

Linked rainfall recharge models with groundwater models in NGMS (and looking forward to a future NGMS)

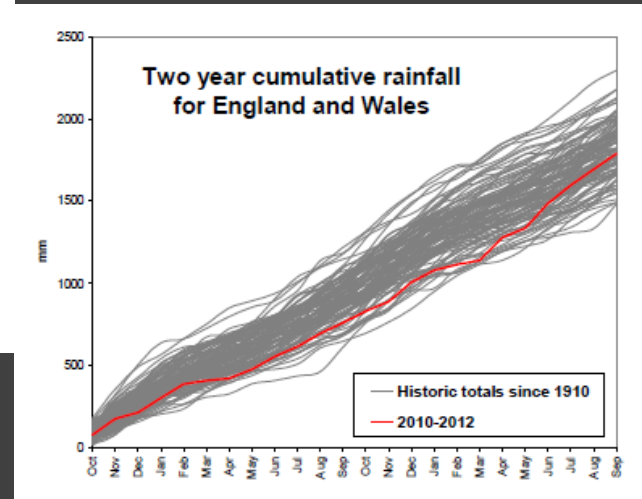
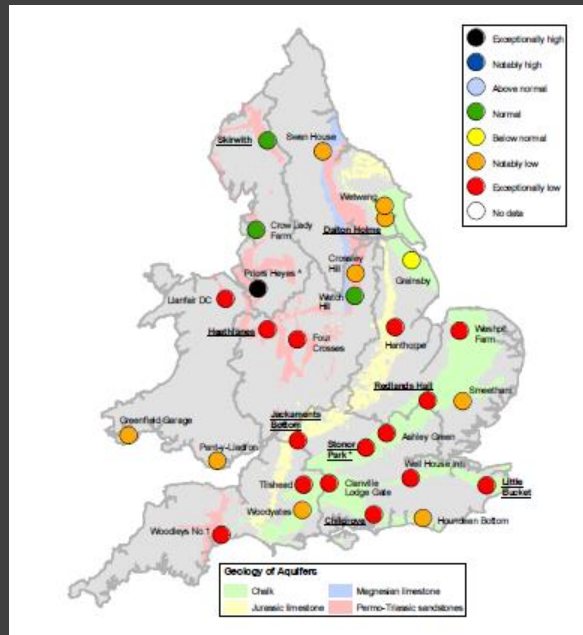
Mark Whiteman¹, Rolf Farrell¹, Harris Tarnanas¹, Marcel Ververs², Alastair Black³

¹ Environment Agency of England

² Deltares

³ Groundwater Science Ltd.

Context



Risk of drought, Spring 2012

Need to undertake scenario runs

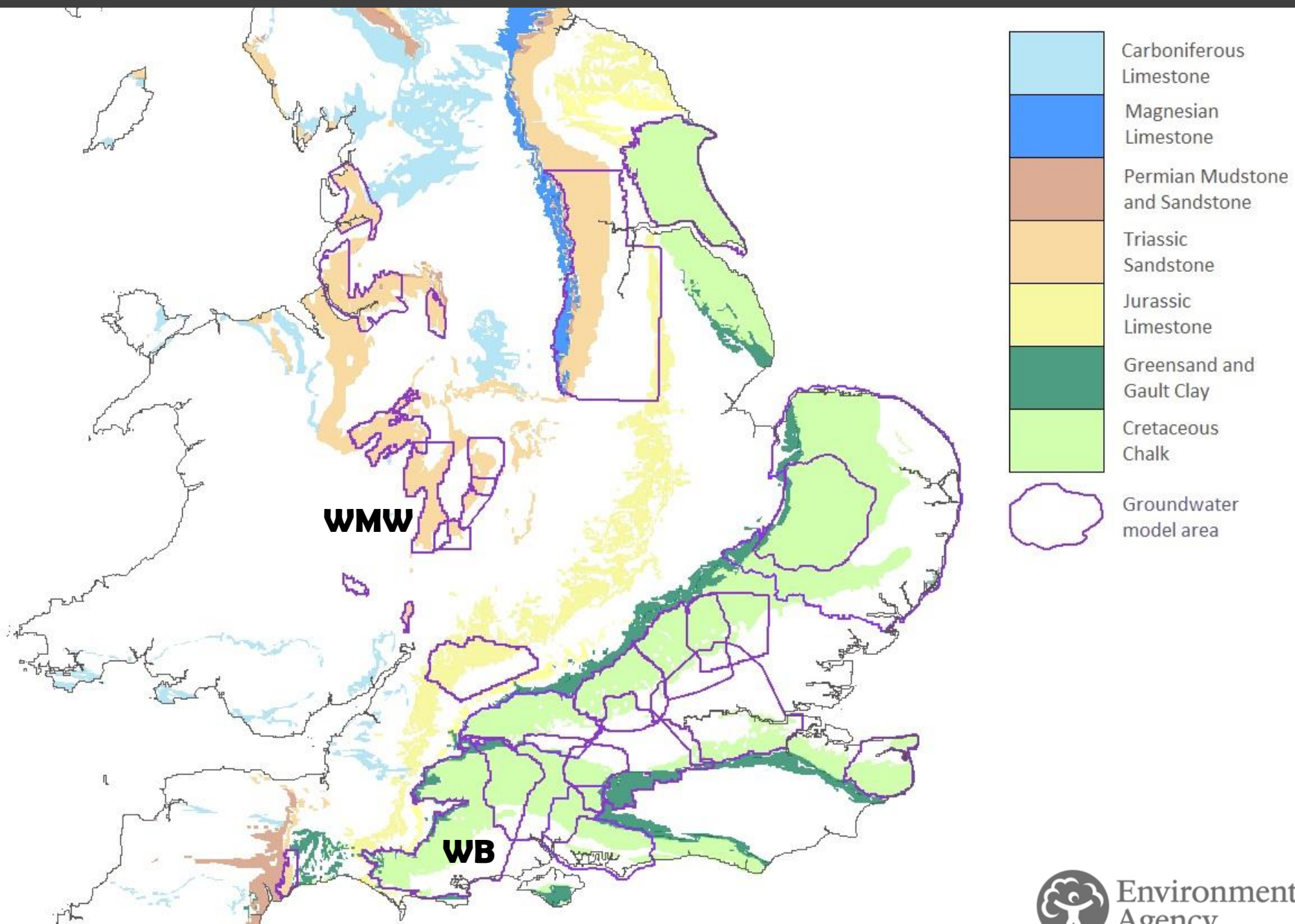
Models not ready for it

Hurried updates and over-reliance on rainfall runoff models

Partial NGMS 4R implementation used to emulate manual process undertaken at the time.

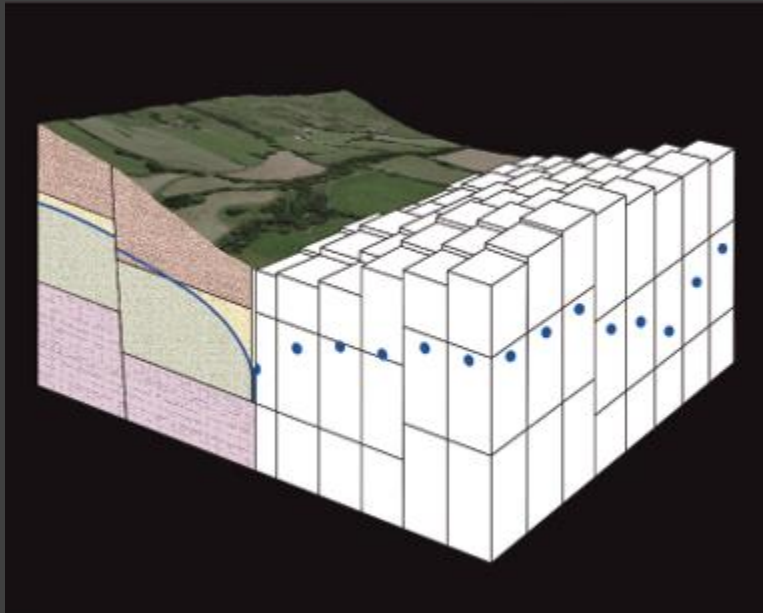
Process (following) published in:

Integrated environmental modelling to solve real world problems – Geological Society Special Publication Vol 408; Splicing recharge and groundwater flow models in the Environment Agency National Groundwater Modelling System; Rolf Farrell, Marcel Ververs, Paul Davison, Paul Howlett and Mark Whiteman.

