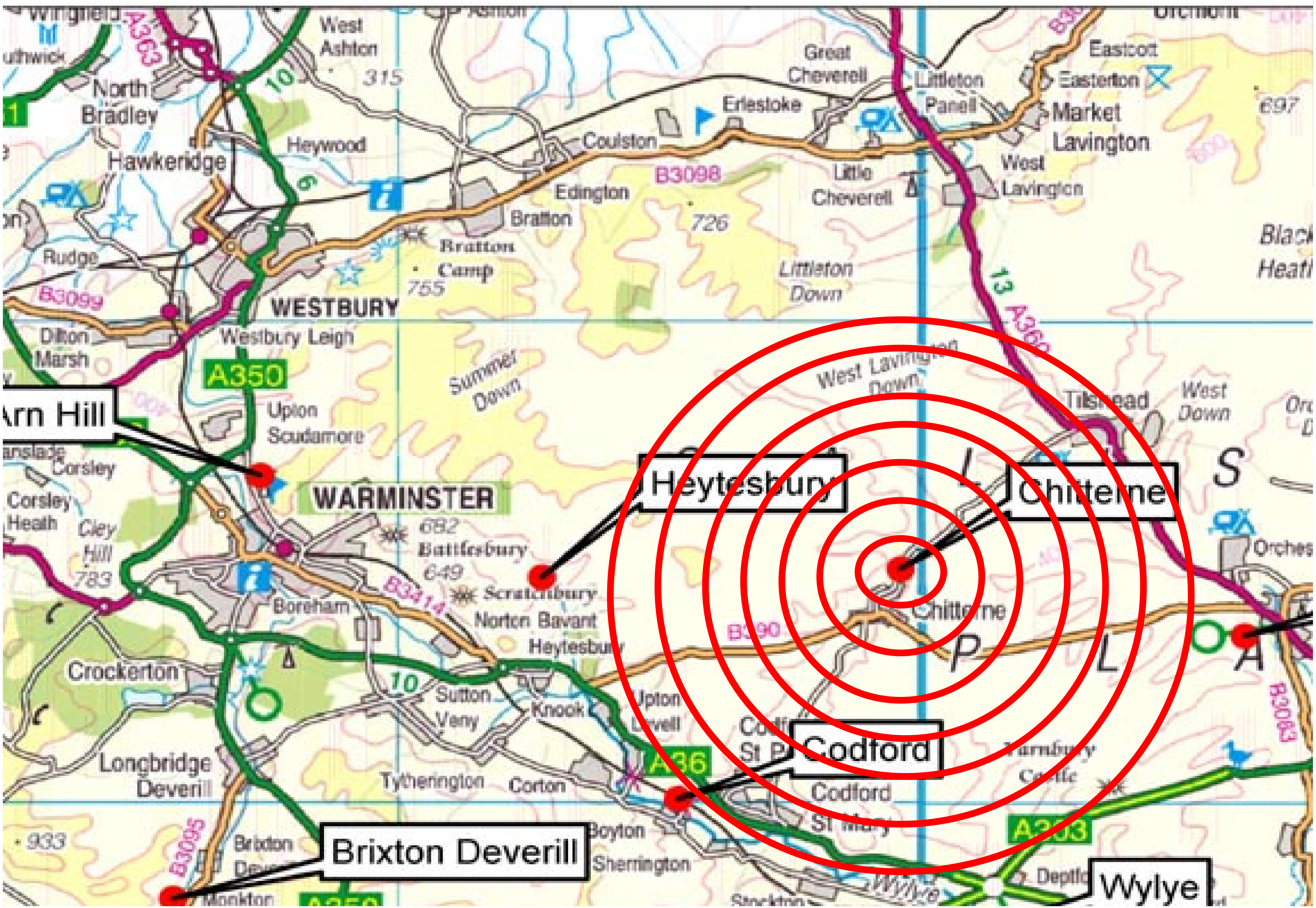
- Predict how much water we can take out through the year
- Cut back in winter to save for summer use
- Tough call if source is low cost

Minimise impact on river flows

- **Distance from river**

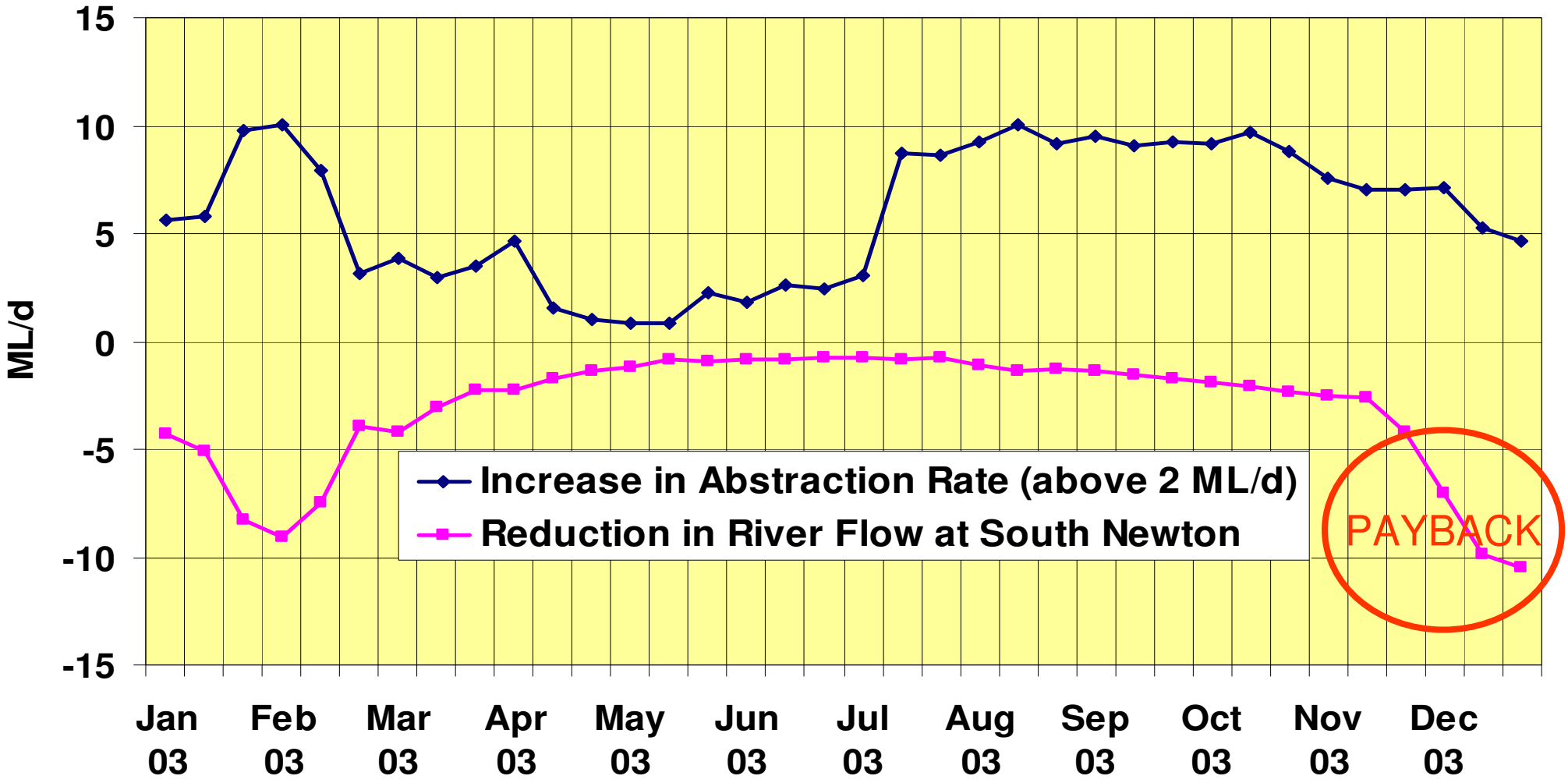
- **T**
- **S**

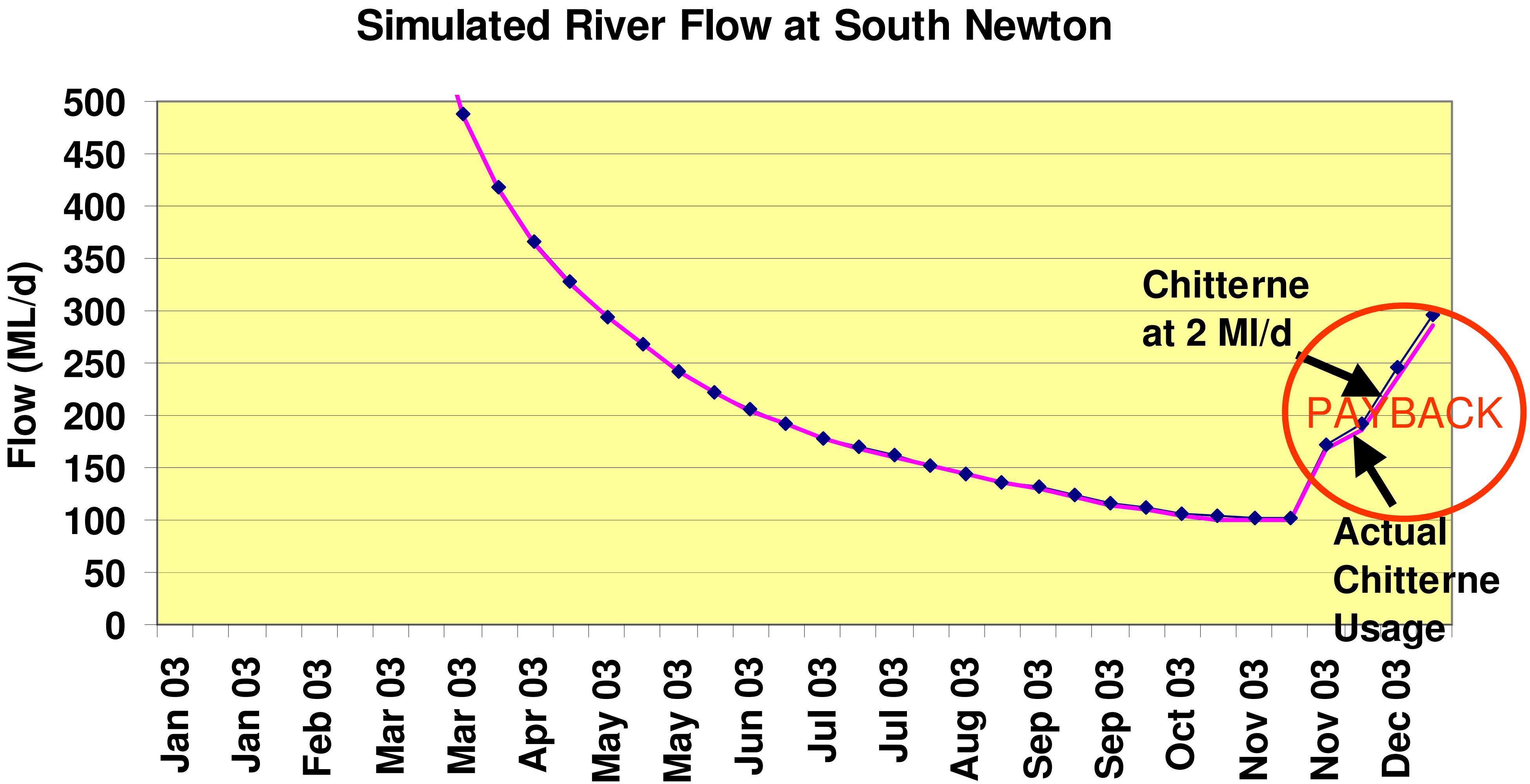
- **Drawdown is good**



Arn Hill
Heytesbury
Chitterne
Codford
Brixton Deverill
Wylye
WESTBURY
WARMINSTER
A350
A36
B3098
B3414
B3090
A303
A360
Edington
Bratton
Coulston
Erlestoke
Great Cheverell
Little Cheverell
Littleton Panell
Market Lavington
West Lavington
Eastcott
Easterton
North Bradley
Hawkeridge
Heywood
West Ashton
Rudge
Dilton Marsh
Westbury Leigh
Upton Scudamore
Corsley
Corsley Heath
Cley Hill
Boreham
Norton Bavant
Heytesbury
Crockerton
Sutton Veny
Knook
Upton Lovell
Longbridge Deverill
Tytherington
Corton
Codford St Mary
Boyton
Sherrington
Tilshead
West Down
Littleton Down
Summer Down
Battlesbury
Scratchbury
Bratton Camp
Yarnbury Castle

