EPA Webinar: Plume Stability Analyses with GWSDAT

GWSDAT

GroundWater Spatiotemporal Data Analysis Tool

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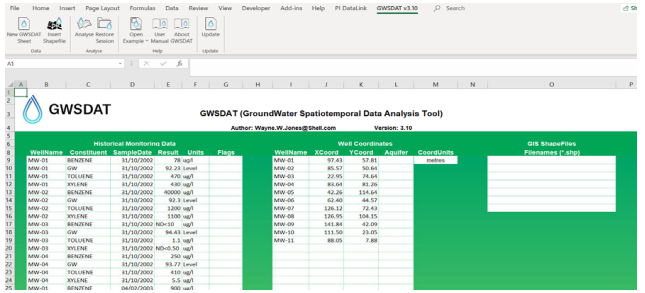
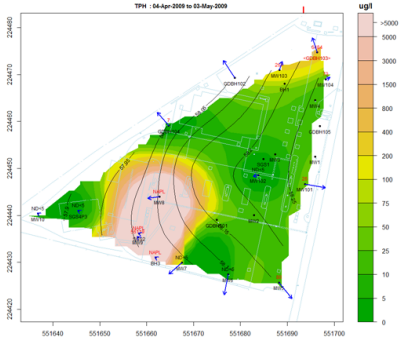
GWSDAT – what is it?



- User-friendly, open source, **decision support software tool** for analysis & reporting of **monitoring data**.
- Robust, easy to install, intuitive to use, **requires only standard monitoring data input** (e.g. well coordinates, time series solute concentration data
- Dataset **upload in variety of formats**, analysis at the **click of a button**, **export of output** (e.g. PowerPoint), no special expertise or software required.
- **Run locally** on a user's PC / laptop **or online** via web app.
- Works equally well for both **small** (e.g. retail) **or large** (e.g. refinery) **sites**.



GWSDAT - business benefits

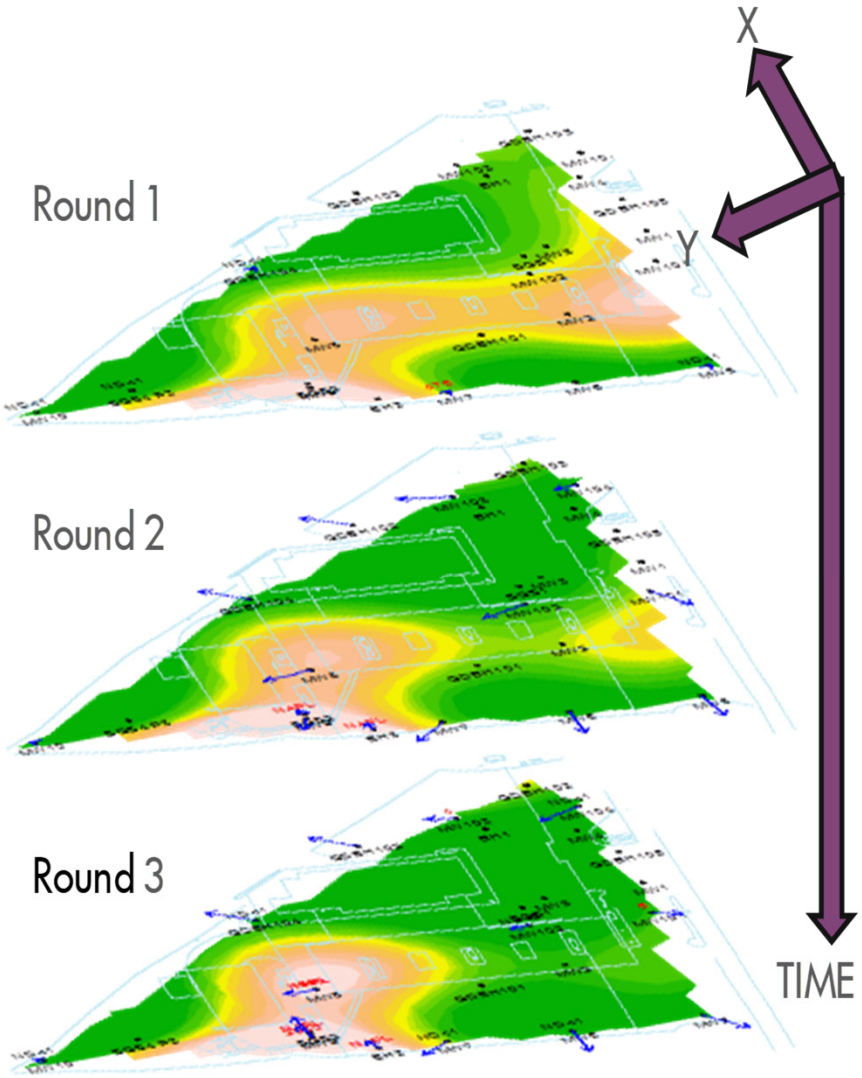
- **Tool used operationally in monitoring & assessment** of Shell's global downstream assets (e.g. refineries, terminals, fuel stations) for a period of **over 10 years** → achieved **significant efficiencies & savings**, e.g.:
  - Support **design and optimization** of monitoring and/or remediation programs (i.e., avoid collection of redundant data).
  - **Early identification** of potentially new releases, migration pathways, need for corrective action, stable / declining trends that may aid in assessing project closure.
  - **Rapid interpretation** of complex datasets from large monitoring networks (e.g. refineries, terminals).
  - **Efficient evaluation and reporting** of monitoring trends via simple, standardised plots and tables created at the 'click of a mouse'.

GWSDAT – evidence of increased global adoption.