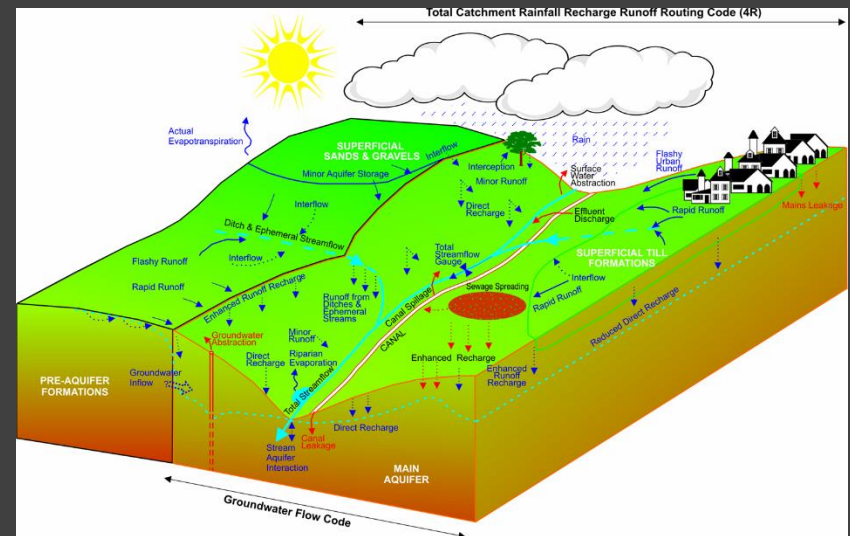


Recharge models and groundwater models

Groundwater model
(MODFLOW96-VKD)



Recharge model (4R)



4R and Modflow

Input –
Rainfall, Et

Run
Recharge
Model

Output -
Modelled
recharge

4R and NGMS Modflow

Input –
Rainfall, Et

Run
Recharge
Model

Output -
Modelled
recharge

NGMS 4R and NGMS Modflow

Input –
Rainfall, Et

NGMS Runs
Recharge
Model

NGMS Output -
Modelled
recharge

Input –
Recharge,
abstractions,
discharges, aquifer
parameters

Run
Modflow
Model

NGMS Output -
Modelled Flow
and level data

Input –
Recharge,
abstractions,
discharges, aquifer
parameters

NGMS Runs
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Recharge,
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NGMS Runs
Modflow
Model

NGMS Output -
Modelled Flow
and level data

Input files

Model Process

Post Processing

Stages in the model
Run process

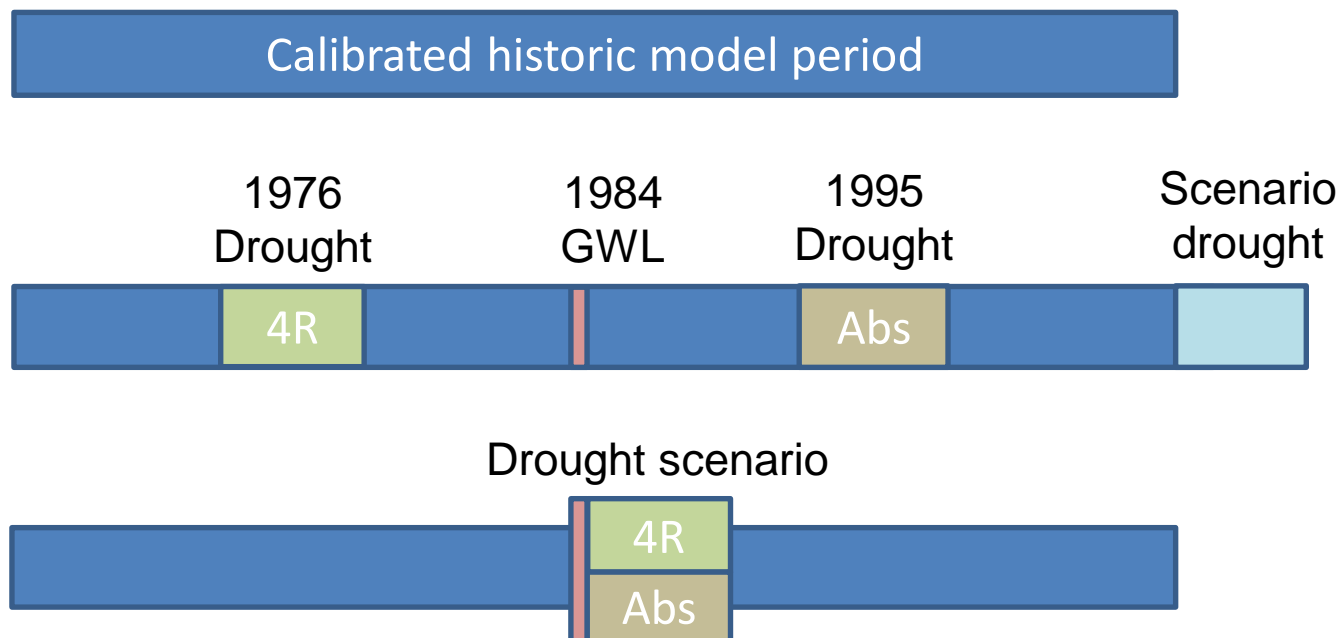
NGMS Processes

A Fusion Issue

Breaks in the model
run process

1965

April 2012



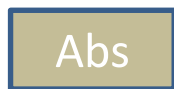
Potential groundwater drought event



Historic groundwater levels match current event



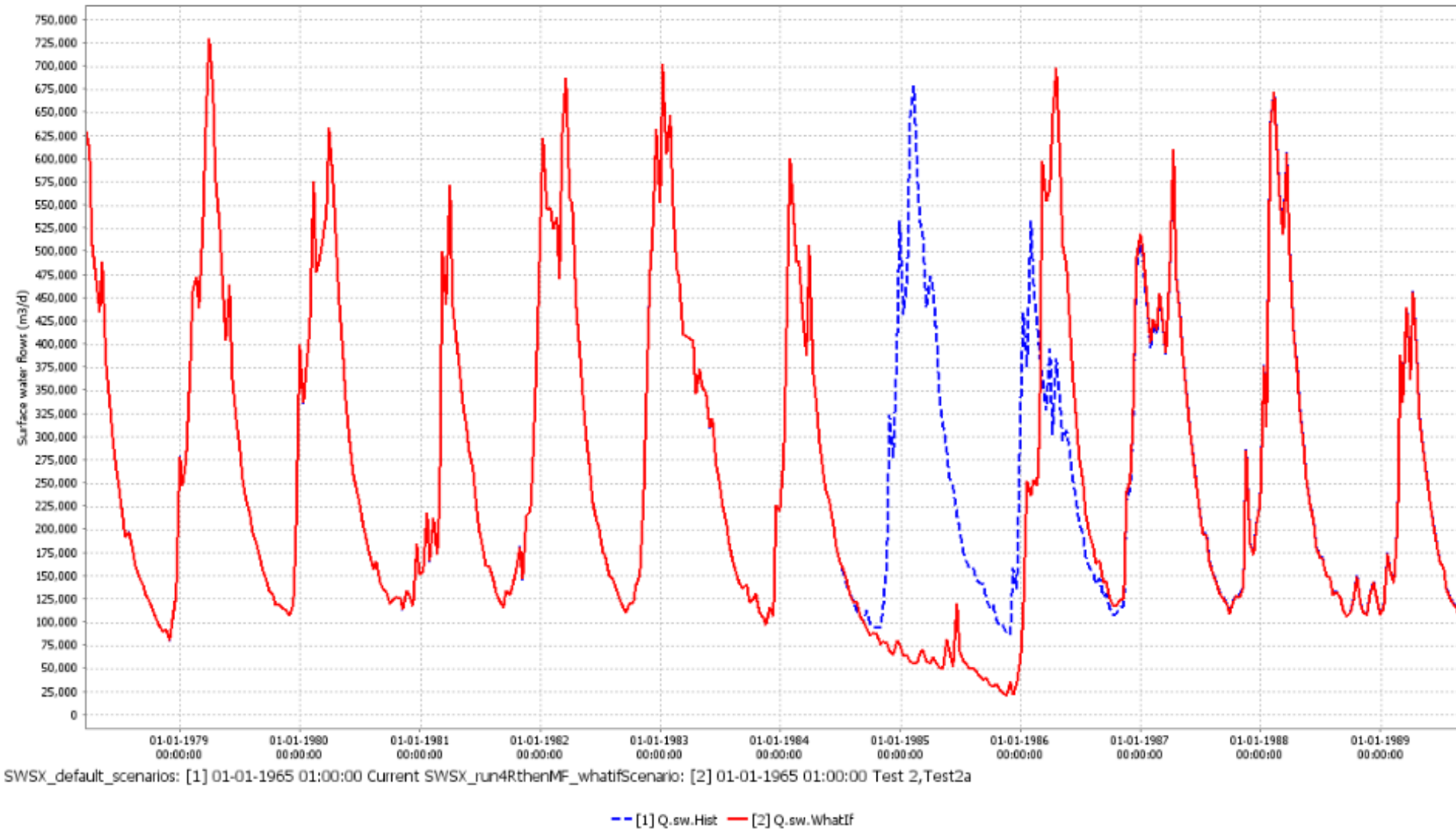
Historic rainfall matches current scenario event