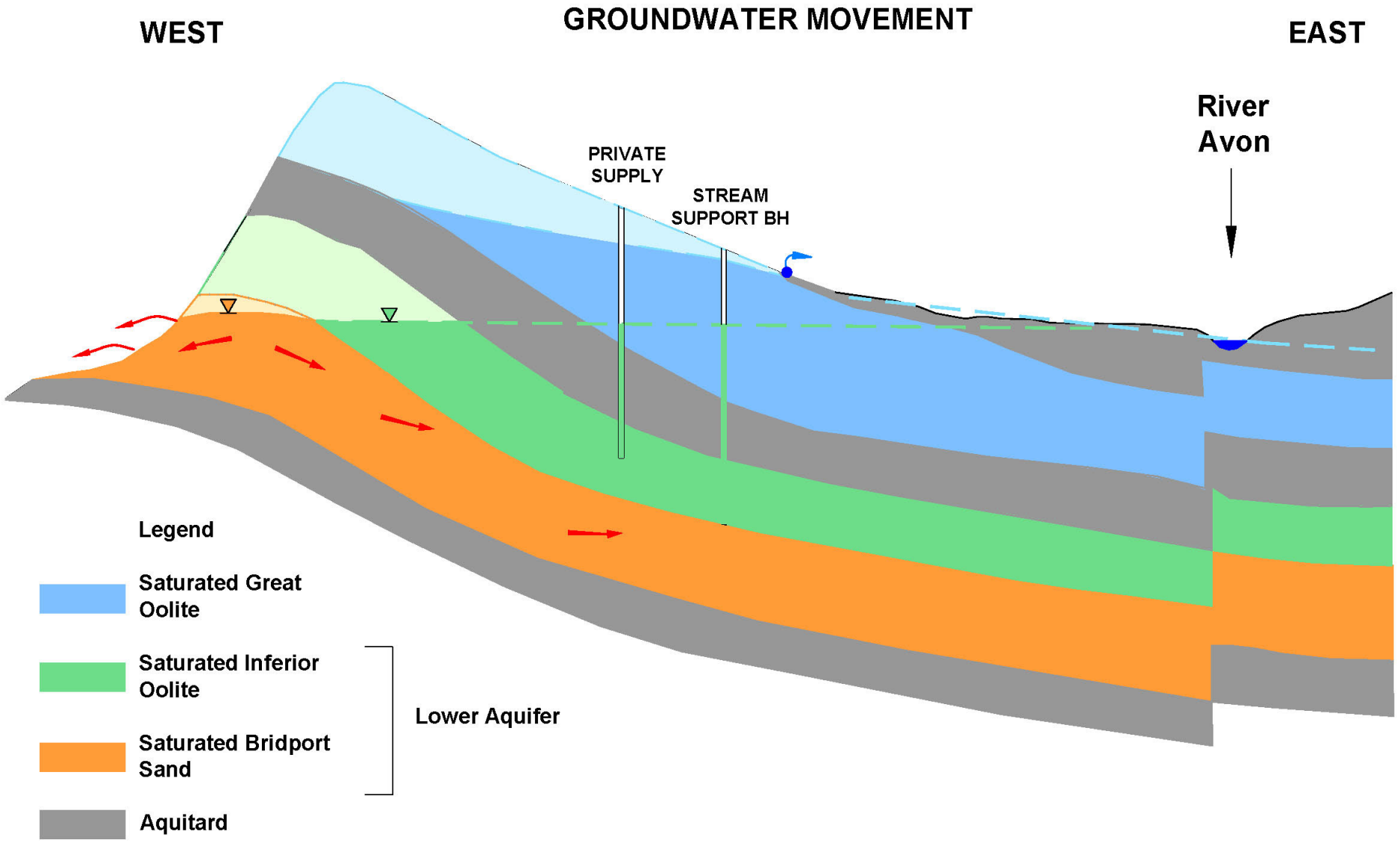
Difficult slide

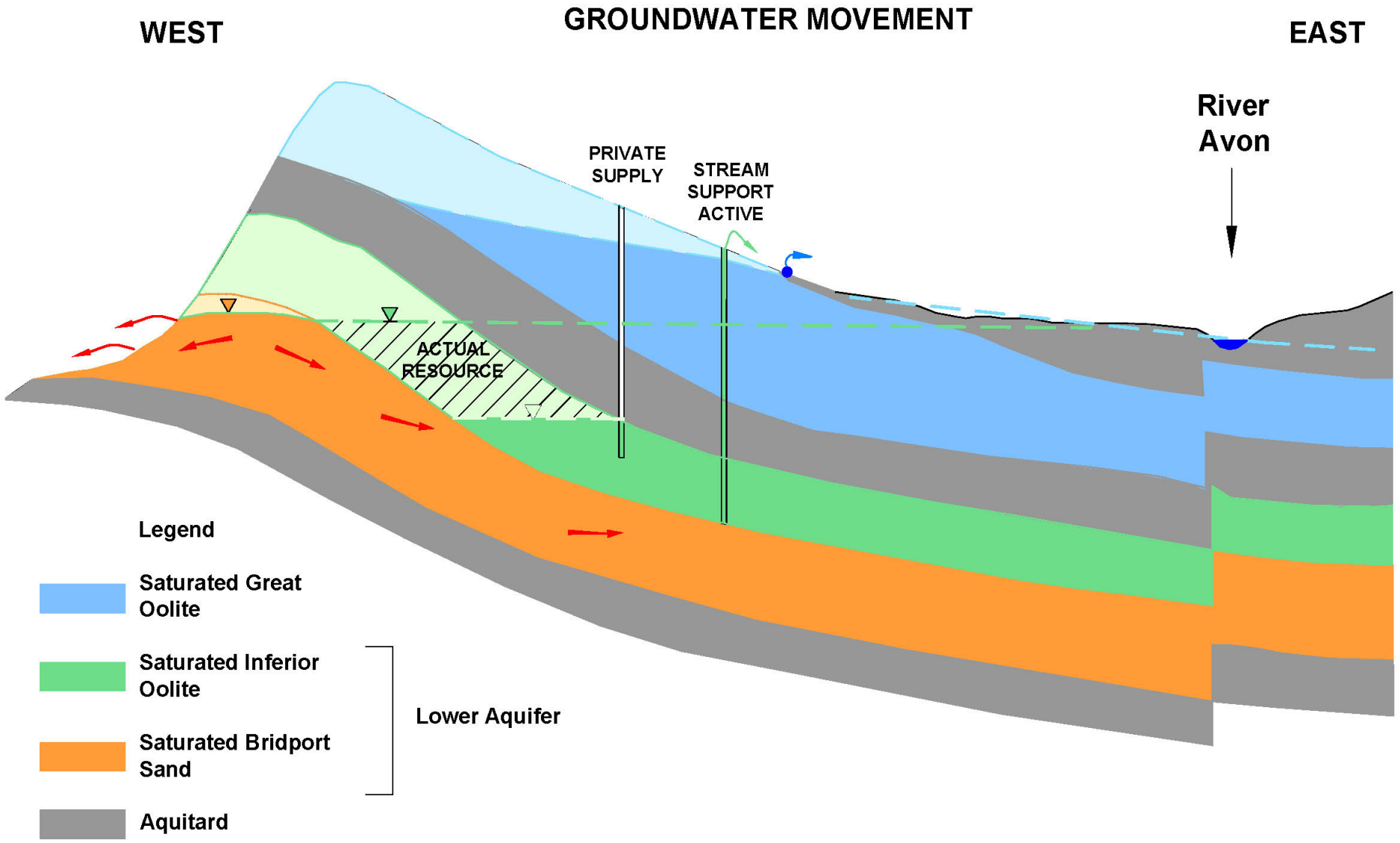


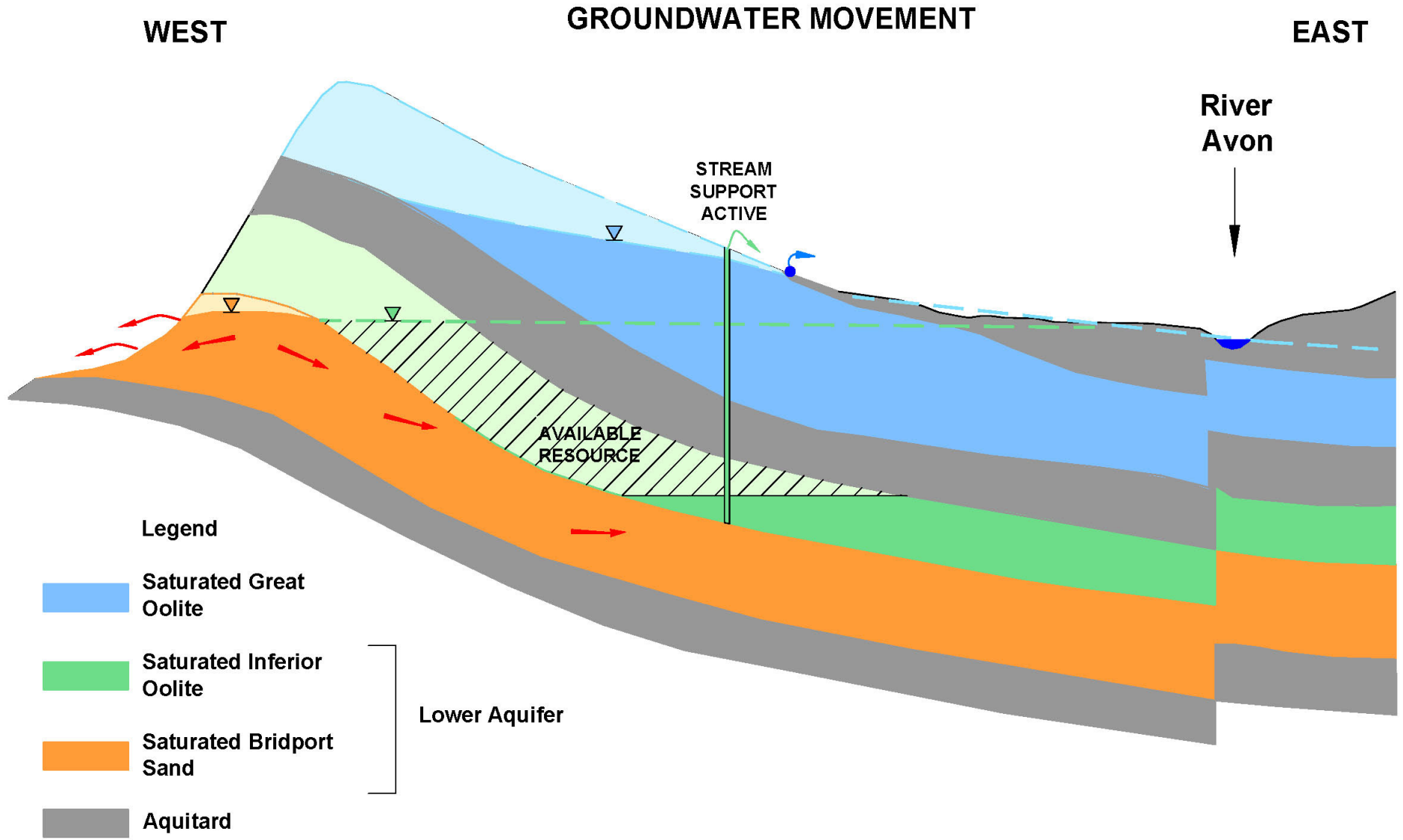

Simulated River Flow at South Newton
Flow (ML/d)
500
450
400
350
300
250
200
150
100
50
0
Jan 03
Jan 03
Feb 03
Mar 03
Mar 03
Apr 03
May 03
May 03
Jun 03
Jul 03
Jul 03
Aug 03
Sep 03
Sep 03
Oct 03
Nov 03
Nov 03
Dec 03
Chitterne at 2 Ml/d
PAYBACK
Actual Chitterne Usage

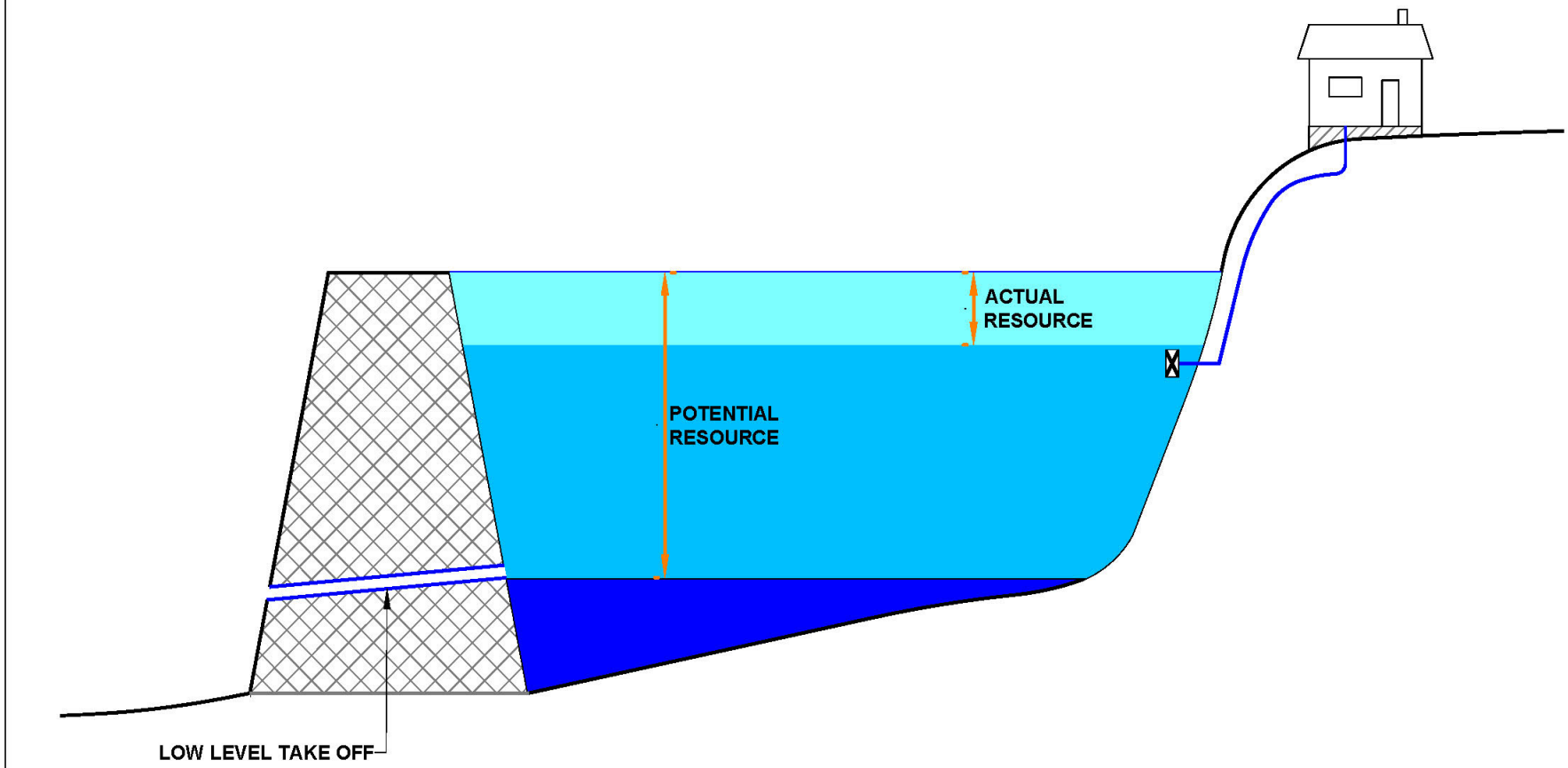
How far can we push this storage concept?

- **Malmesbury**


WEST
GROUNDWATER MOVEMENT
EAST
River Avon
PRIVATE SUPPLY
STREAM SUPPORT BH
Legend
Saturated Great Oolite
Saturated Inferior Oolite
Saturated Bridport Sand
Lower Aquifer
Aquitard


WEST
GROUNDWATER MOVEMENT
EAST
River Avon
PRIVATE SUPPLY
STREAM SUPPORT ACTIVE
ACTUAL RESOURCE
Legend
Saturated Great Oolite
Saturated Inferior Oolite
Saturated Bridport Sand
Lower Aquifer
Aquitard

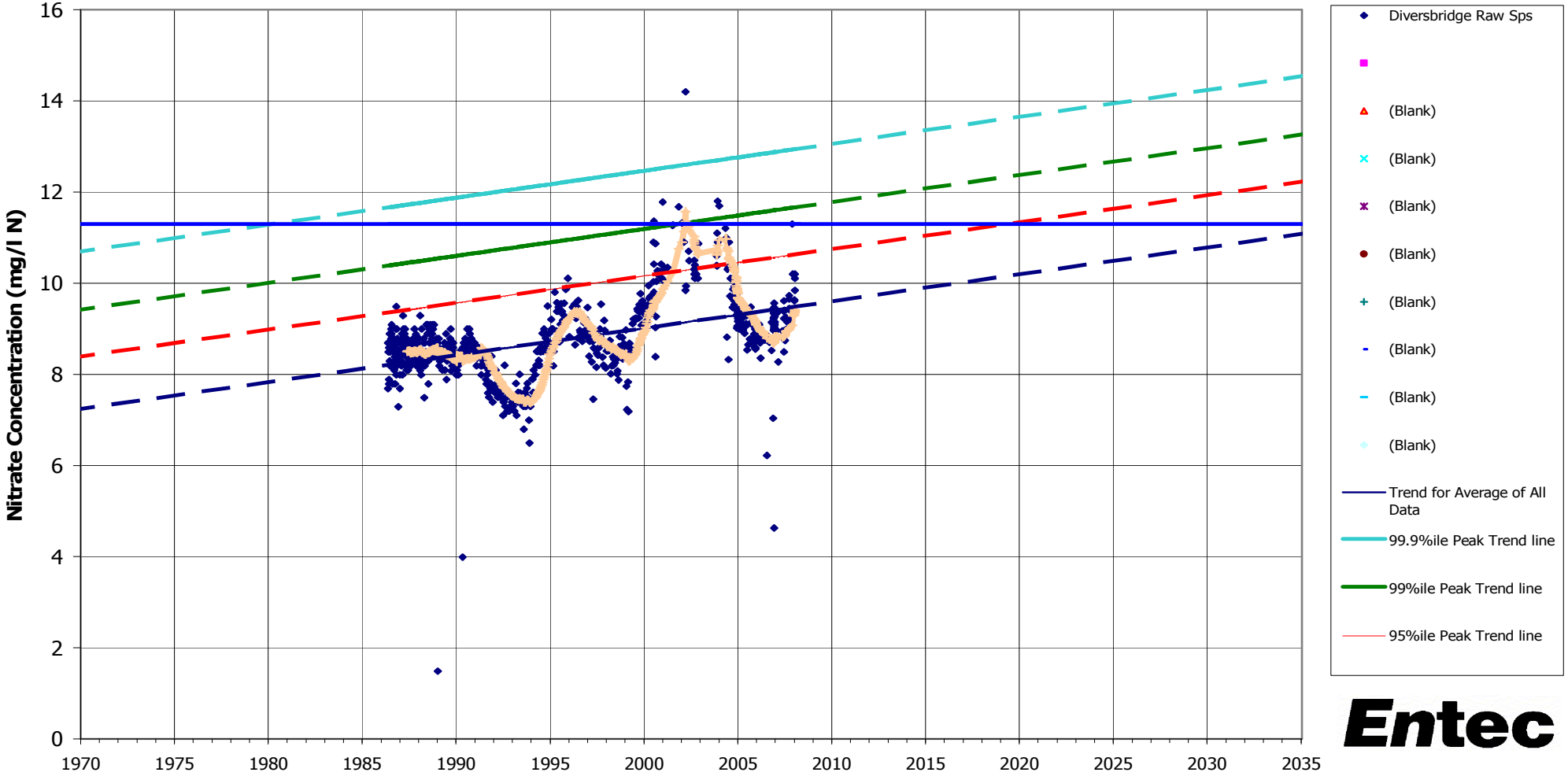

WEST
GROUNDWATER MOVEMENT
EAST
River
Avon
STREAM
SUPPORT
ACTIVE
AVAILABLE
RESOURCE
Legend
Saturated Great
Oolite
Saturated Inferior
Oolite
Saturated Bridport
Sand
Lower Aquifer
Aquitard


ACTUAL
RESOURCE
POTENTIAL
RESOURCE
LOW LEVEL TAKE OFF

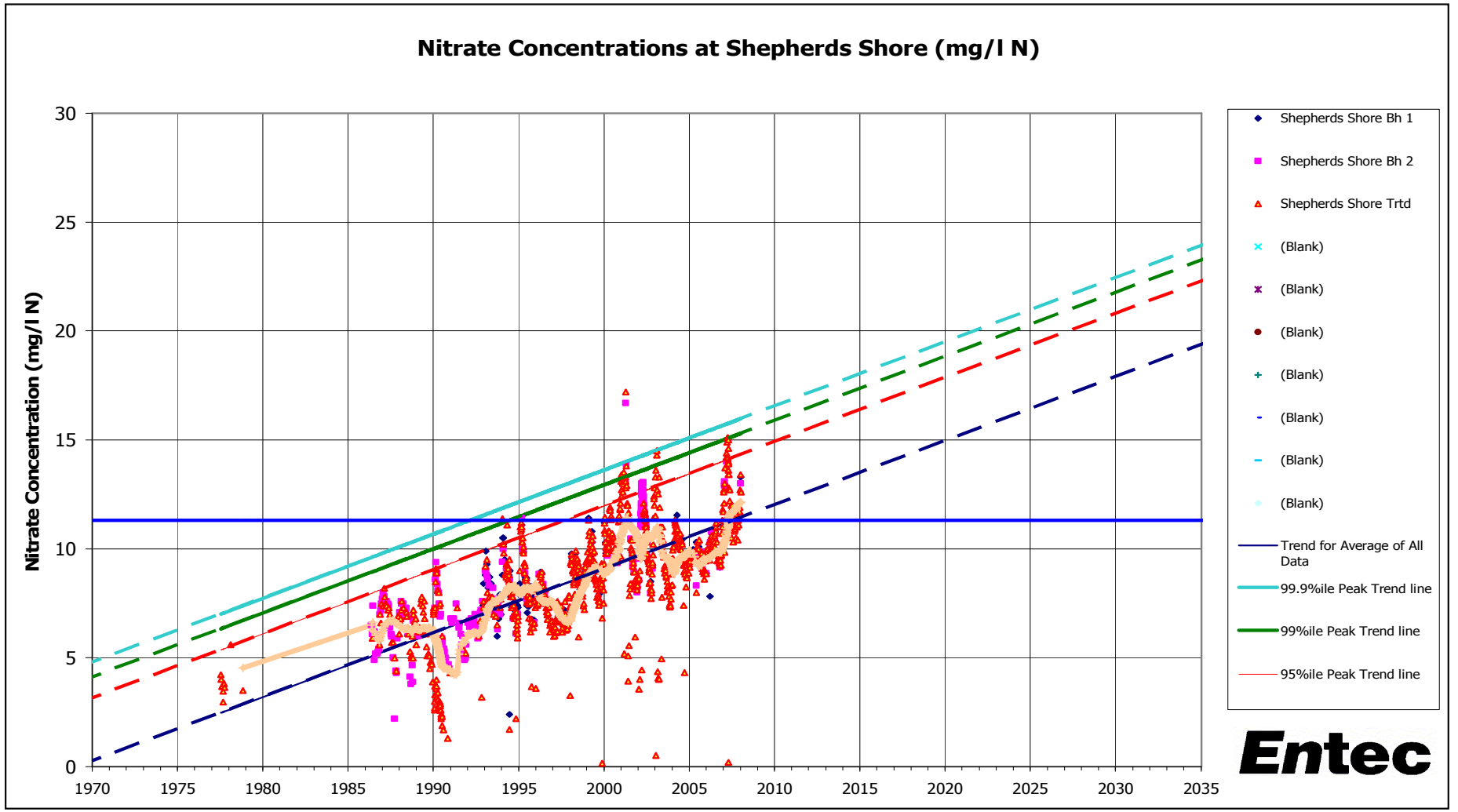
- **Clean water**

Pollution

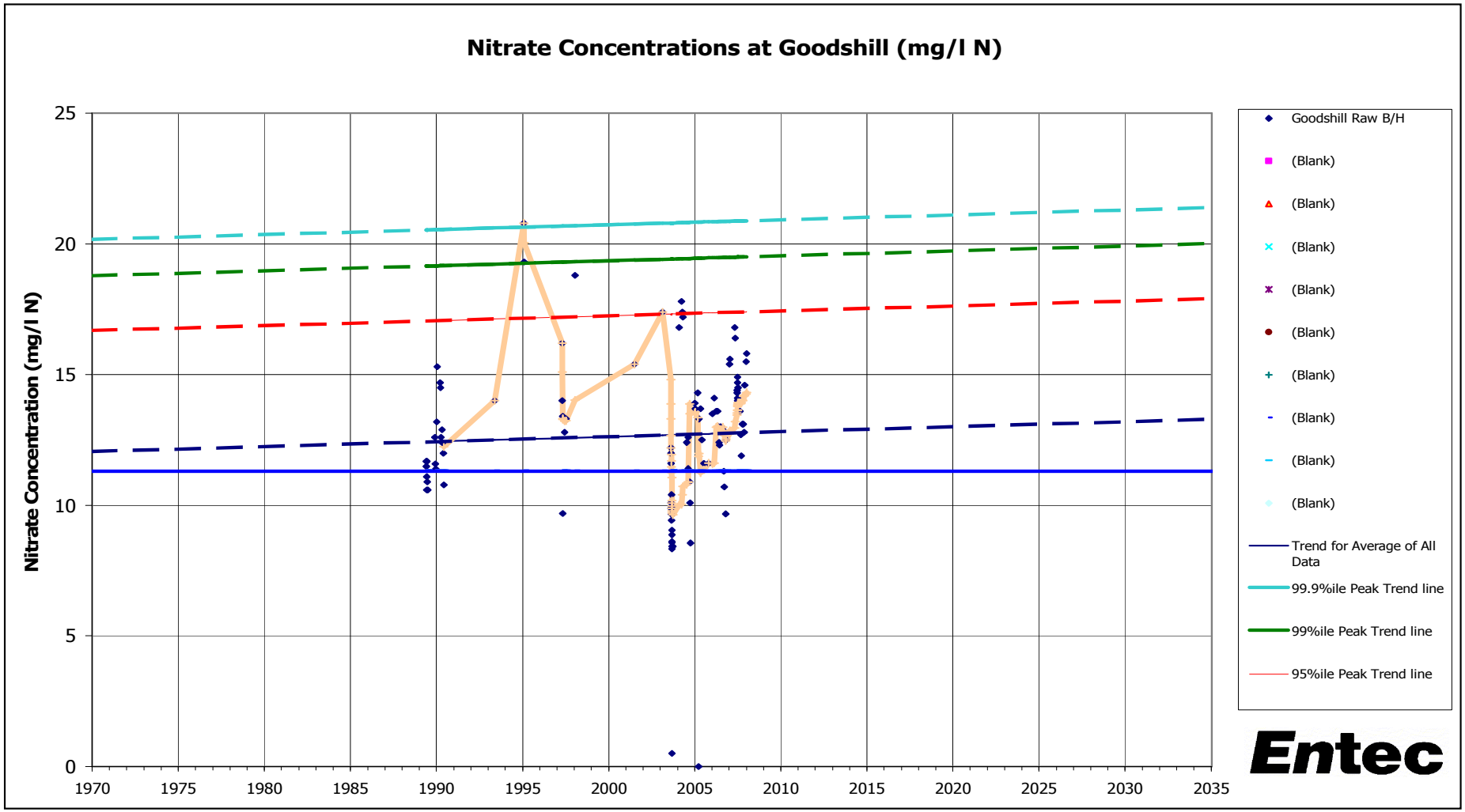
Nitrate Concentrations at Diversbridge (mg/l N)