Historic abstractions closest to predicted current

River flow hydrograph

Amesbury - SU1510041300



2017

- Finally fully implement 4R to NGMS
- Needed due to low spring rainfall 2017
- Subsequent rainfall has addressed SW concerns
- Groundwater drought remains a possibility in 2018; recharge this coming winter still a concern

Rainfall scenario set-up

NGMS-Midlands region: release 1.10 February 2017 - (Stand alone)

File Tools Options Help

Scenario Editor

Graphs and Profiles

Data Viewer

- Birmingham
- Birmingham Recharge
- Lichfield (sandstone)
- Lichfield Recharge
- East Shropshire (sandstone)
- East Shropshire Recharge
- Bromsgrove (sandstone)
- Newent

Locations

Parameters

Activated Scenarios

Logs

Tarnanas, Harris

Scenario Template

- Modified Historic recharge scenarios
- Modified RecentActual recharge scenarios
- Modified RecentActualAuto recharge scenarios

Specified Scenarios

- *1976rech_Into_Jul1984-Dec87

Intervention Types

- Modify rainfall rates
- Modify PE rates
- Select module data set files

New Transformation

West Midlands Worfe

User Defined Profile

typical profile

	A	B
Q_rain.Historic (mm/d)	West Midlands W	Seasonal factor (-)
West Midlands W	WMW_4R	West Midlands W
WMW_4R	WMW_run4R_Ht	WMW_4R
WMW_run4R_Ht		WMW_run4R_Ht
22-06-1984 00:00	1984-06-22	
23-06-1984 00:00	1984-06-23	
24-06-1984 00:00	1984-06-24	
25-06-1984 00:00	1984-06-25	
26-06-1984 00:00	1984-06-26	
27-06-1984 00:00	1984-06-27	
28-06-1984 00:00	1984-06-28	
29-06-1984 00:00	1984-06-29	
30-06-1984 00:00	1984-06-30	
01-07-1984 00:00	1976-07-01	
02-07-1984 00:00	1976-07-02	
03-07-1984 00:00	1976-07-03	
04-07-1984 00:00	1976-07-04	
05-07-1984 00:00	1976-07-05	
06-07-1984 00:00	1976-07-06	
07-07-1984 00:00	1976-07-07	
08-07-1984 00:00	1976-07-08	
09-07-1984 00:00	1976-07-09	
10-07-1984 00:00	1976-07-10	
11-07-1984 00:00	1976-07-11	
12-07-1984 00:00	1976-07-12	

Close Help

6 : Logs

Tarnanas, Harris

Current system time:01-01-1969 00:00 GMT

13:45:55 GMT

14:45:55 BST

Stand alone

317170 , 592394

0.0 MB/s

163 MB

Potential Evapotranspiration scenario set-up

The screenshot displays the 'Scenario Editor' window for 'NGMS-Midland'. The interface is divided into several panels:

- Left Panel:** Contains a 'Data View' tree on the left and a 'Scenario Template' list on the right. The 'Scenario Template' list includes:
 - Modified Naturalized recharge scenarios
 - Modified Historic recharge scenarios
 - Modified RecentActual recharge scenarios
 - Modified RecentActualAuto recharge scenarios
 The 'Specified Scenarios' section shows a list with '1976rech_Inte_Jul1984-Dec87' selected.
- Top Panel:** Shows 'New Transformation' set to 'MORECS 135'. Below it, a table lists 'Existing Transformations':

Location	Transformation	View	Delete
MORECS 124	Profile		
MORECS 125	Profile		
MORECS 135	Profile		
MORECS 136	Profile		
- Bottom Panel:** Features a graph titled 'MORECS 135' showing 'QPE Timeseries (mm/day)' from 01-01-1974 to 01-01-2009. The graph displays two overlapping lines: a solid red line for 'QPE.Historic "MORECS 135"' and a dashed blue line for 'QPE.Historic.modified "MORECS 135"'. Below the graph, a status bar reads: '20-10-2017 10:02:42 INFO - Scenario Editor started successfully'. At the bottom of the window, there are buttons for 'Save All', 'Run', 'Close', and 'Help', along with a 'Display Time: 01-01-1969 00:00:00' indicator.

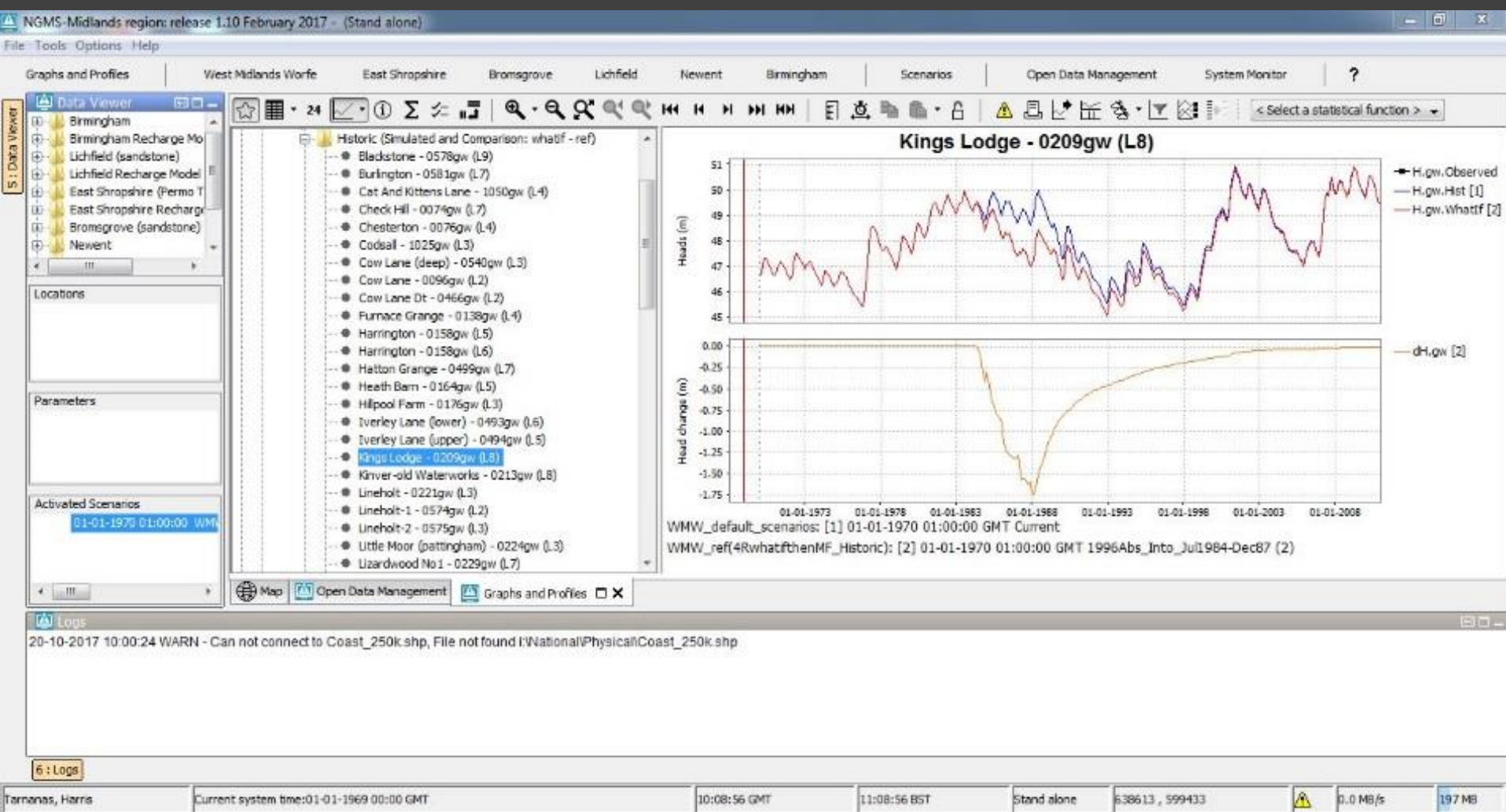
Abstraction scenario set-up

The screenshot displays the 'Scenario Editor' window of the NGMS-Midland software. The interface is divided into several panels:

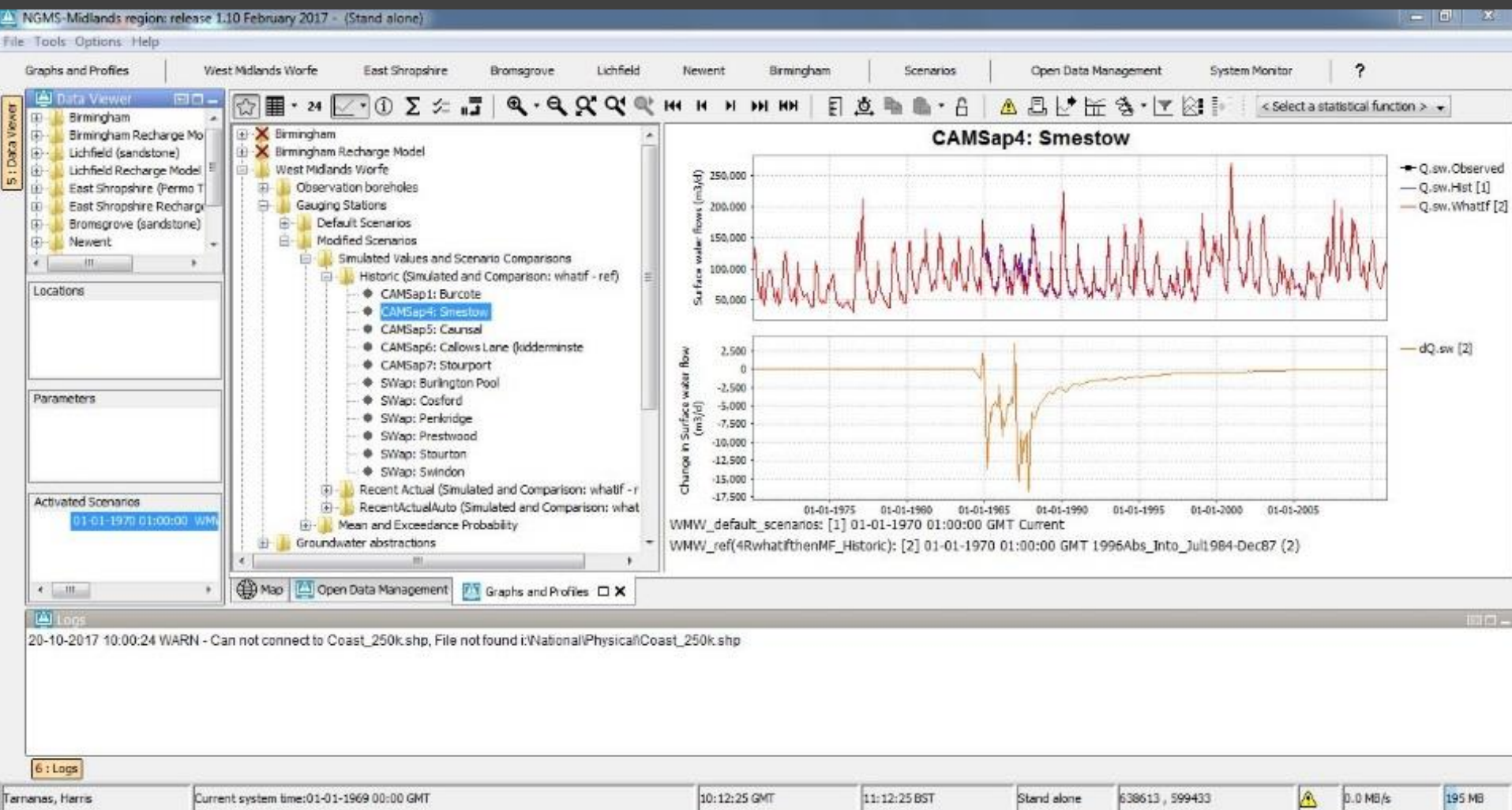
- Left Panel:** Contains a 'Data View' tree on the left with categories like 'Area', 'Locations', 'Parameters', and 'Activated Scenarios'. The 'Area' section is expanded, showing 'Birmingham scenarios', 'Bromsgrove scenarios', 'Lichfield scenarios', and 'West Midlands Work scenarios'. The 'Specified Scenarios' list includes '1996Abs_Into_Jul1984-Dec87' and '1996Abs_Into_Jul1984-Dec87 (2)'. The 'Intervention Types' section is also visible.
- Top Panel:** 'New Transformation' dropdown is set to '18/54/05/0177_Sir - Old Lodge Farm, Quatford - Borehole (L7)'. Below it, a table lists 'Existing Transformations'.
- Table of Existing Transformations:**

Location	Transformation	View	Delete
18/54/05/0025_Pws - Beckbury (L8)	Profile		
18/54/05/0129_Pws - Beckbury (L8)	Profile		
18/54/05/0129_Pws - Beckbury (L9)	Profile		
18/54/05/0177_Sir - Old Lodge Farm, Quatford - Borehole (L7)	Profile		
- Bottom Panel:** Features a graph titled '18/54/05/0177_Sir - Old Lodge Farm, Quatford - Borehole (L7)'. The y-axis is 'Abstraction (m³/d)' ranging from -25 to 0. The x-axis shows dates from 01-01-1974 to 01-01-2004. The graph displays two data series: a solid line for 'Q.abs.gw.Hist "18/54/05/0177_Sir - Old Lodge Farm, Quatford - Borehole (L7)"' and a dashed line for 'Q.modified.abs.gw.Hist "18/54/05/0177_Sir - Old Lodge Farm, Quatford - Borehole (L7)"'. Below the graph, a status bar indicates '20-10-2017 10:02:42 INFO - Scenario Editor started successfully'. At the bottom right, there are buttons for 'Save All', 'Run', 'Close', and 'Help'.

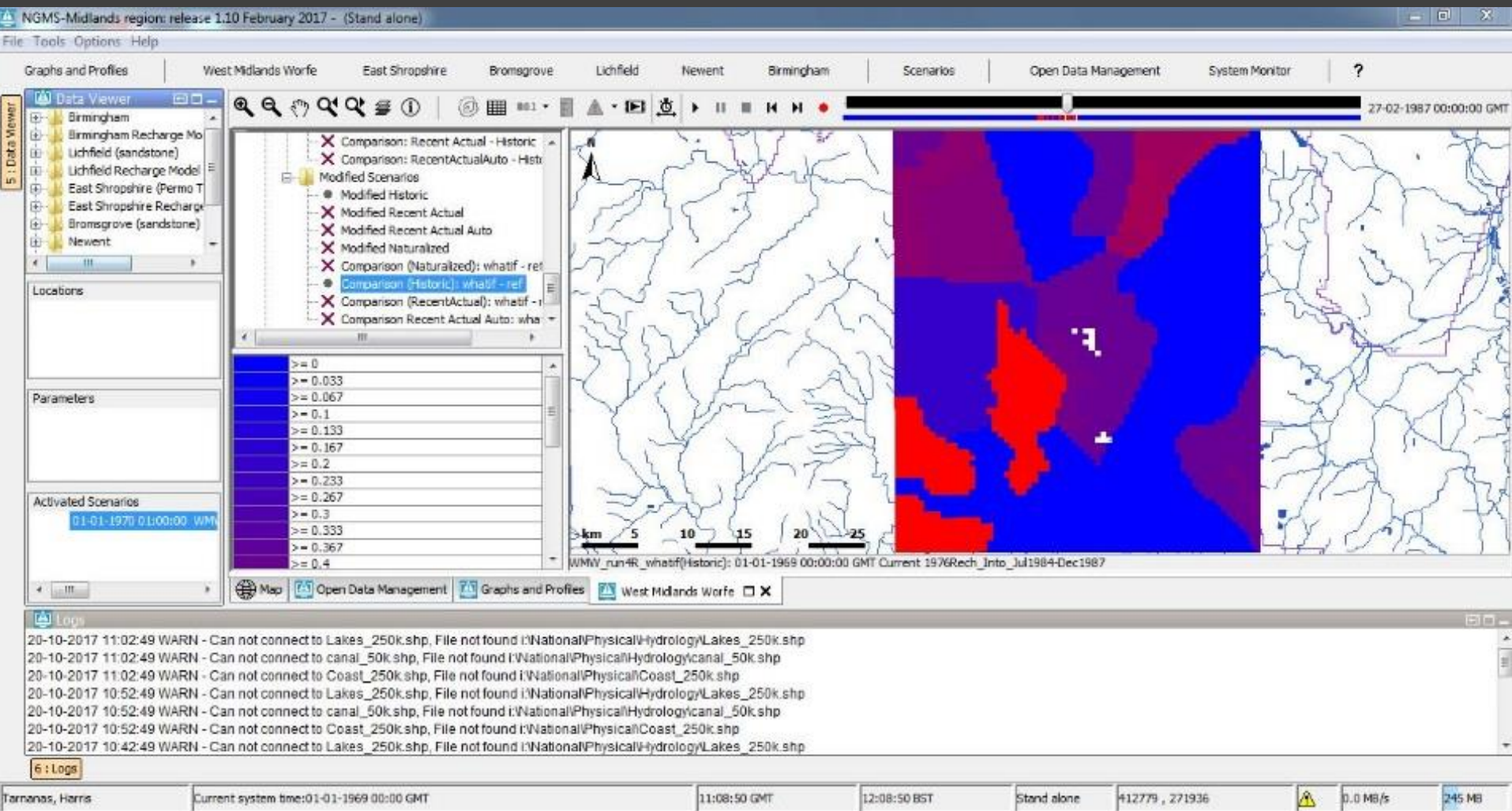
Recharge scenario results – groundwater levels