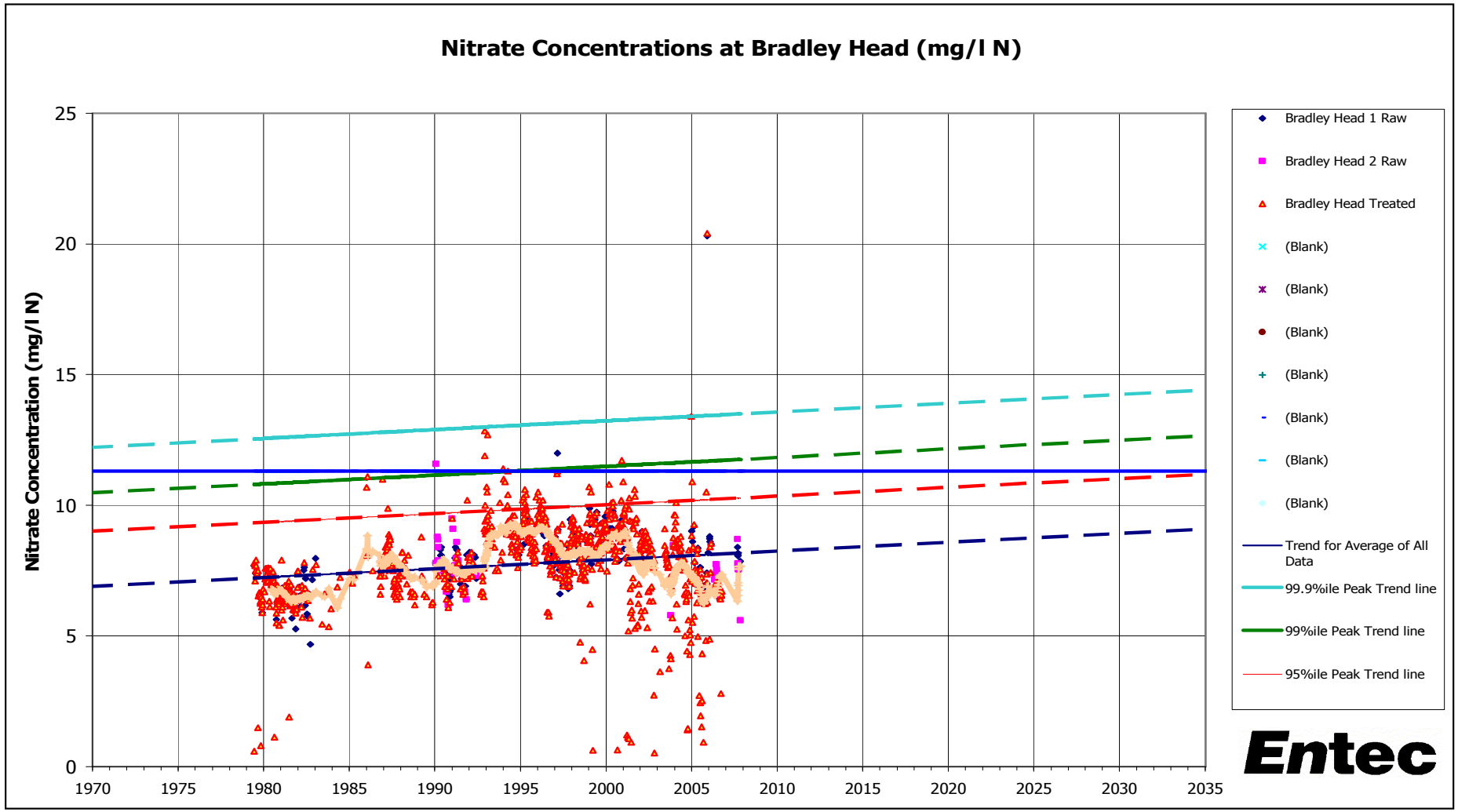
Pollution


Nitrate Concentrations at Shepherds Shore (mg/l N)
Nitrate Concentration (mg/l N)
0
5
10
15
20
25
30
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Shepherds Shore Bh 1
Shepherds Shore Bh 2
Shepherds Shore Trtd
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

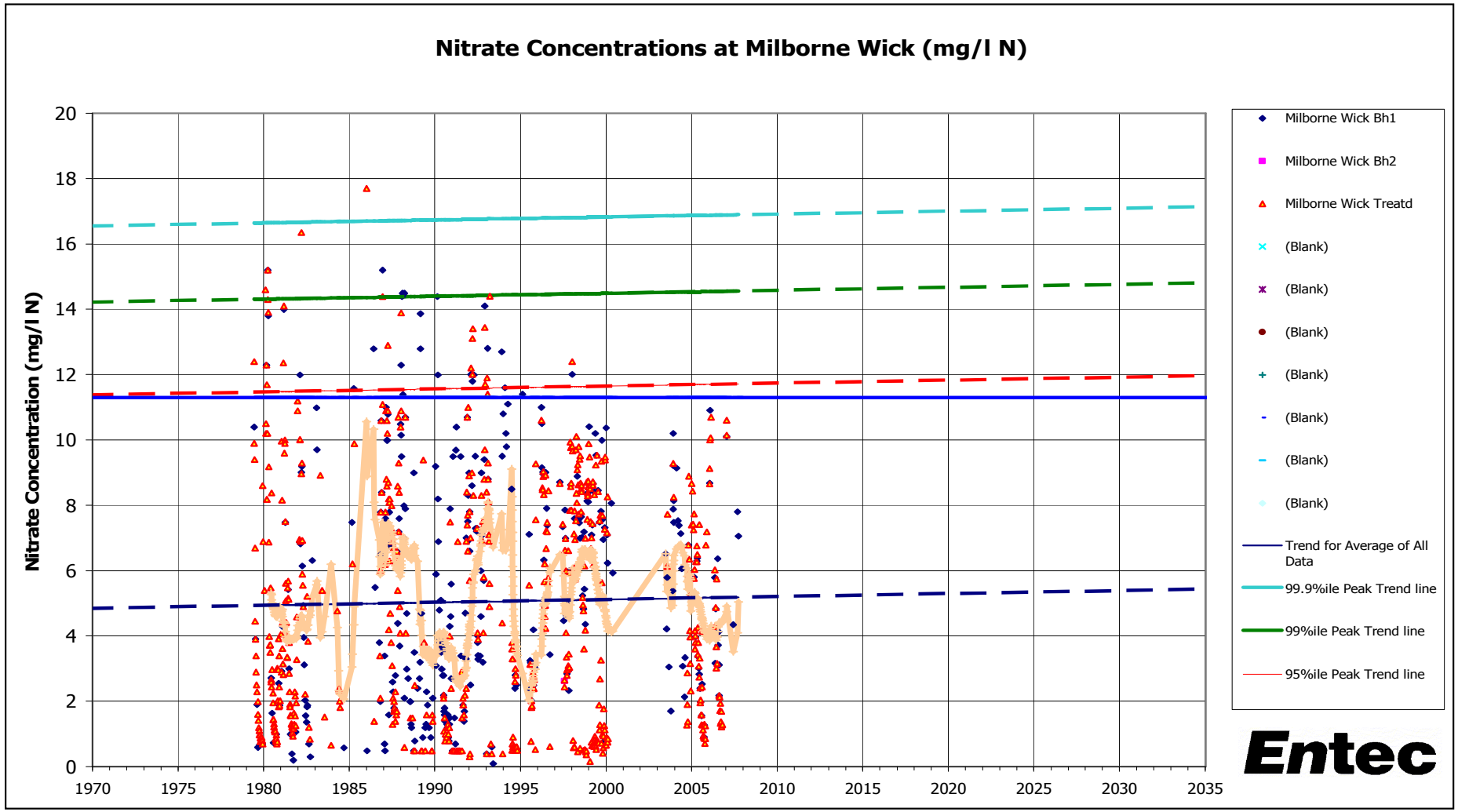
Pollution


Nitrate Concentrations at Goodshill (mg/l N)
Nitrate Concentration (mg/l N)
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Goodshill Raw B/H
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

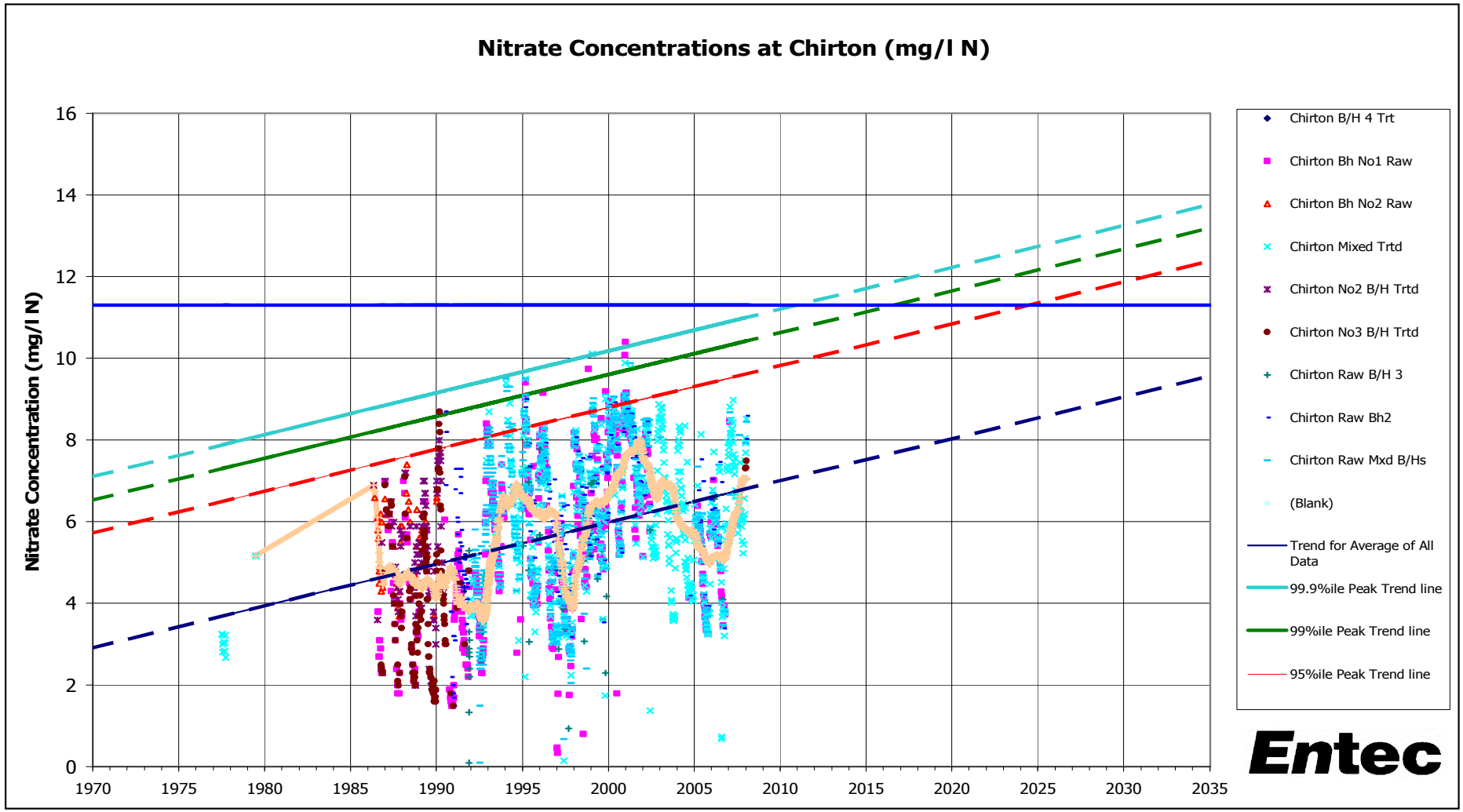
Pollution


Nitrate Concentrations at Bradley Head (mg/l N)
Nitrate Concentration (mg/l N)
0
5
10
15
20
25
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Bradley Head 1 Raw
Bradley Head 2 Raw
Bradley Head Treated
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

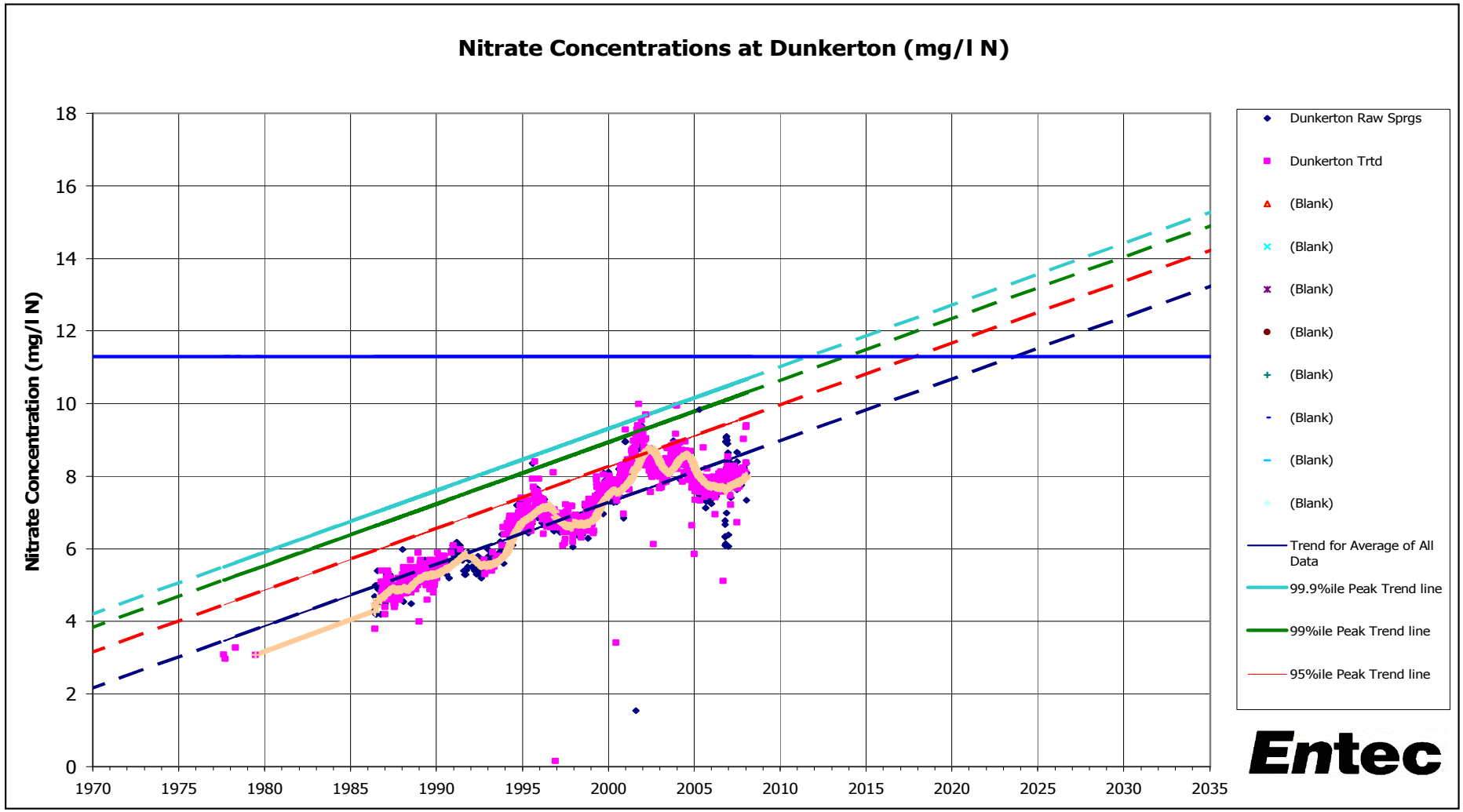
Pollution


Nitrate Concentrations at Milborne Wick (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
20
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Milborne Wick Bh1
Milborne Wick Bh2
Milborne Wick Treatd
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