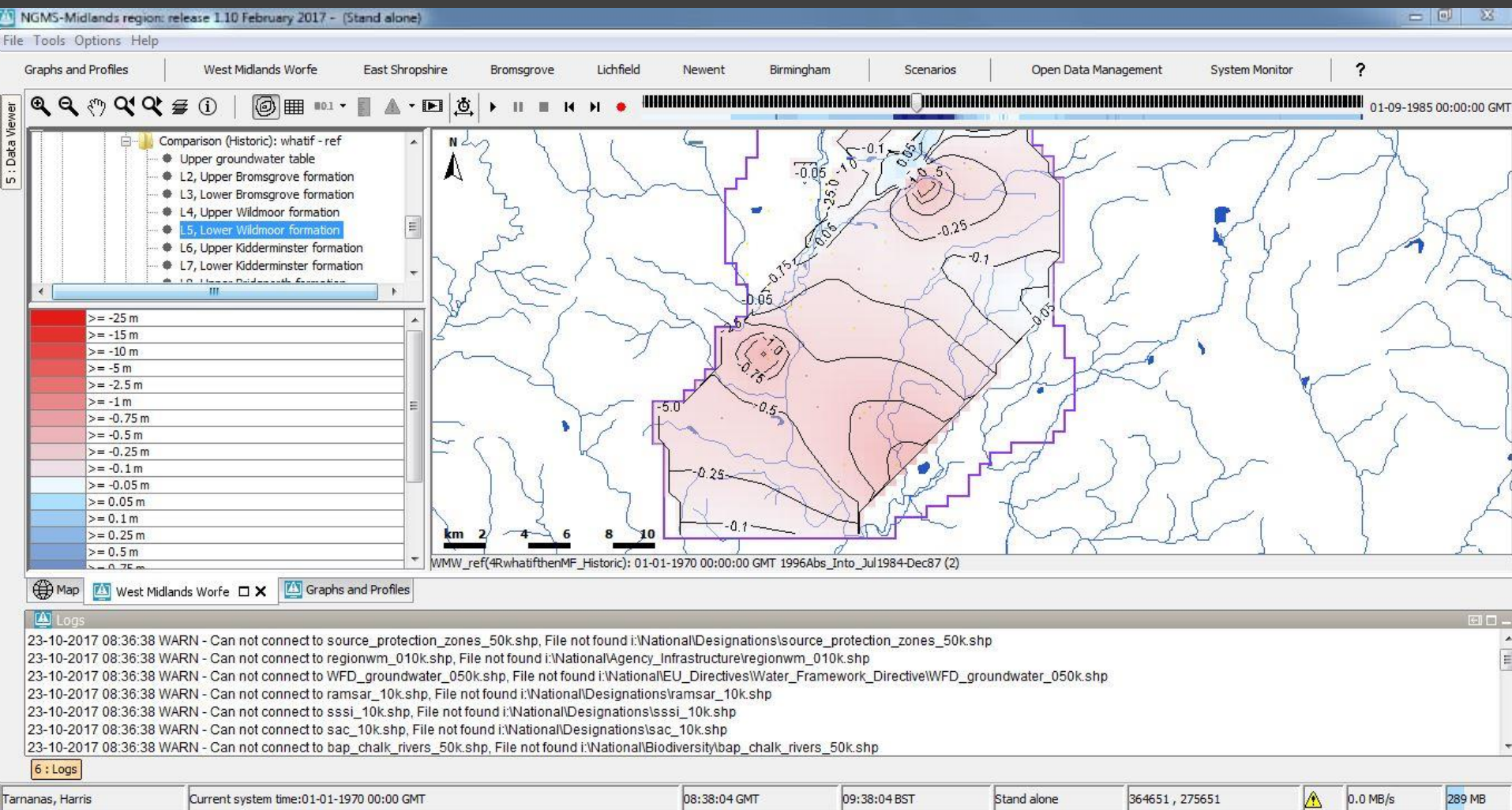
Recharge scenario results – river flows



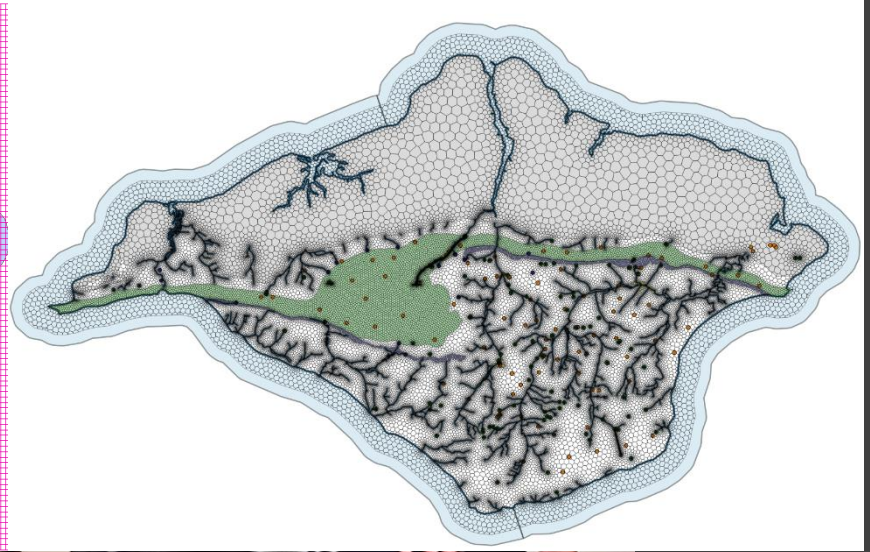
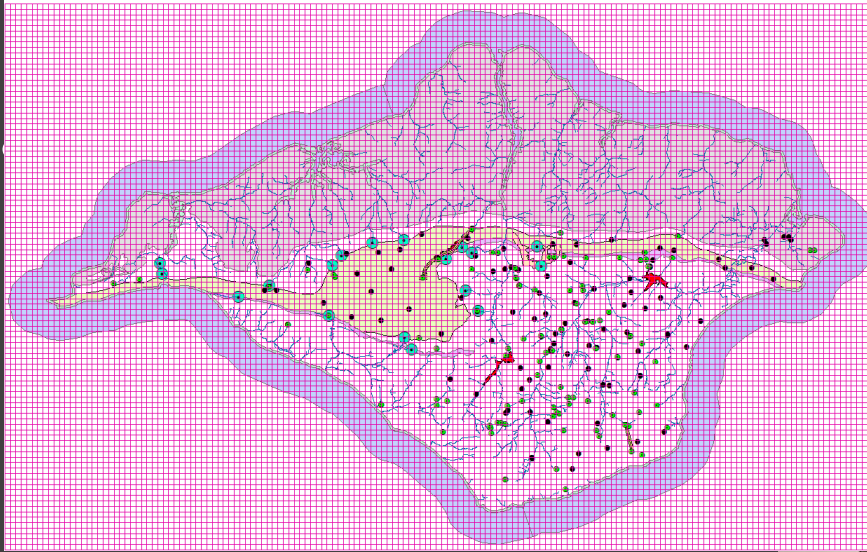
Rainfall difference plot – end of drought