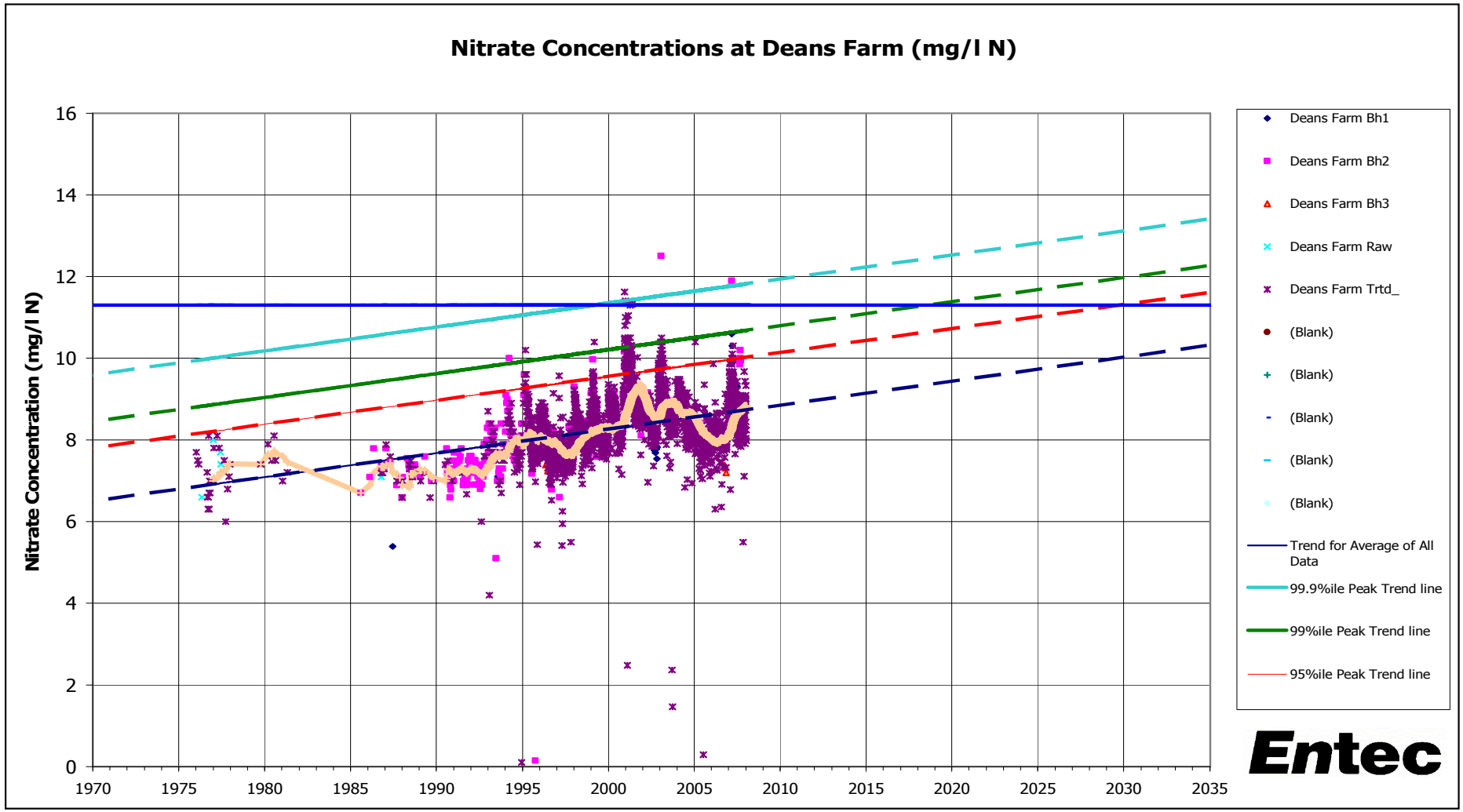
Pollution


Nitrate Concentrations at Chirton (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Chirton B/H 4 Trt
Chirton Bh No1 Raw
Chirton Bh No2 Raw
Chirton Mixed Trtd
Chirton No2 B/H Trtd
Chirton No3 B/H Trtd
Chirton Raw B/H 3
Chirton Raw Bh2
Chirton Raw Mxd B/Hs
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

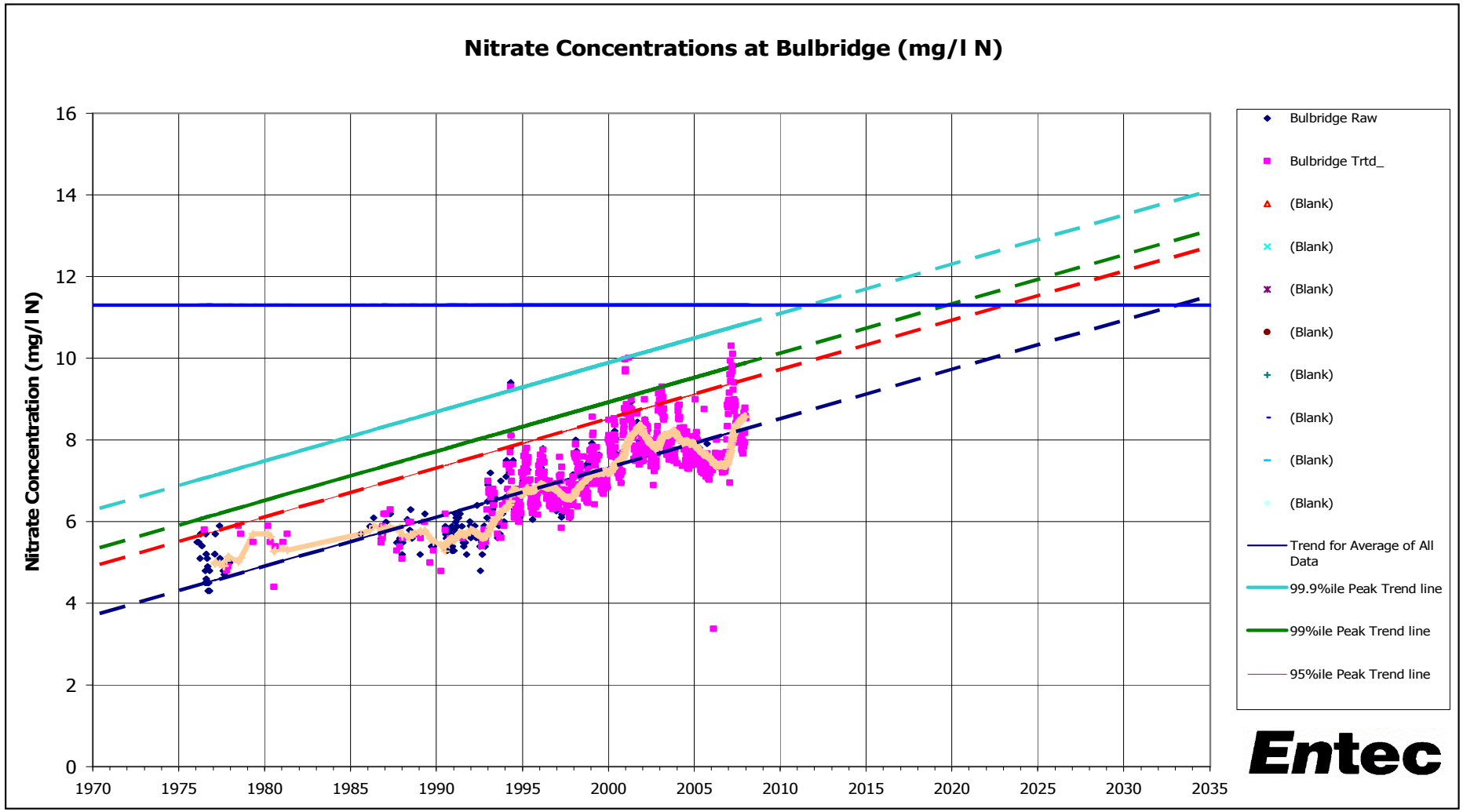
Pollution


Nitrate Concentrations at Dunkerton (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Dunkerton Raw Sprgs
Dunkerton Trtd
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

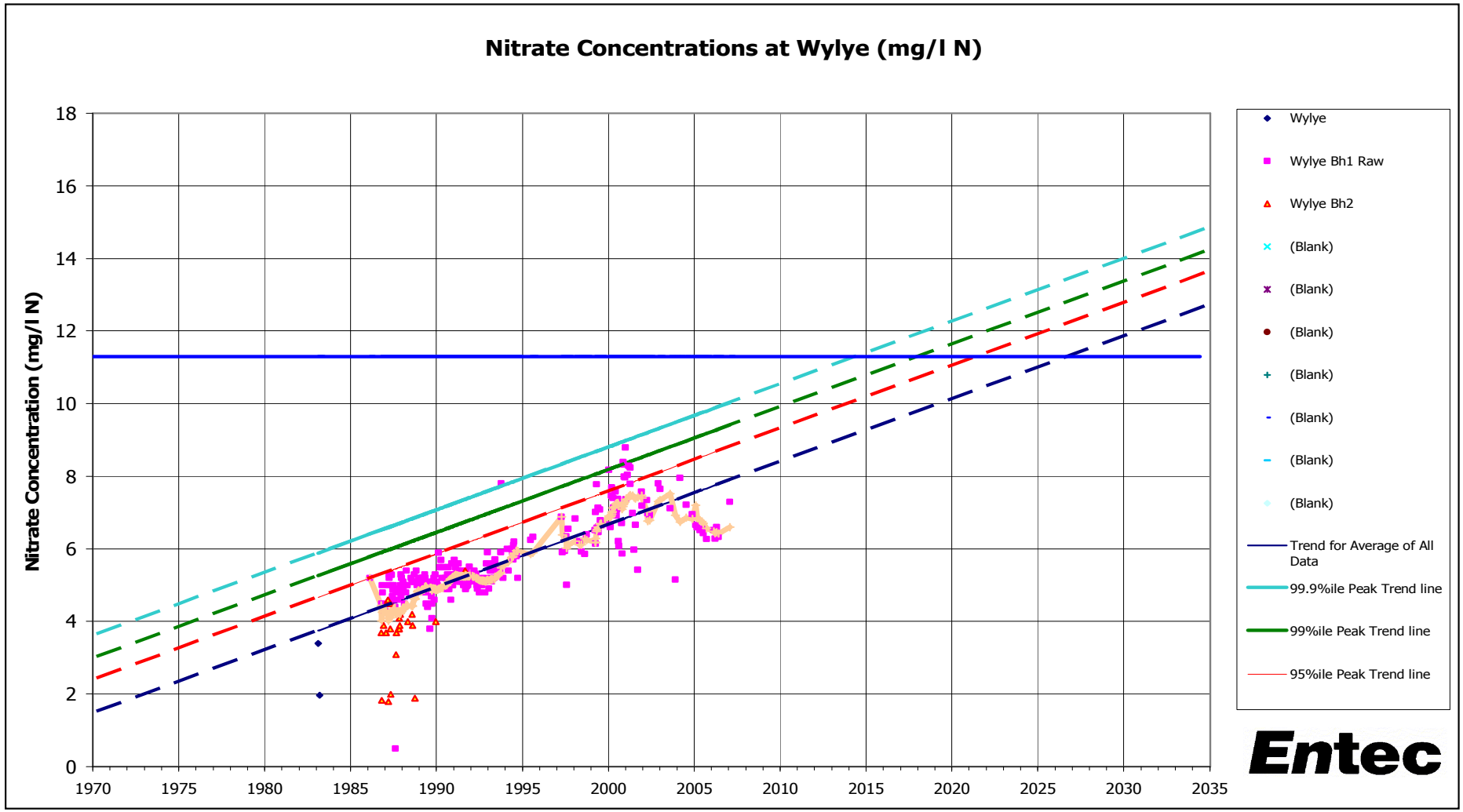
Pollution


Nitrate Concentrations at Deans Farm (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Deans Farm Bh1
Deans Farm Bh2
Deans Farm Bh3
Deans Farm Raw
Deans Farm Trtd_
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

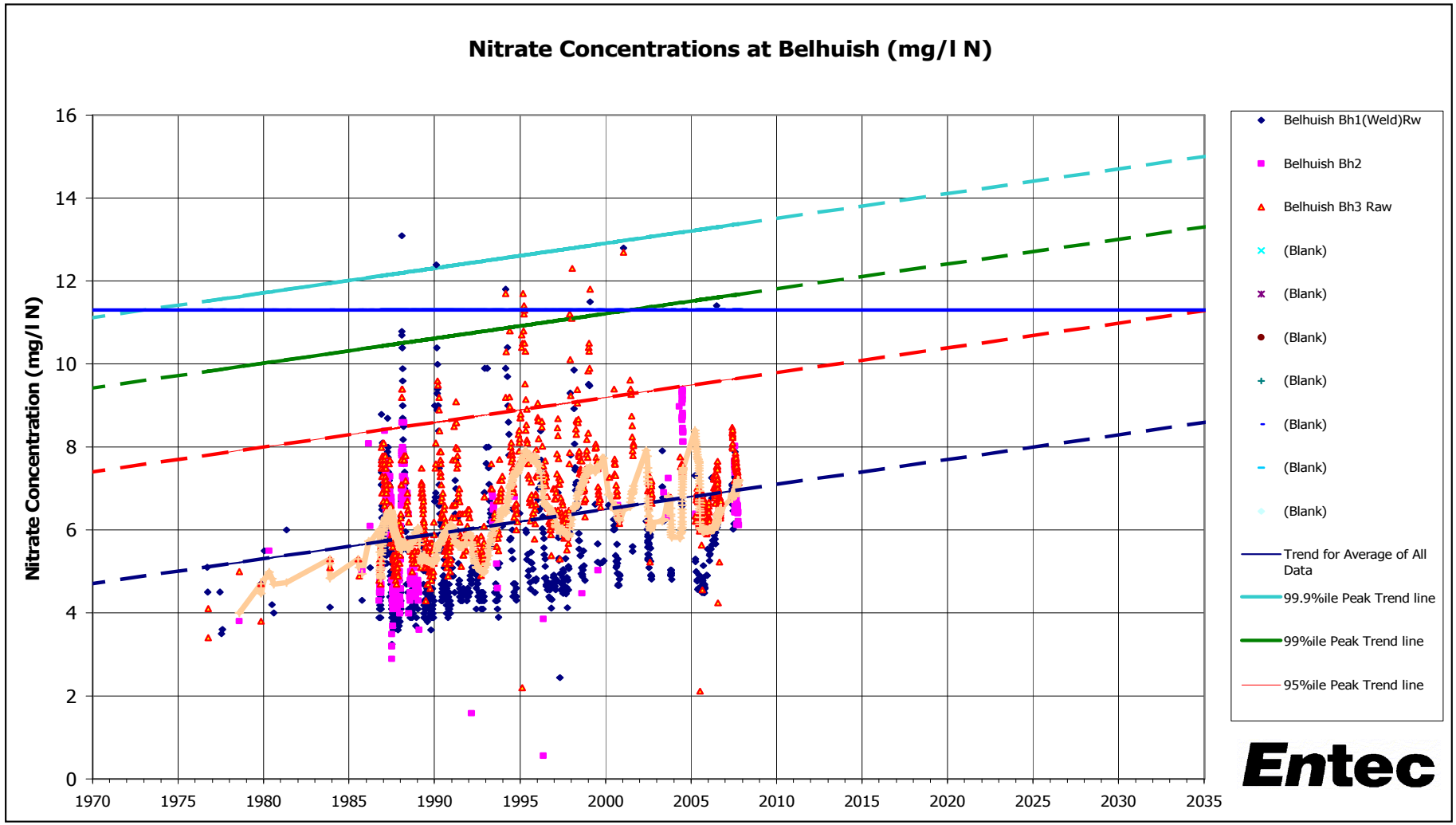
Pollution


Nitrate Concentrations at Bulbridge (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Bulbridge Raw
Bulbridge Trtd_
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

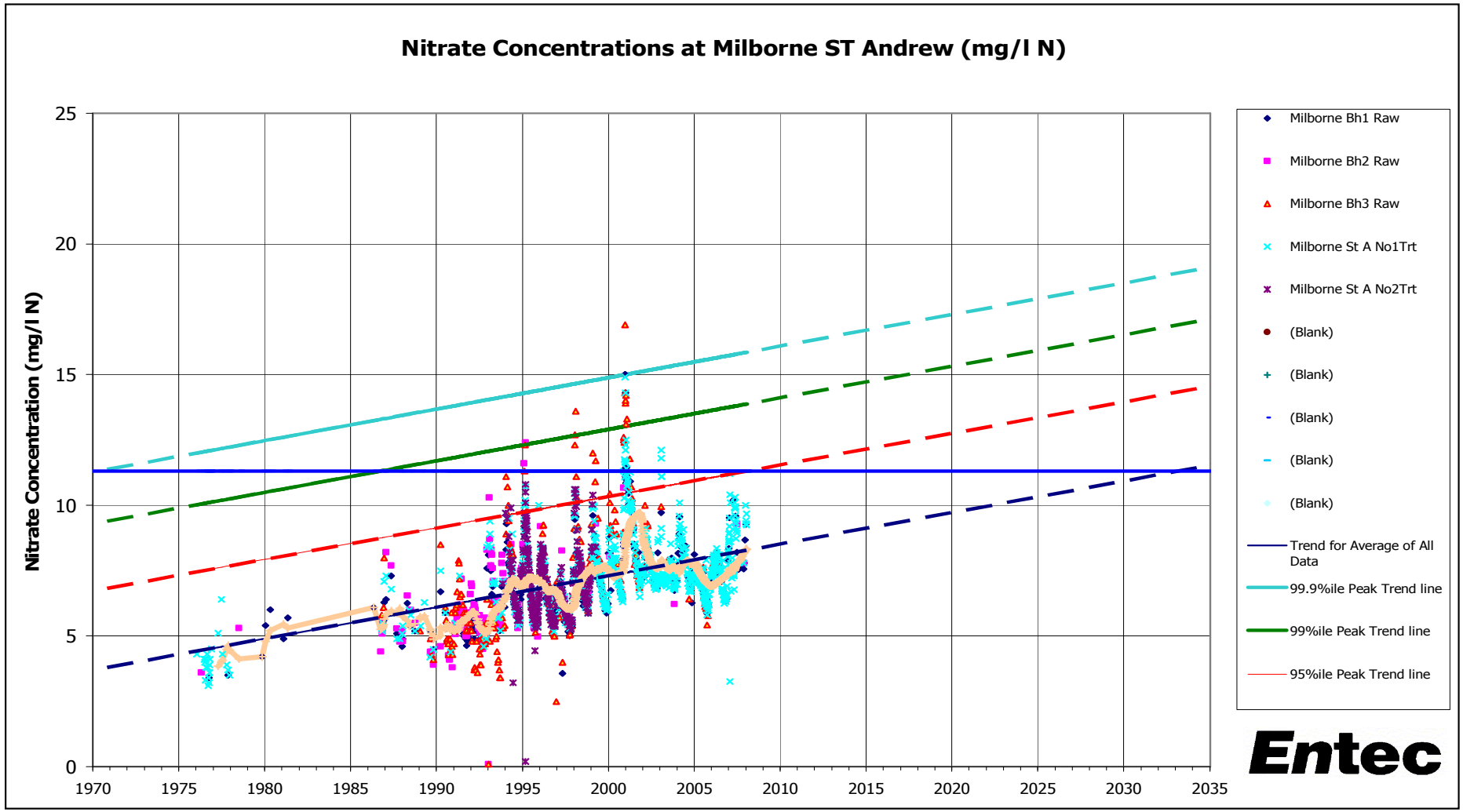
Pollution


Nitrate Concentrations at Wylye (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Wylye
Wylye Bh1 Raw
Wylye Bh2
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