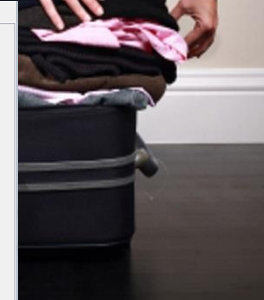
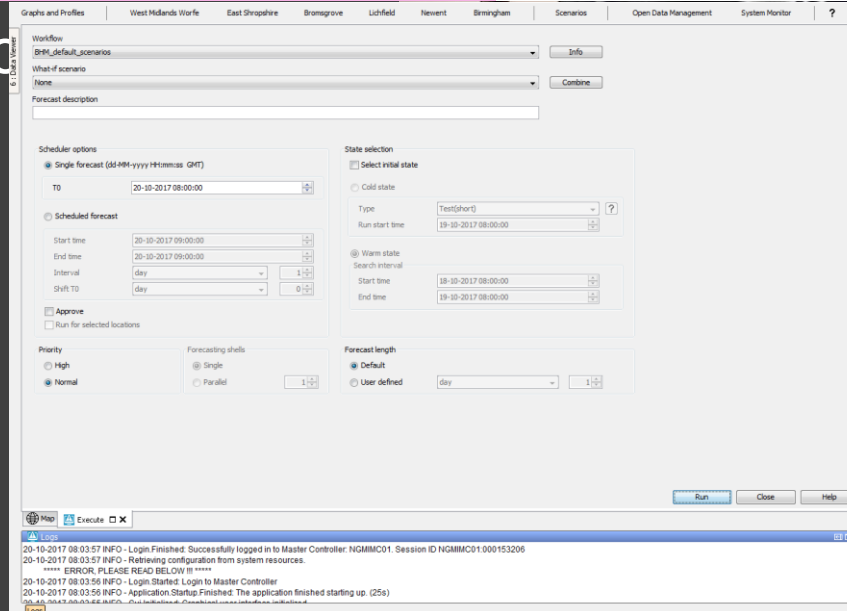
Recharge scenario results – groundwater head difference (end of drought)



Future NGMS

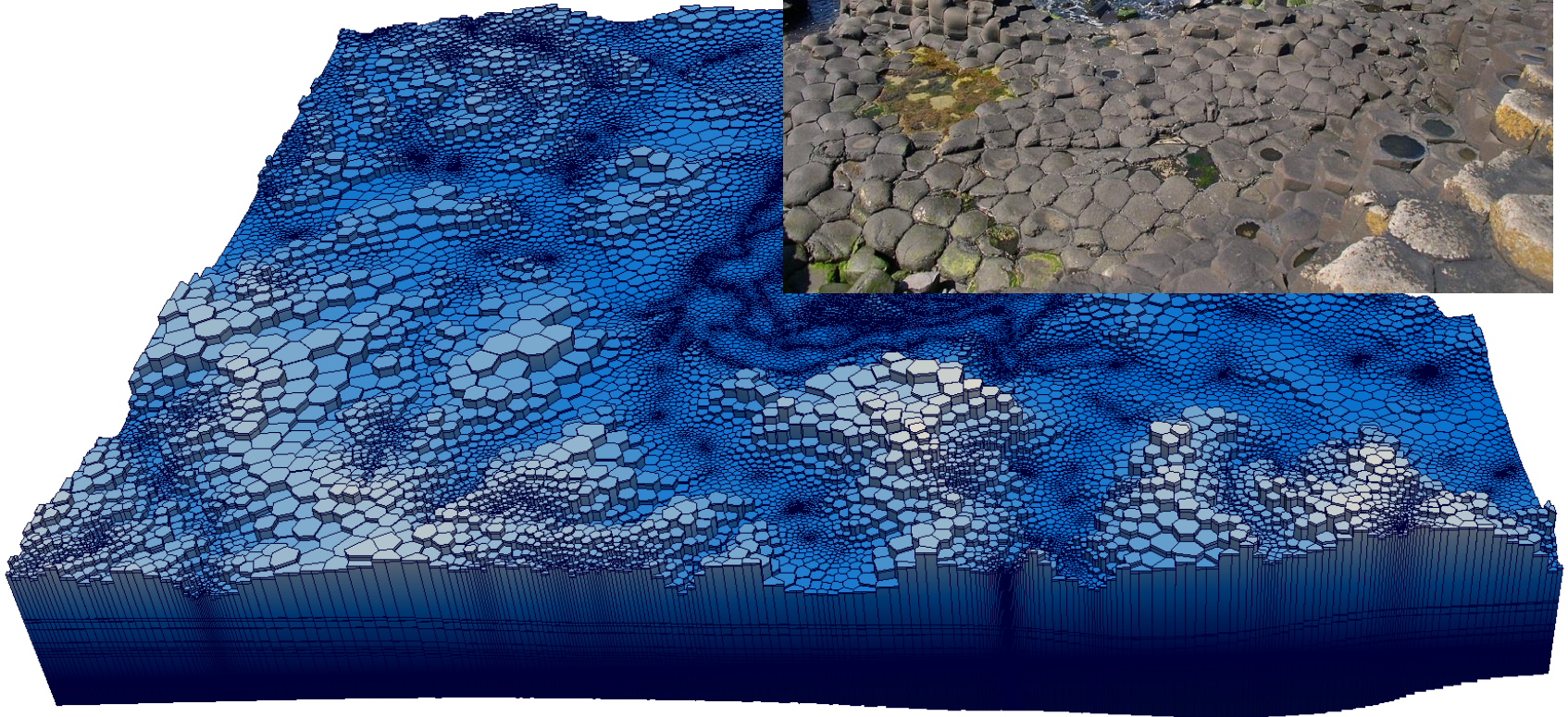


- Water Co
- NGMS

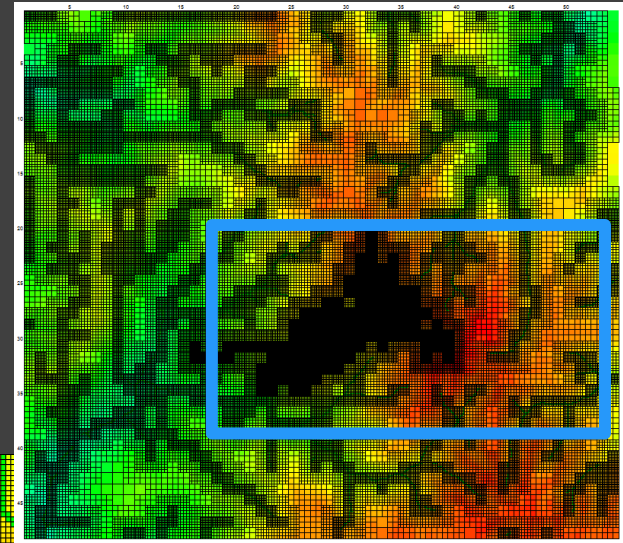
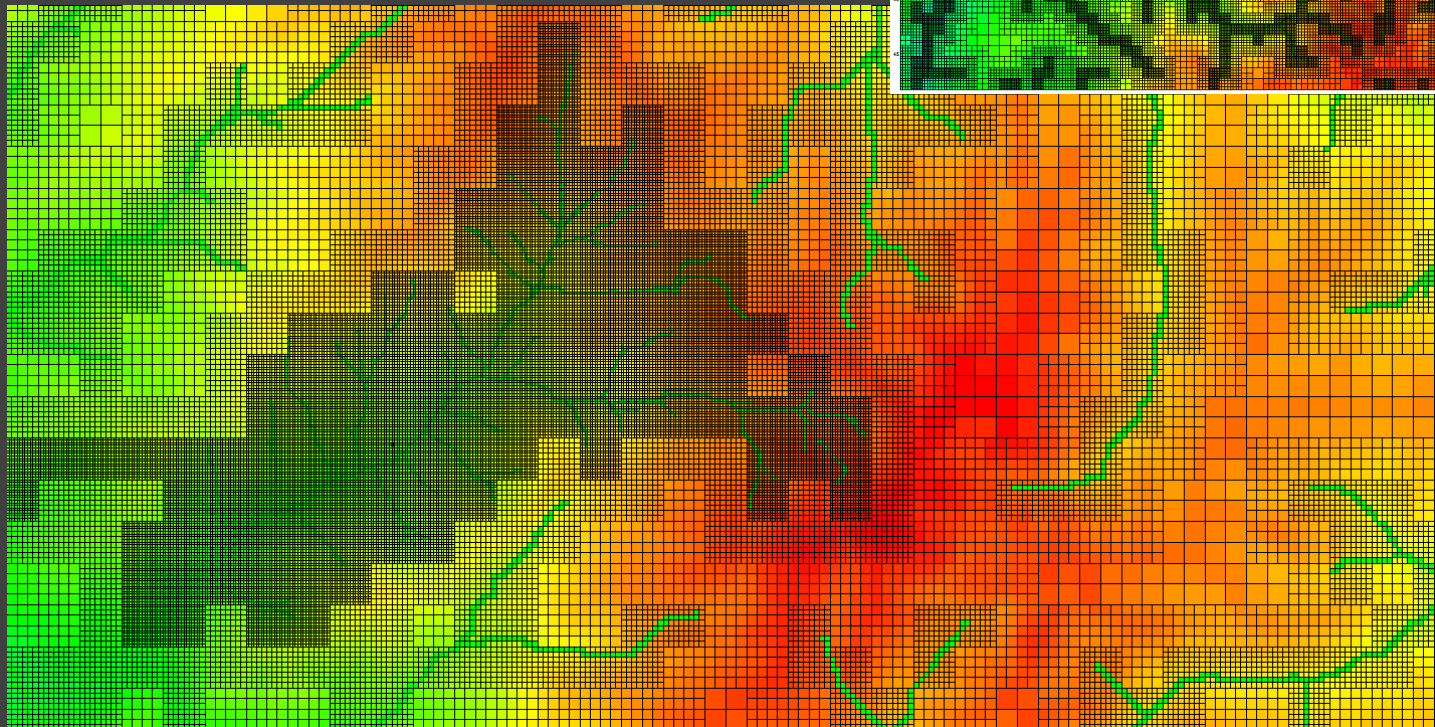