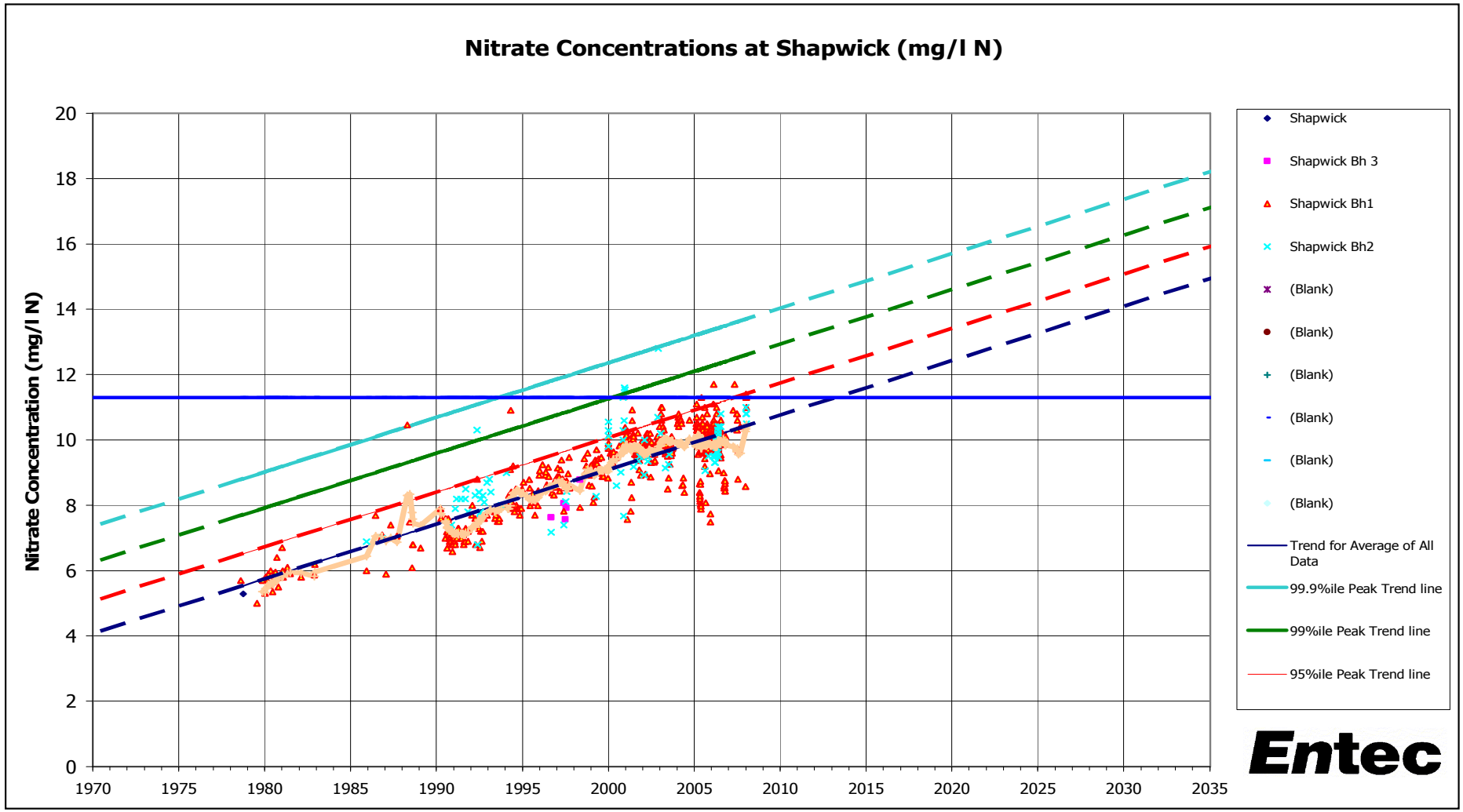
Pollution


Nitrate Concentrations at Belhuish (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Belhuish Bh1(Weld)Rw
Belhuish Bh2
Belhuish Bh3 Raw
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

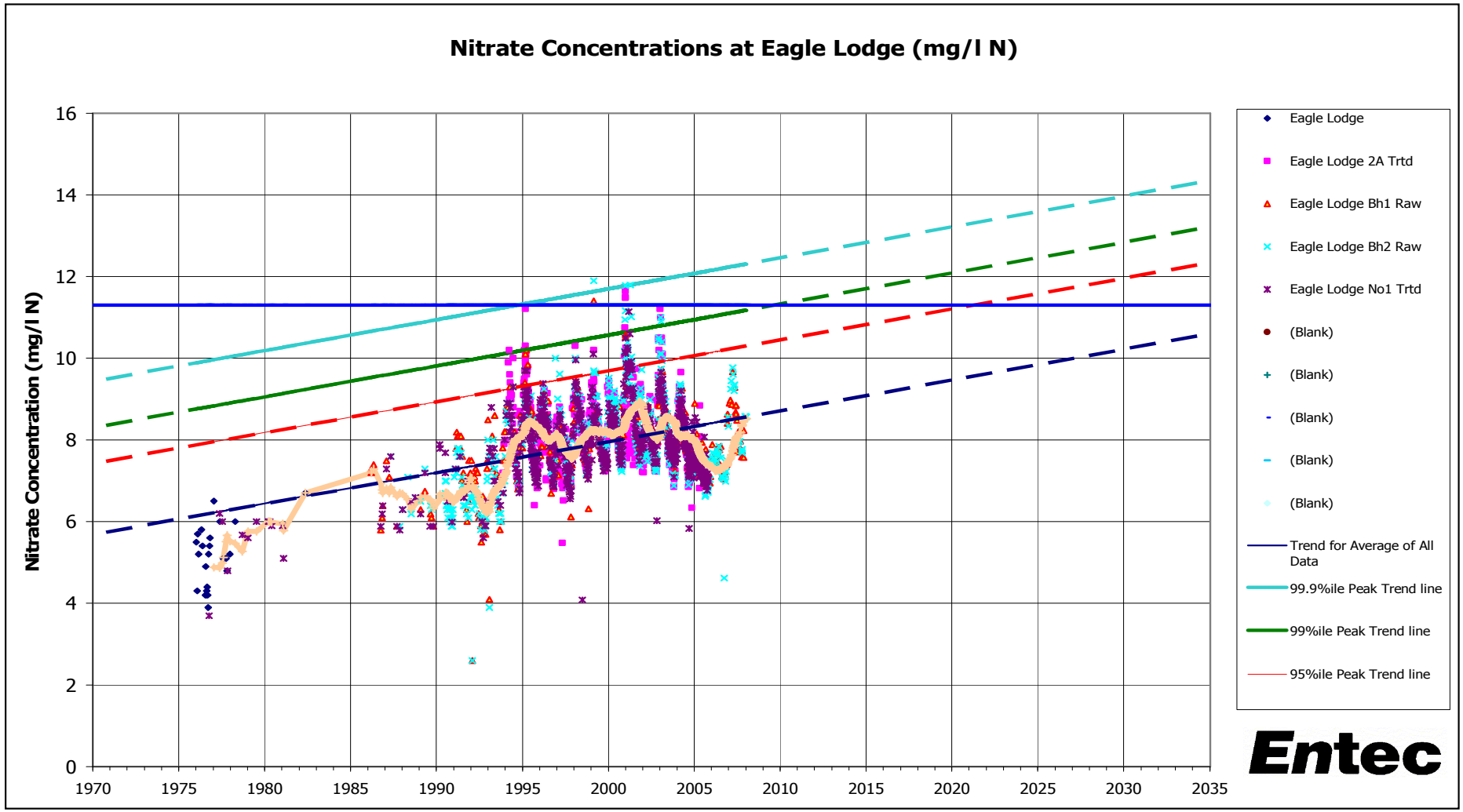
Pollution


Nitrate Concentrations at Milborne ST Andrew (mg/l N)
Nitrate Concentration (mg/l N)
0
5
10
15
20
25
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Milborne Bh1 Raw
Milborne Bh2 Raw
Milborne Bh3 Raw
Milborne St A No1Trt
Milborne St A No2Trt
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

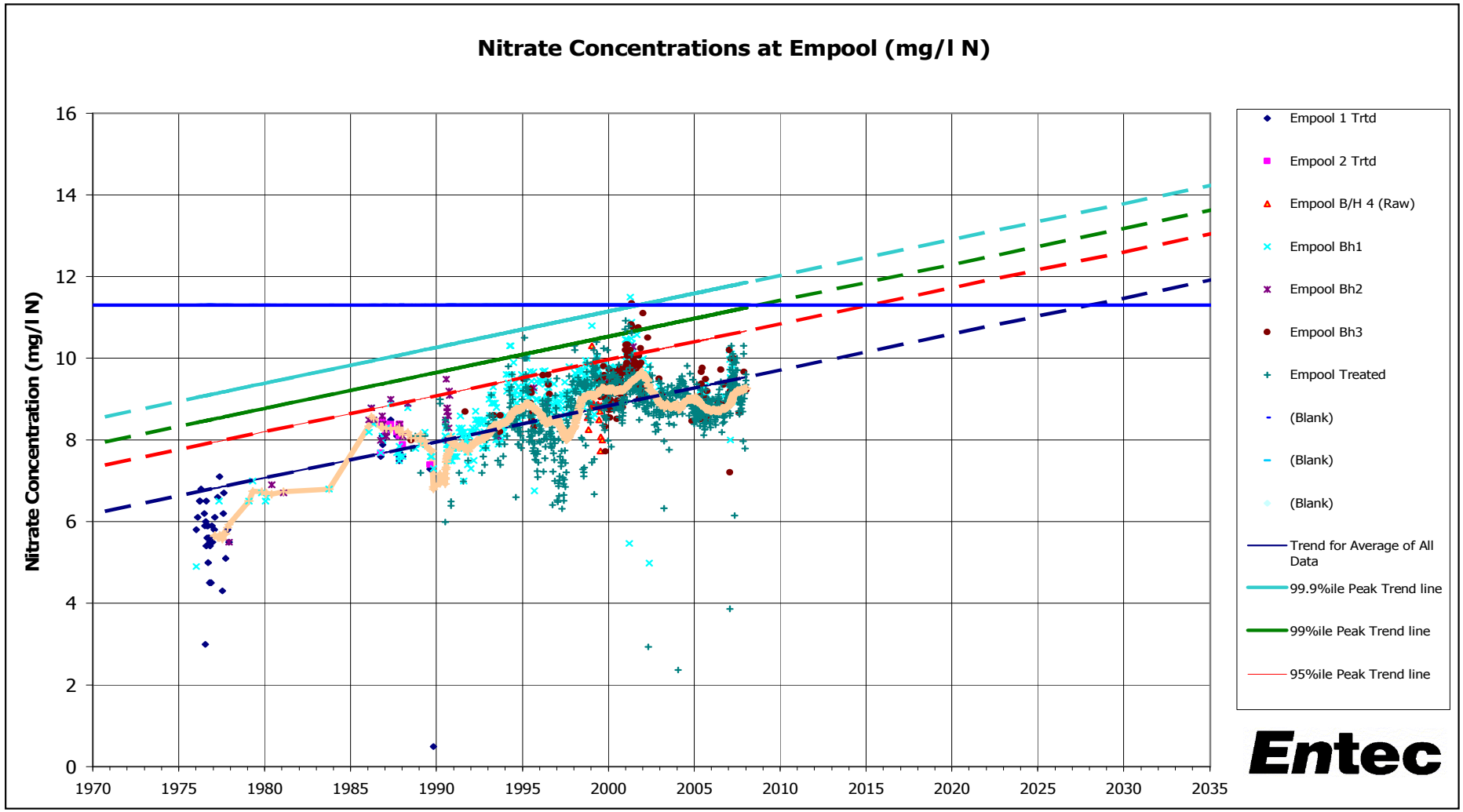
Pollution


Nitrate Concentrations at Shapwick (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
20
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Shapwick
Shapwick Bh 3
Shapwick Bh1
Shapwick Bh2
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

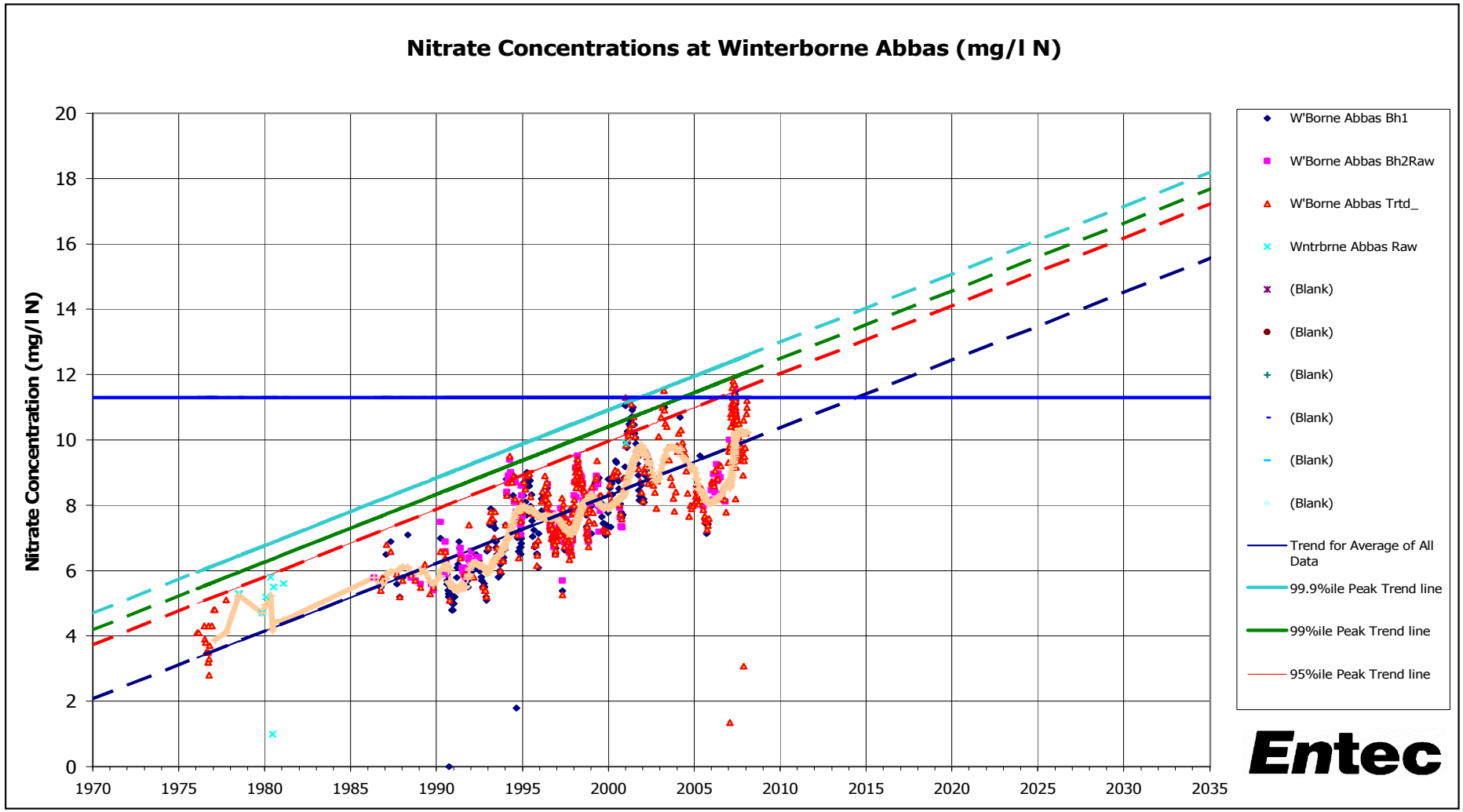
Pollution


Nitrate Concentrations at Eagle Lodge (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Eagle Lodge
Eagle Lodge 2A Trtd
Eagle Lodge Bh1 Raw
Eagle Lodge Bh2 Raw
Eagle Lodge No1 Trtd
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

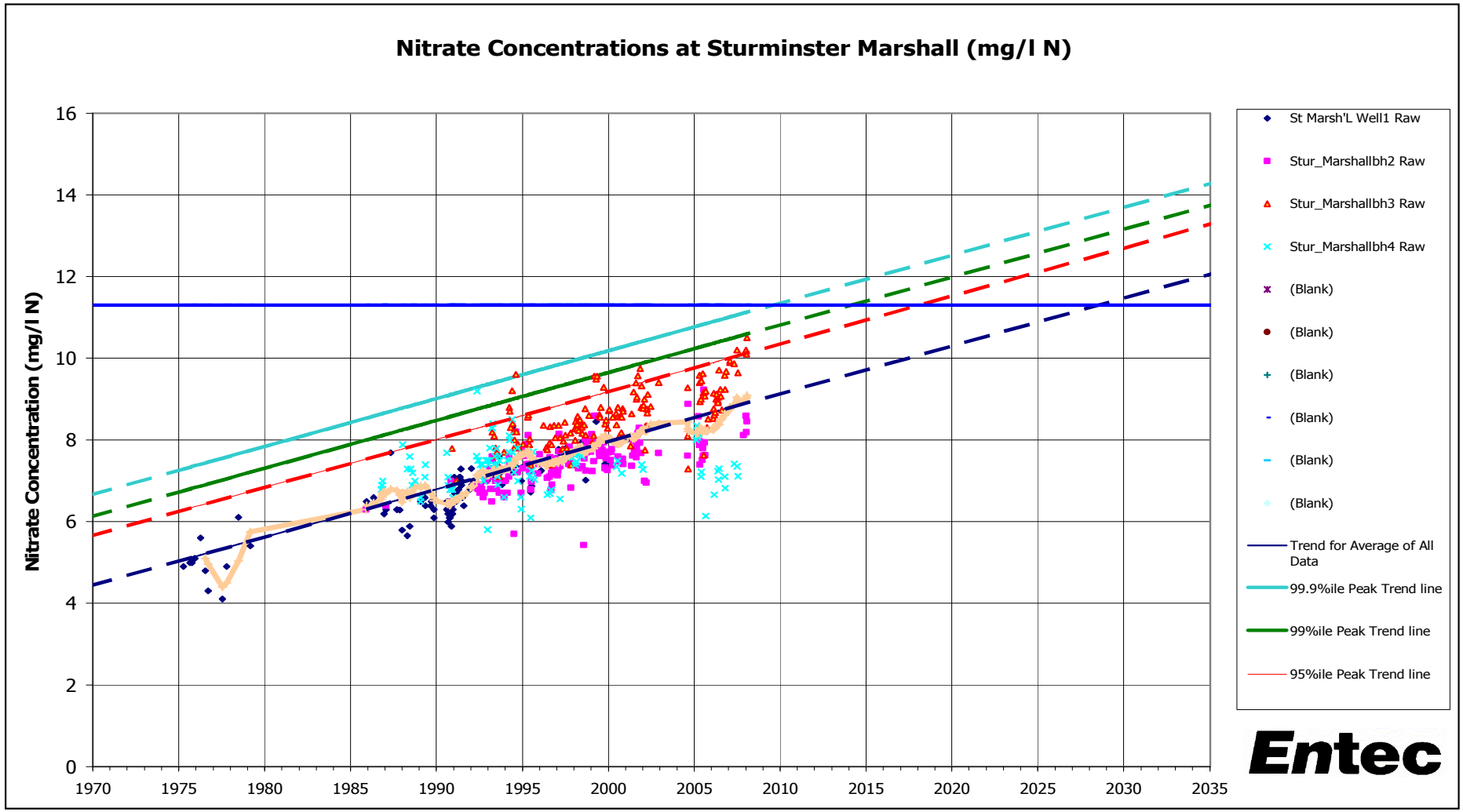
Pollution


Nitrate Concentrations at Empool (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Empool 1 Trtd
Empool 2 Trtd
Empool B/H 4 (Raw)
Empool Bh1
Empool Bh2
Empool Bh3
Empool Treated
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

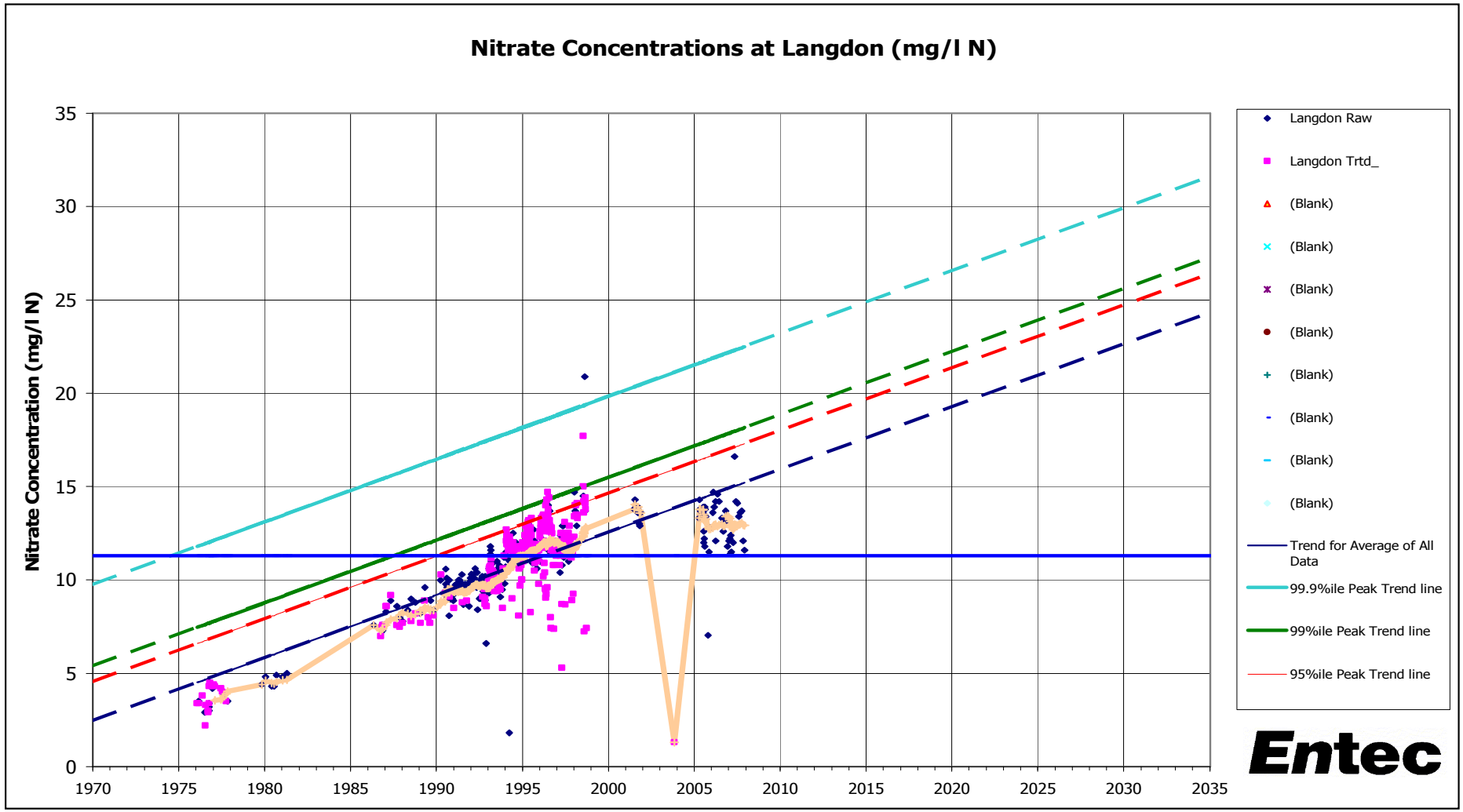
Pollution


Nitrate Concentrations at Winterborne Abbas (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
20
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
W'Borne Abbas Bh1
W'Borne Abbas Bh2Raw
W'Borne Abbas Trtd_
Wntrbrne Abbas Raw
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

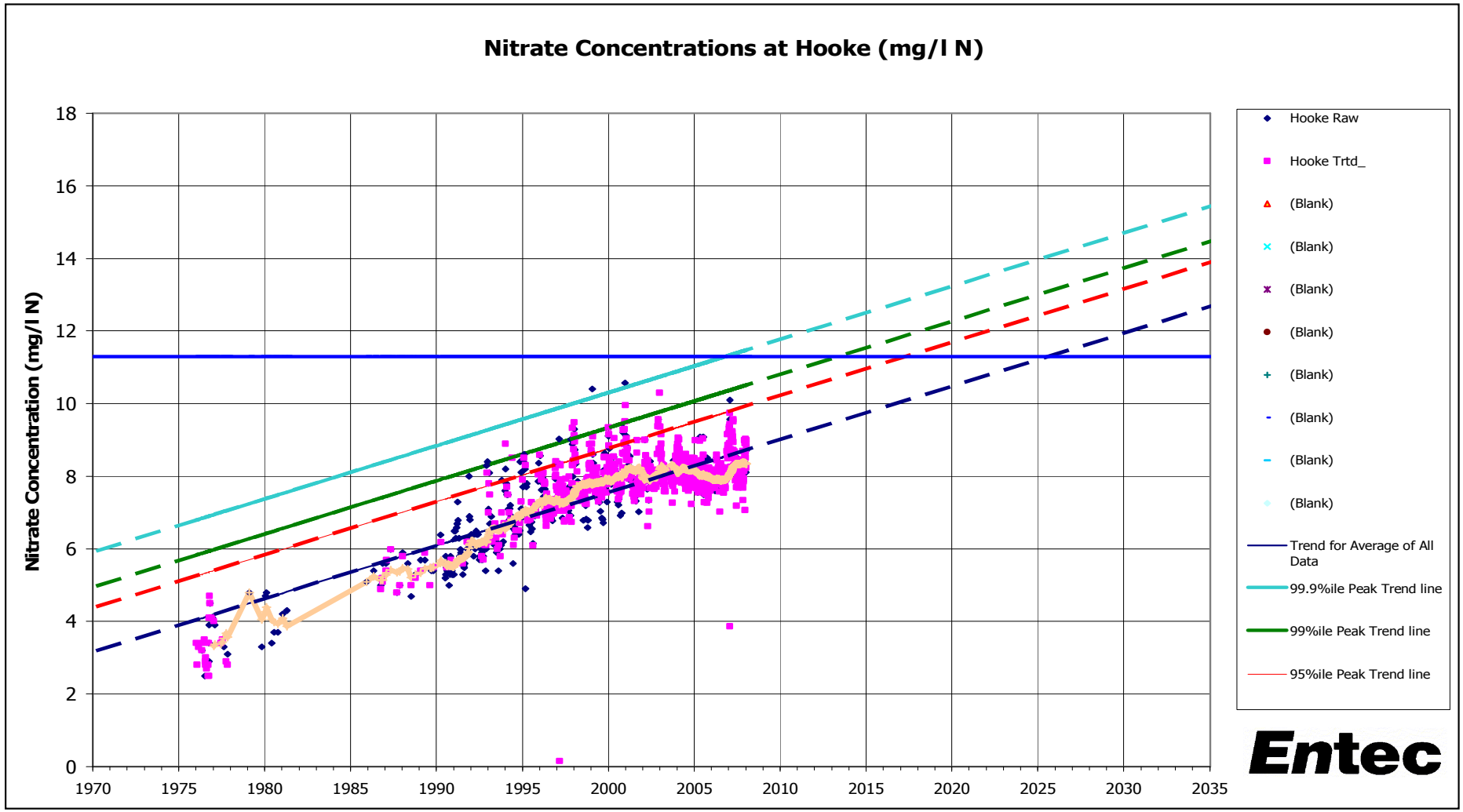
Pollution


Nitrate Concentrations at Sturminster Marshall (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
St Marsh'L Well1 Raw
Stur_Marshallbh2 Raw
Stur_Marshallbh3 Raw
Stur_Marshallbh4 Raw
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

Pollution


Nitrate Concentrations at Langdon (mg/l N)
Nitrate Concentration (mg/l N)
0
5
10
15
20
25
30
35
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Langdon Raw
Langdon Trtd_
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

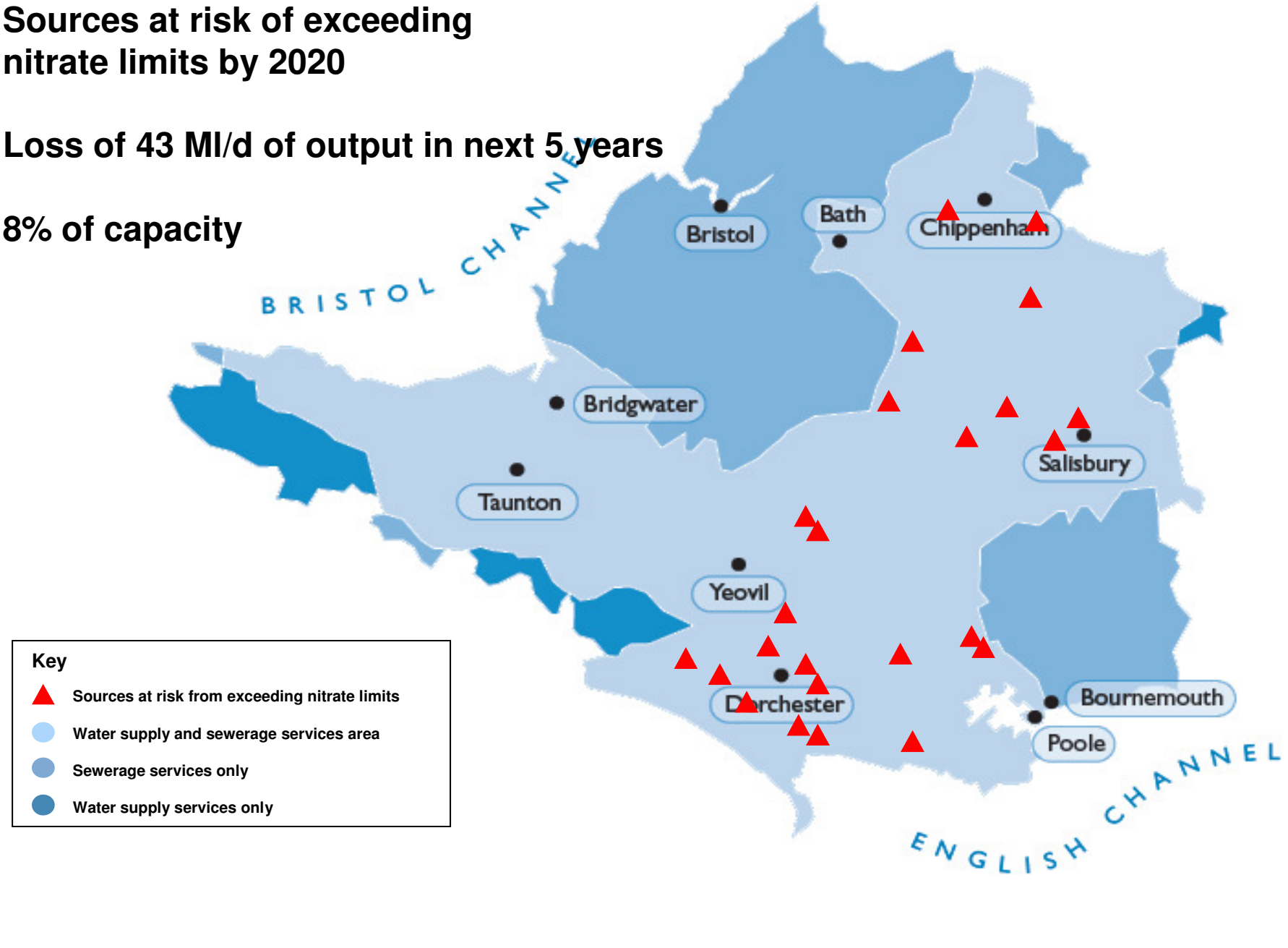
Pollution


Nitrate Concentrations at Hooke (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Hooke Raw
Hooke Trtd_
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec

Sources at risk of exceeding nitrate limits by 2020

Loss of 43 Ml/d of output in next 5 years

8% of capacity



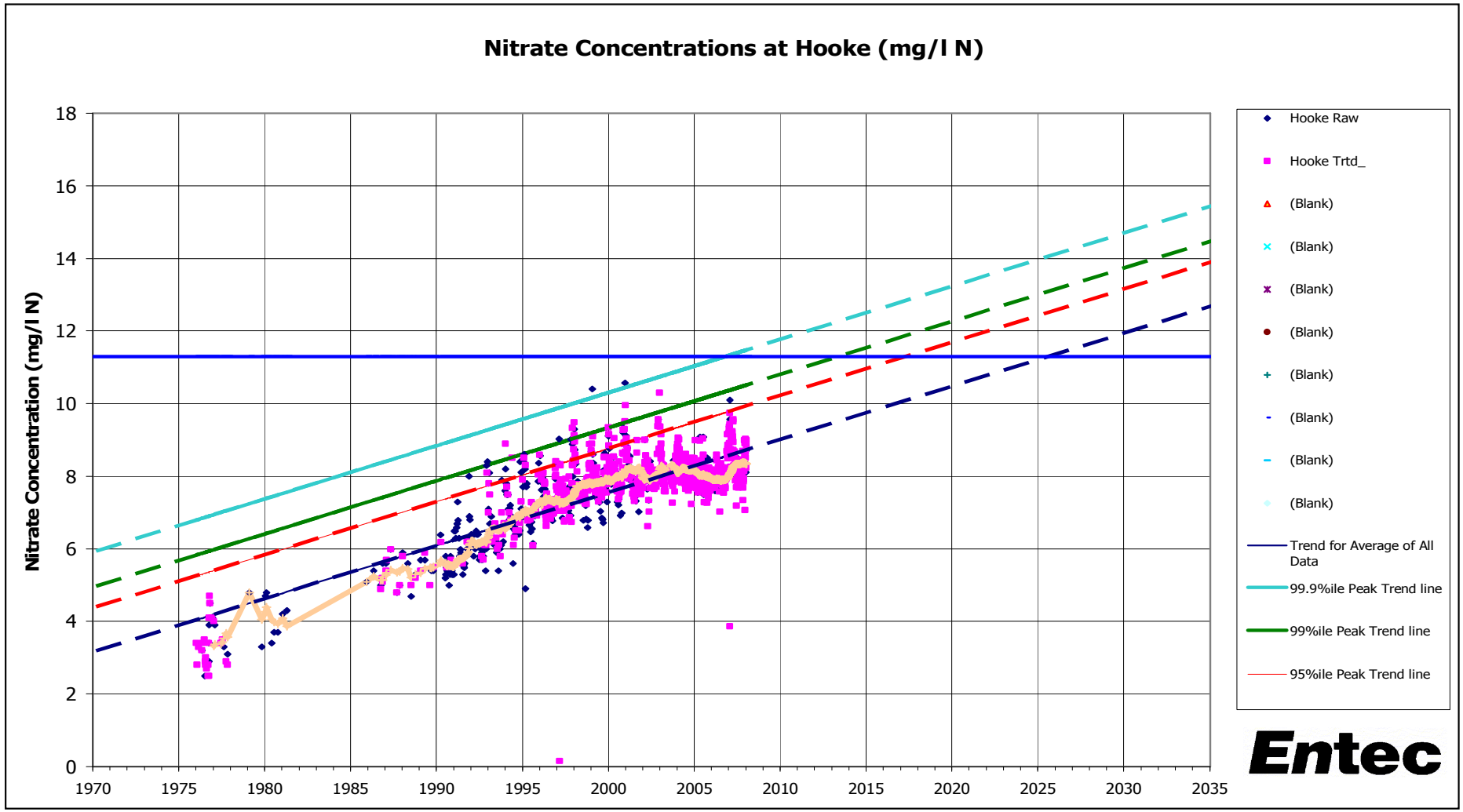
How do we deal with this problem

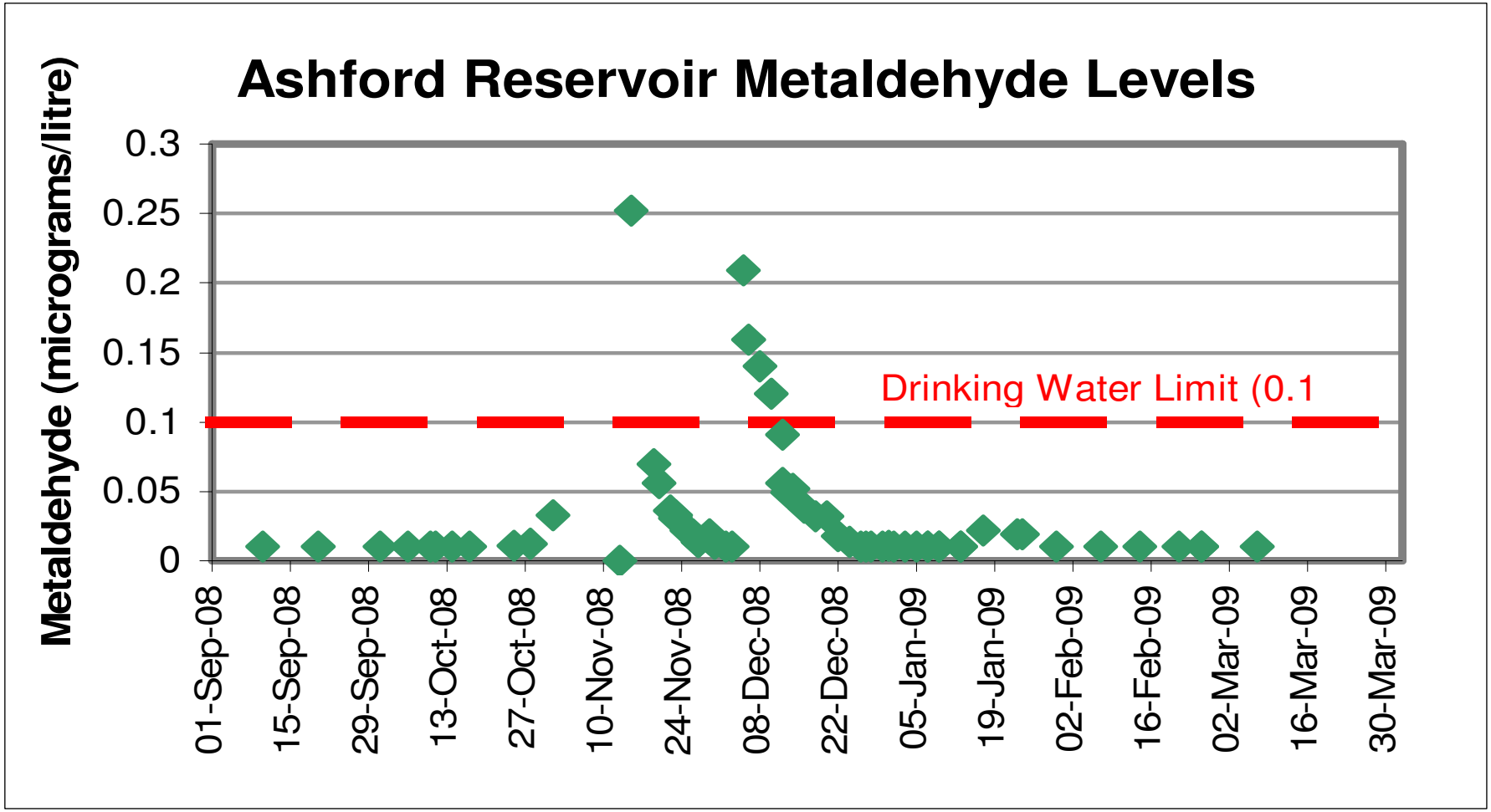
- **Treatment**
- **Blending**
- **Solve problem at source**