code

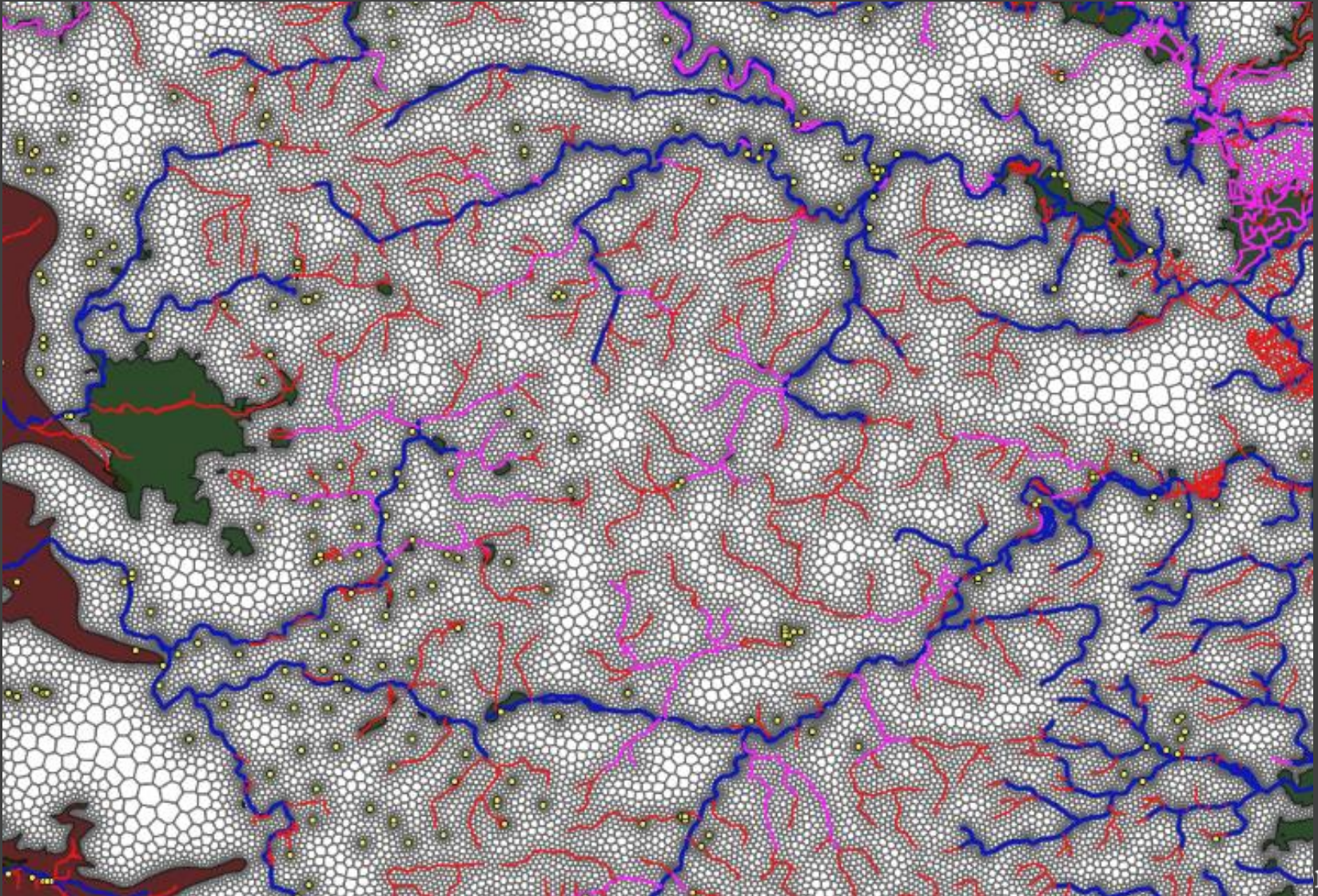
Modflow 6 mesh



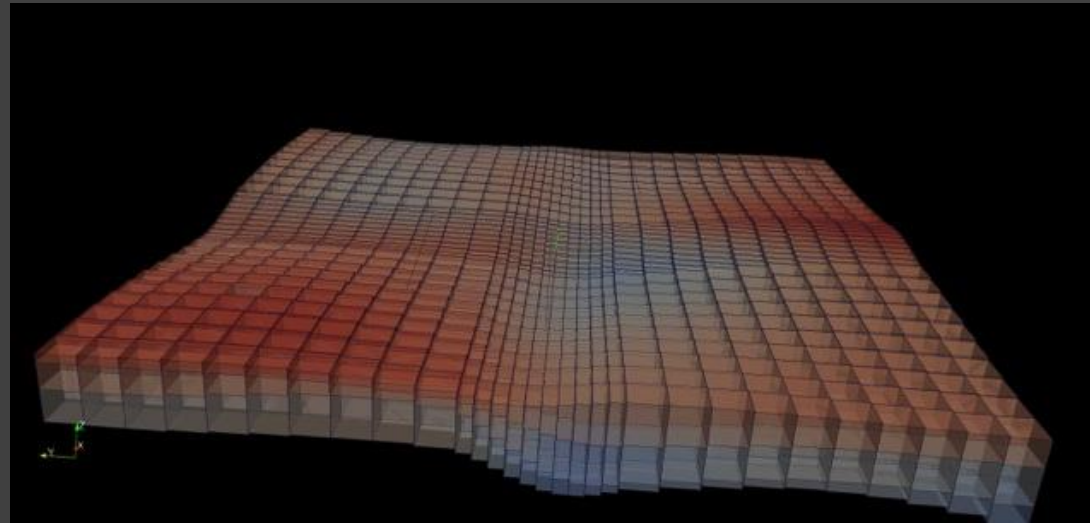
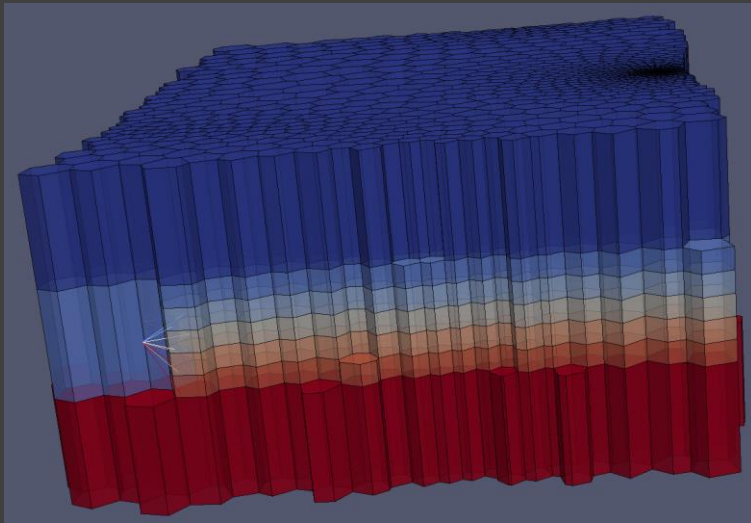
Unstructured Quad Tree mesh



Unstructured Complex Voronoi



Vertical Discretisation and discontinuous layers



Run time.....