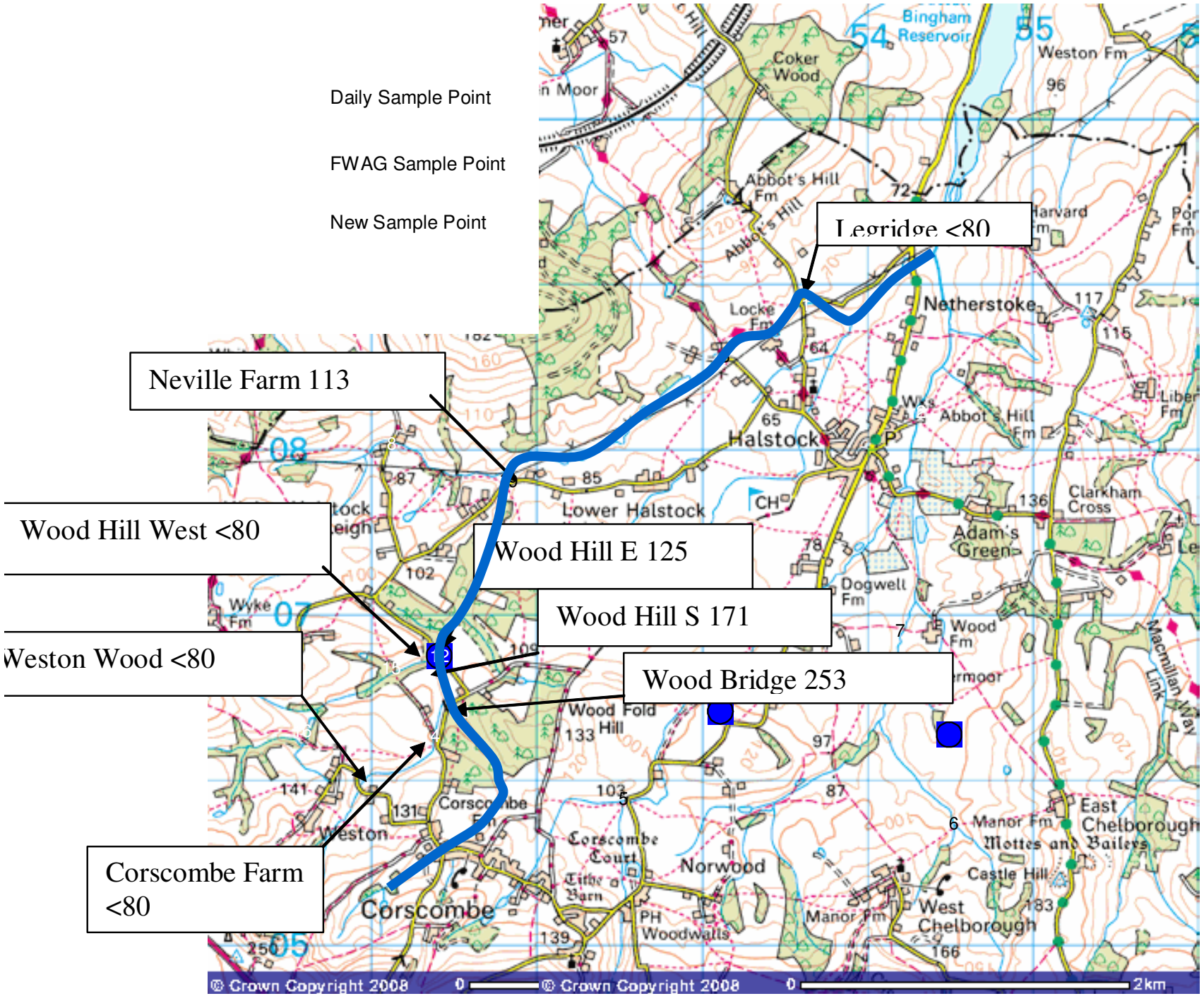
How long to solve the problem as source

- **Hydrogeologists**

Pollution


Nitrate Concentrations at Hooke (mg/l N)
Nitrate Concentration (mg/l N)
0
2
4
6
8
10
12
14
16
18
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Hooke Raw
Hooke Trtd_
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
(Blank)
Trend for Average of All Data
99.9%ile Peak Trend line
99%ile Peak Trend line
95%ile Peak Trend line
Entec


Ashford Reservoir Metaldehyde Levels
Metaldehyde (micrograms/litre)
0.3
0.25
0.2
0.15
0.1
0.05
0
Drinking Water Limit (0.1
01-Sep-08
15-Sep-08
29-Sep-08
13-Oct-08
27-Oct-08
10-Nov-08
24-Nov-08
08-Dec-08
22-Dec-08
05-Jan-09
19-Jan-09
02-Feb-09
16-Feb-09
02-Mar-09
16-Mar-09
30-Mar-09

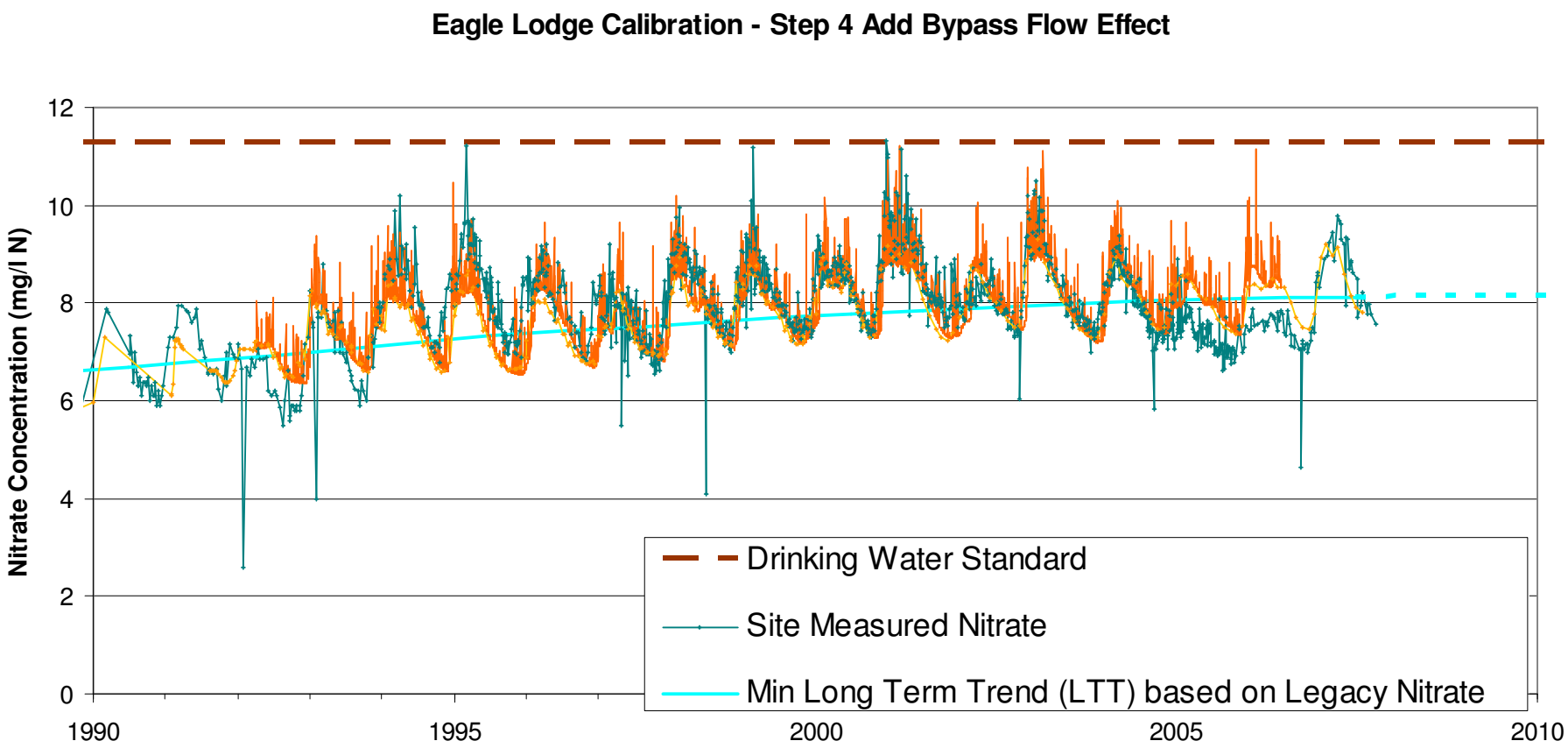

Daily Sample Point
FWAG Sample Point
New Sample Point
Legridge <80
Neville Farm 113
Wood Hill West <80
Wood Hill E 125
Wood Hill S 171
Weston Wood <80
Wood Bridge 253
Corscombe Farm <80
Bingham Reservoir
Coker Wood
Abbot's Hill Fm
Netherstoke
Halstock
Lower Halstock
Adam's Green
Clarkham Cross
Dogwell Fm
Wood Fm
Wood Fold Hill
Corscombe
Corscombe Court
Norwood
PH Woodwalls
Manor Fm
West Chelborough
East Chelborough
Castle Hill
Mottes and Baileys
Macmillan Way Link
© Crown Copyright 2008
0
© Crown Copyright 2008
0
2km

Conceptual model

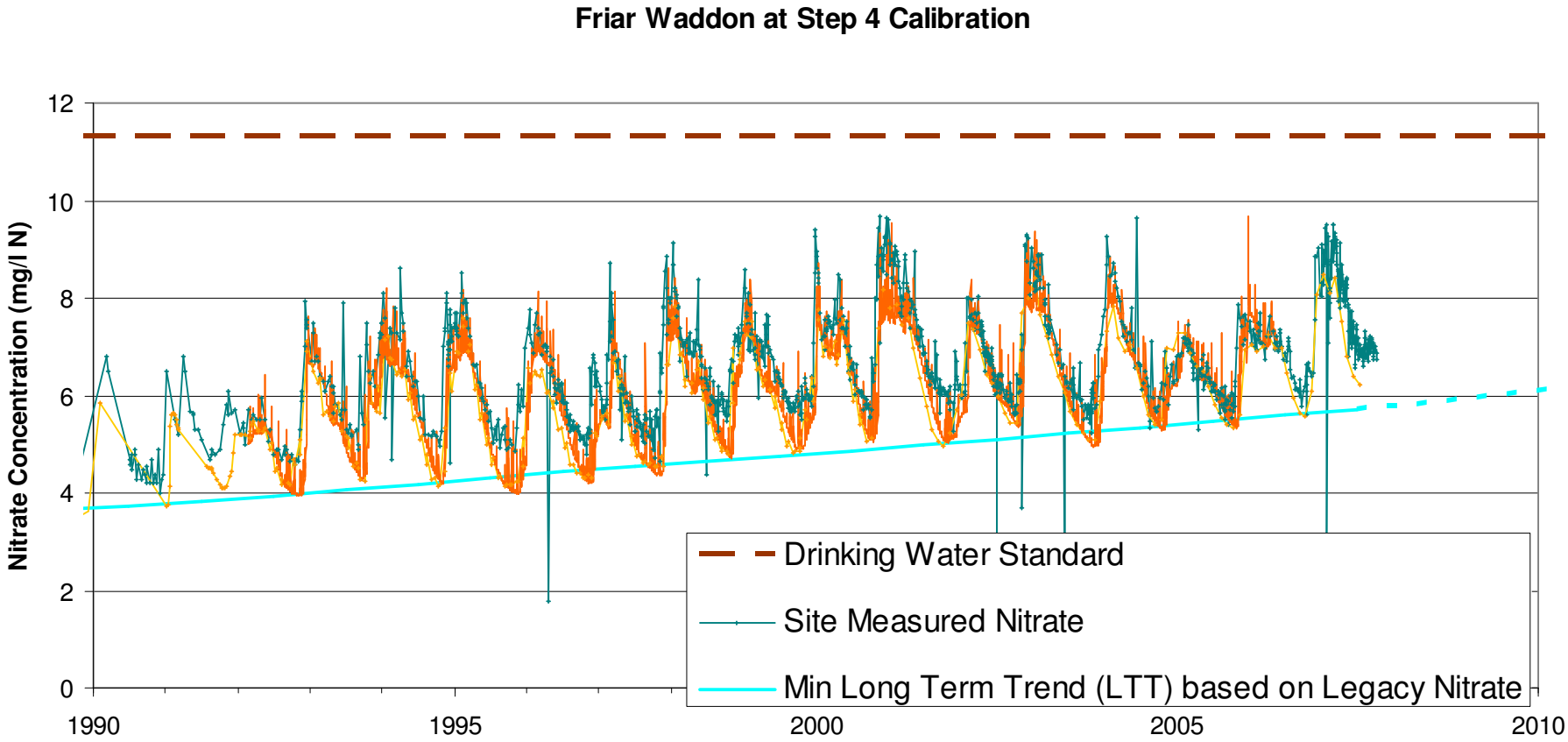
- **Nitrate level at time t =**

- **Function of historic application of nitrate / thickness of the unsaturated zone**
- **+**
- **Leachate concentration * function of groundwater level**
- **+**
- **Leachate concentration * function of recharge**

Good calibration

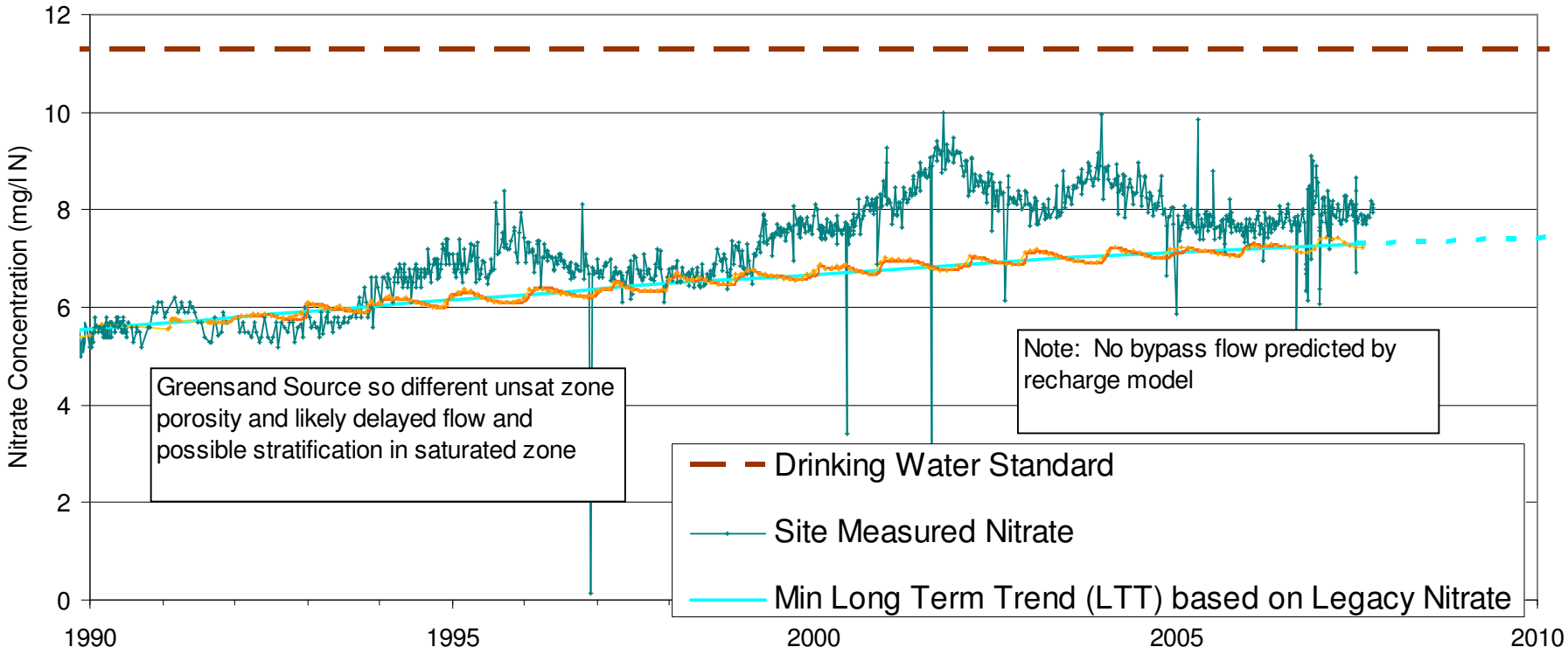


Good Calibration with a Number of Sites

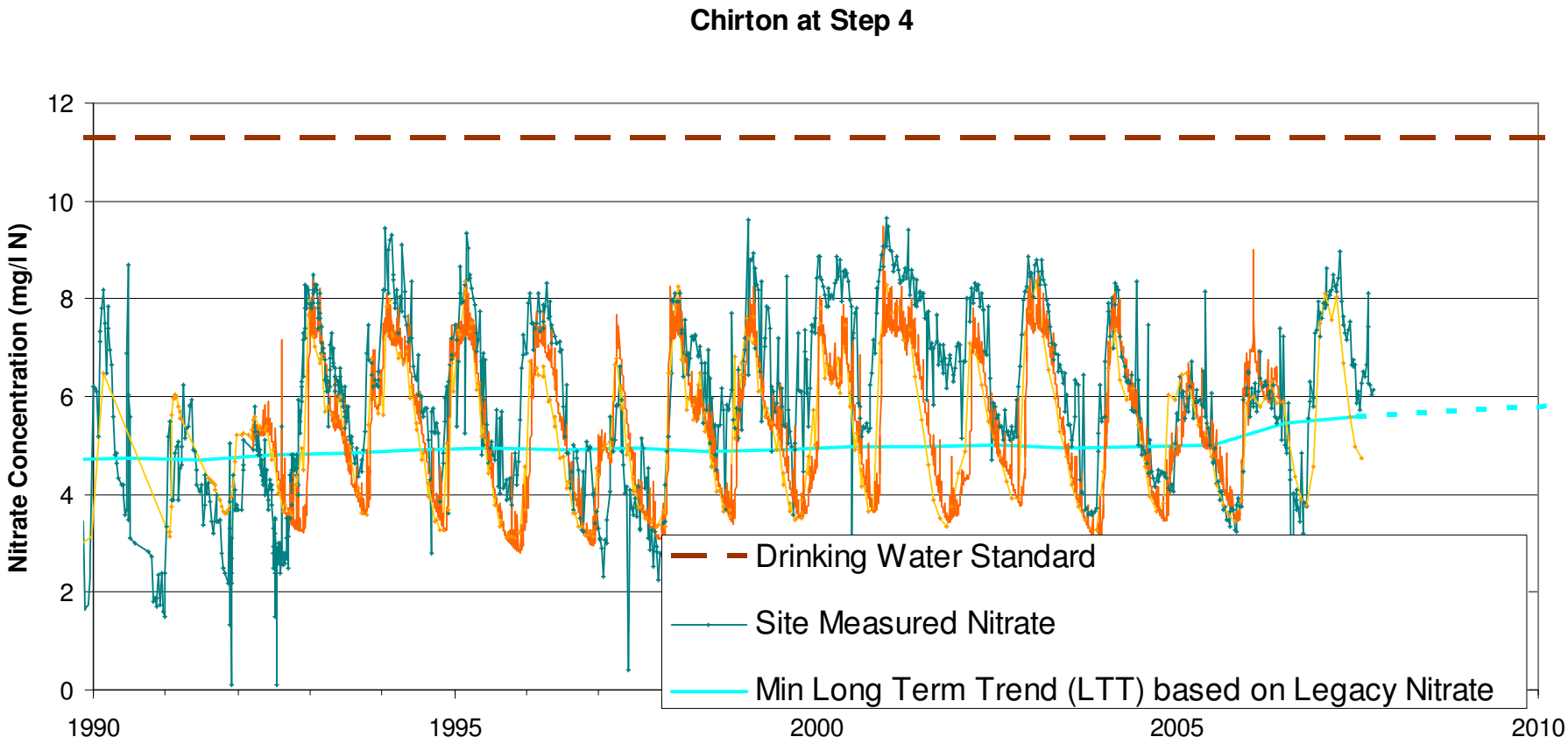


Whoops!

Dunkerton at Step 4



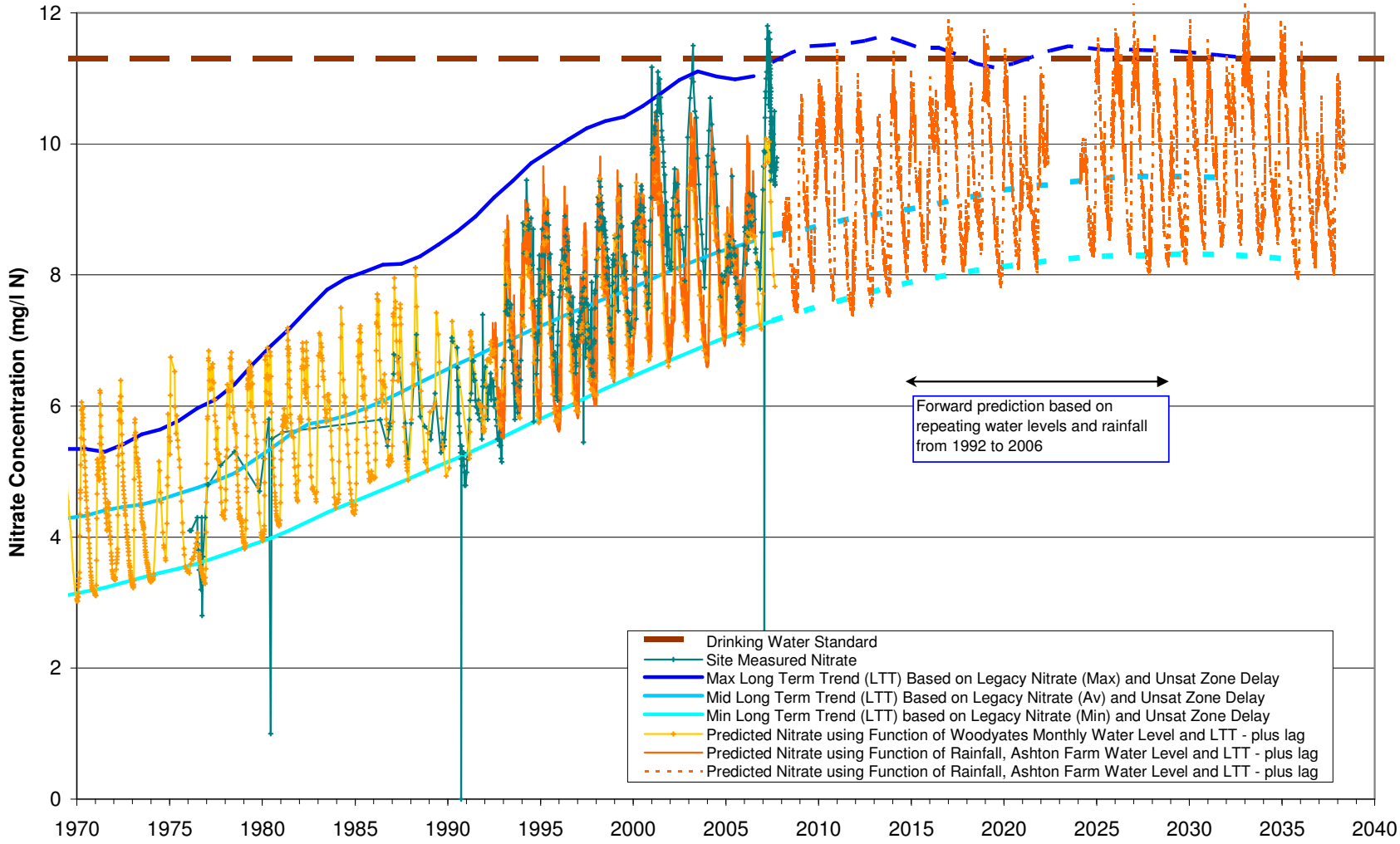
But Generally Good for Chalk Sources



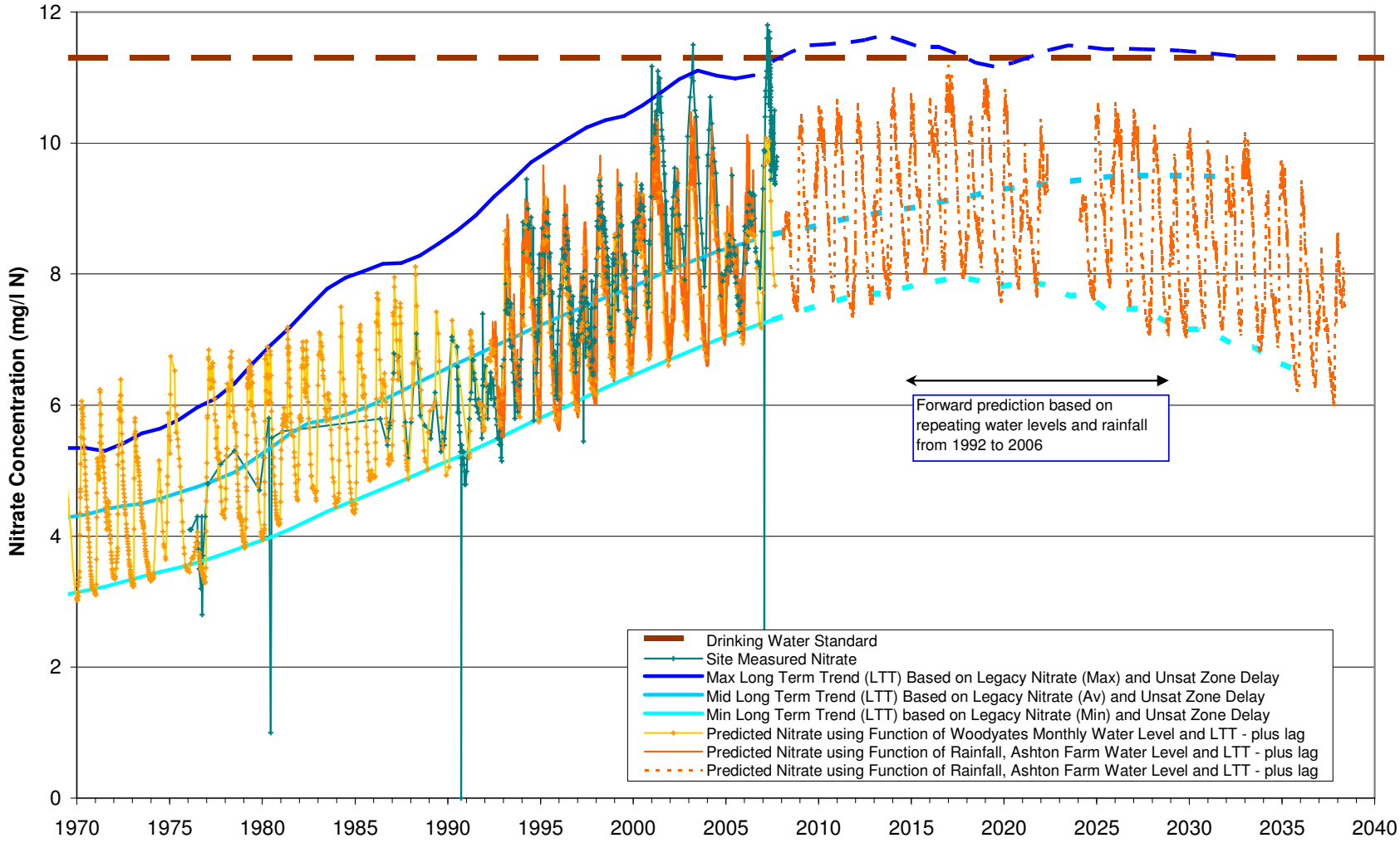
Modelled Scenarios

- Scenario 1 – nitrate leaching at 2006/7 rates
- Scenario 3 – nitrate leaching reduced to 50% of 2006/7 rates
- Scenario 2 – nitrate leaching reduced to zero

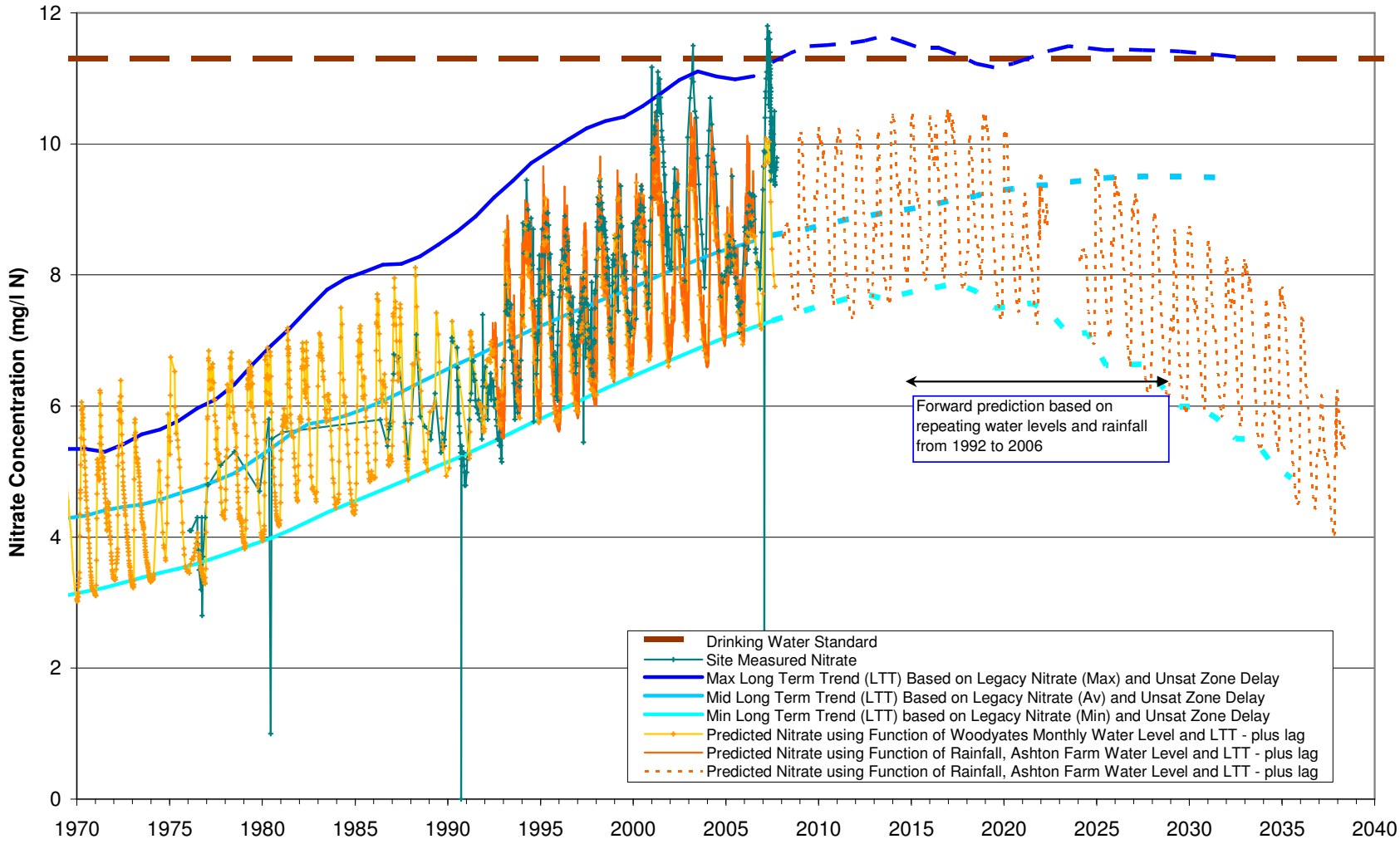
Winterbourne Abbas Scenario 1 Forward Prediction of Nitrate at PWS



Winterbourne Abbas Scenario 3 Forward Prediction of Nitrate at PWS



Winterbourne Abbas Scenario 2 Forward Prediction of Nitrate at PWS

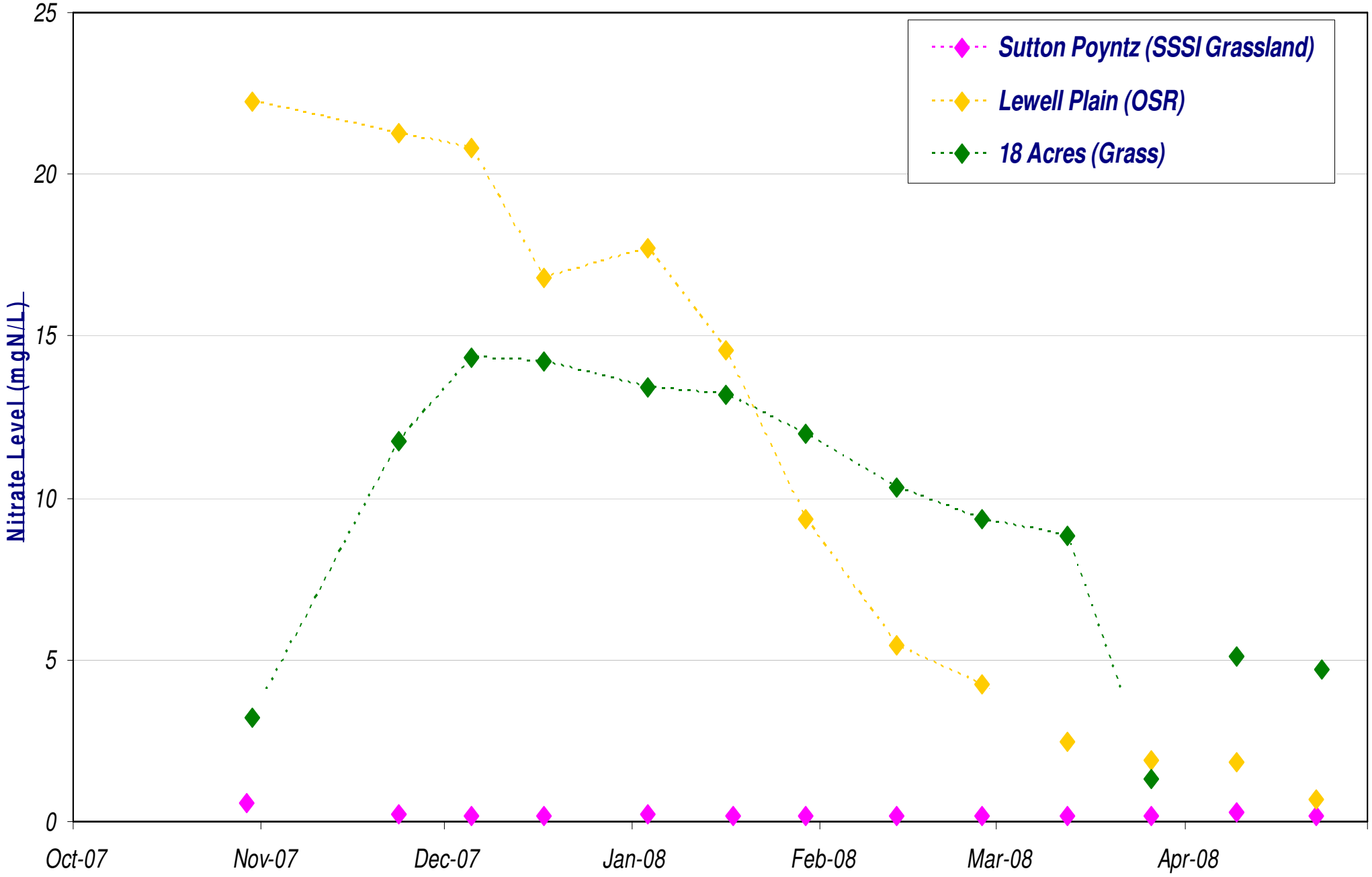


- **But how radical do you need to be?**

That is great!

- **But how do we achieve a 50% or 100% reduction in leaching?**

- **CSFOs?**
- **NVZ regulations?**
- **Catchment management based on advice and data?**
- **Catch-crops – WAgrico?**
- **Growing grass?**
- **Growing trees?**


Comparison of Average Nitrate Concentration (mgN/L) in Porous Pots Under different Crop types
Nitrate Level (mgN/L)
25
20
15
10
5
0
Oct-07
Nov-07
Dec-07
Jan-08
Feb-08
Mar-08
Apr-08
Sutton Poyntz (SSSI Grassland)
Lewell Plain (OSR)
18 Acres (Grass)

Clarendon

- **Luke de Vial, MSc (Hydrogeology)**