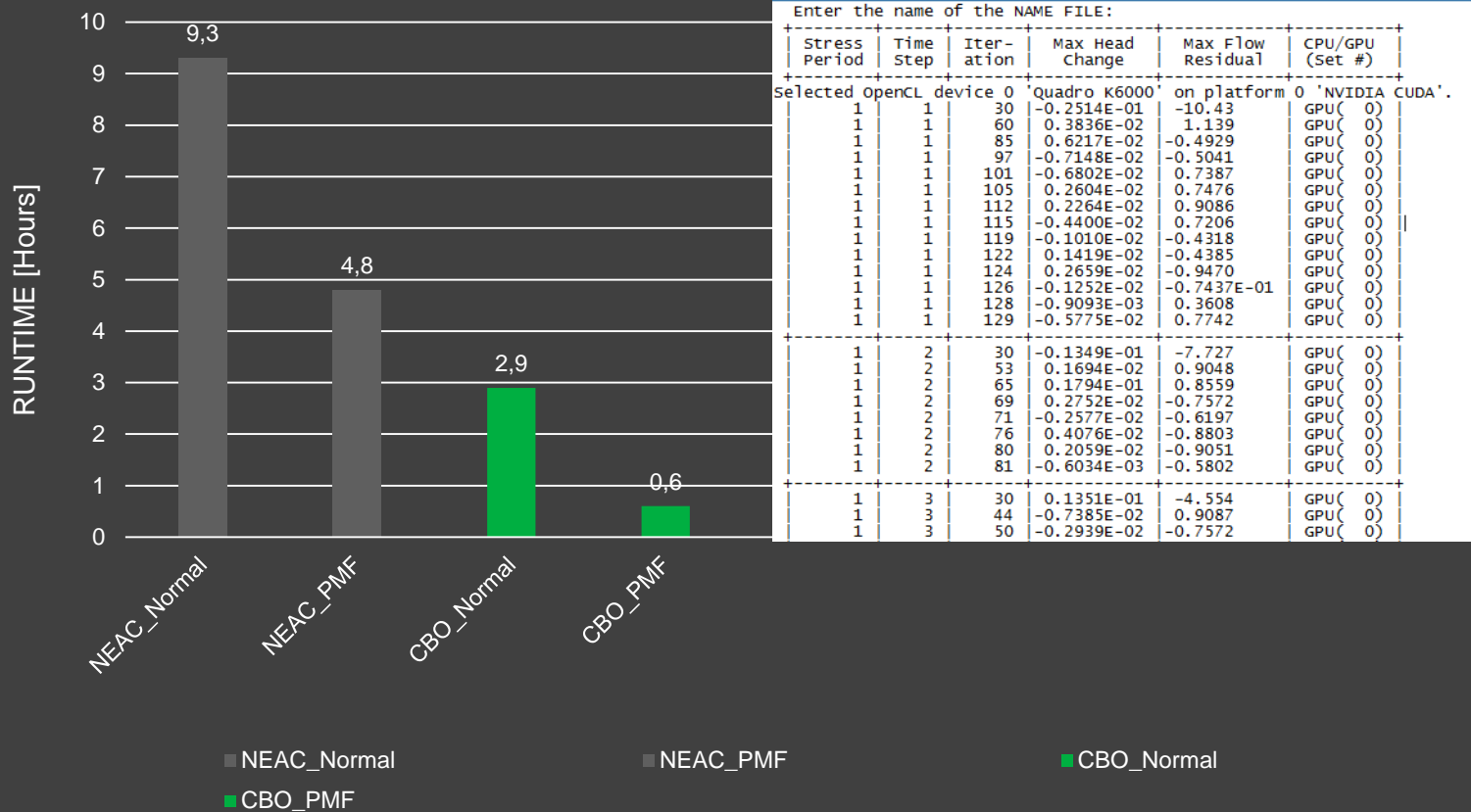
- What makes models bigger???
 - “Big is best”
 - Consultancy steer
 - Irregular grids
 - Insufficient focus on model efficiency (stability, inactive cells, grid spacing)

More usability =

- Control of physical size of model
- Faster Modflow processes
- Faster Delft FEWS processes
- Better (different) hardware
- Avoid unnecessary processes (inactive layers/cells, running “sub models”, shorter scenario periods etc)

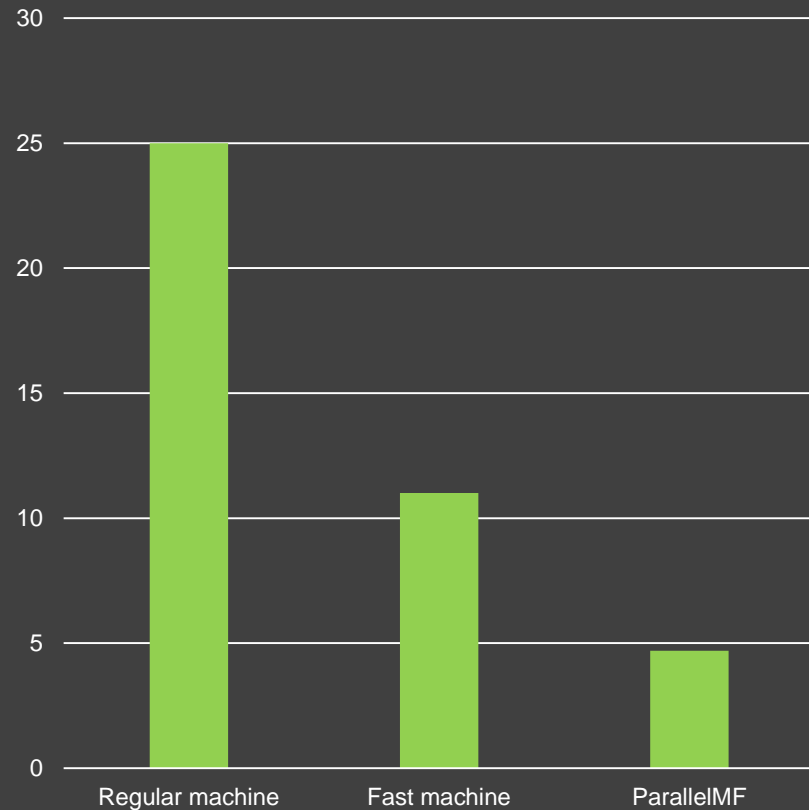
Parallel Modflow (PMF) vs “Normal” Modflow

RUNTIME [Hours] -
on a very fast CPU = 4.4Ghz, 12 core vs GPU = RX480 - 2304 core @
1.2Ghz.



A faster running NEAC model

MODFLOW6 / USG can be notably faster
Parallel MODFLOW further improvement
Model stability is key



NEAC runtime (hours)
per scenario

Reducing run time – an unhelpfully large model from Southern England.....

	File size (Gb)	MF runtime (hours)	NGMS Runtime (hours)	Total runtime (hours)
As delivered	630	96	96	192
Parallel Modflow	630	24	96	120
Remove inactive layers, rows and columns	302	19	46	65
Reduce stress periods per timestep (reduce output file sizes)	75	13	11	25
Single Scenario	18.8	3.4	2.9	6.3

Future NGMS

- New developments in Modflow 6 not compatible with current NGMS
 - Unstructured grids
 - Completely new input file format
 - New module adapter needed
- New system structure
 - Focus on ease of use (actual functionality OK)
 - Focus on system reliability/availability

Questions to the audience

- Benefits of moving to cloud?
 - Dealing with physical servers seems a bit old fashioned
- Handling irregular growth (multiple dimensions)
- Faster run times in large scale



Thank you.....