- More than 10 use-cases including Shell, US EPA, Exxon and training videos in Indonesian. http://gwsdat.net/case-studies/
- GWSDAT accepted by regulatory agencies, e.g. UK Env. Agency refers to tool as part of guidance document on contaminated land risk management. https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm/lcrm-stage-1-risk-assessment#GWSDAT
- GWSDAT LinkedIn user group. https://www.linkedin.com/groups/8715423/
- ITRC. 2013. GW Statistics and Monitoring Compliance, Statistical Tools for the Project Life Cycle. GSMC-1. Washington. https://projects.itrcweb.org/gsmc-1/

GWSDAT trend analysis

- **Smoothing Statistics** to capture the important patterns and trends in the data.
- **Time Series (Temporal) Statistics** to detect trend components.
- **Spatial Statistics:** for modelling geographic relationships.
- **Spatiotemporal Statistics** providing a clear interpretation of contamination plumes

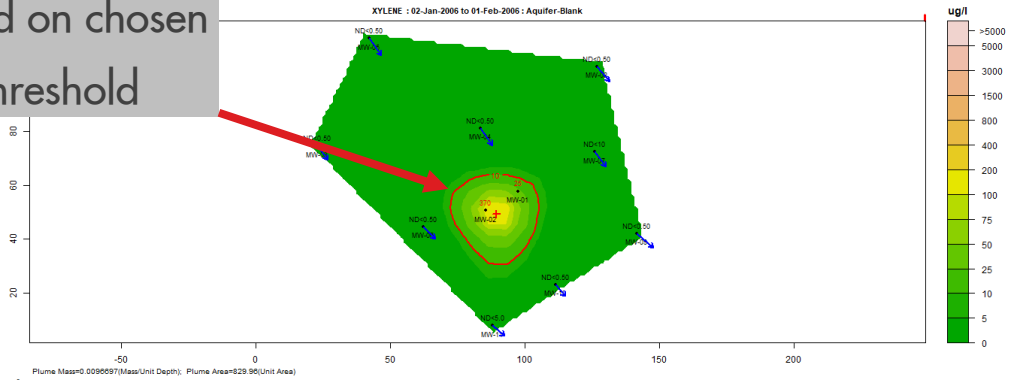


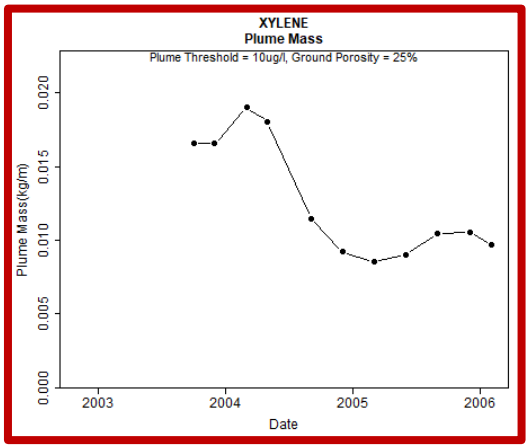
GWSDAT plume diagnostics

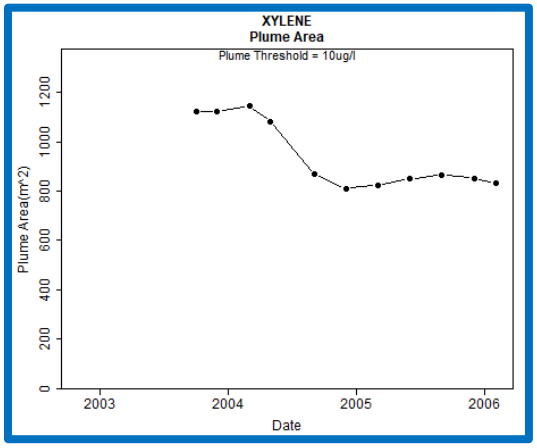
- for a **specific analyte**:
  - plume mass
  - plume area
  - average plume concentration

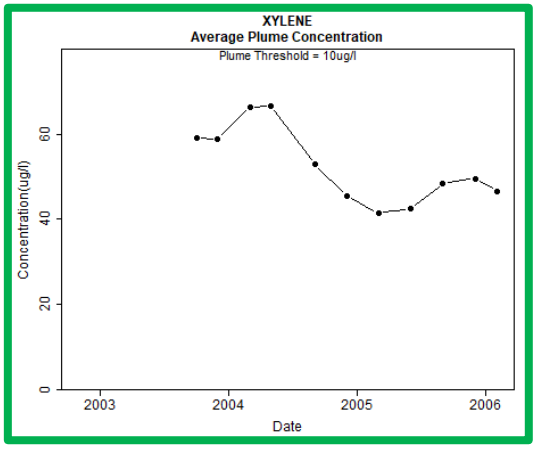
→ Evaluation of plume stability

Plume boundary based on chosen threshold

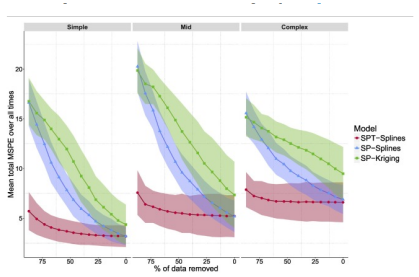








Network Optimisation



- Recent Publication:

  "Statistical modelling of groundwater contamination monitoring data: A comparison of spatial and spatiotemporal methods" Science of the Total Environment: https://doi.org/10.1016/j.scitotenv.2018.10.231 & PhD Thesis: http://theses.gla.ac.uk/38975/

- **Conclusions:**
  - **More** information using **fewer** observations with a spatiotemporal model
  - Spatiotemporal methods can achieve same level of performance but with fewer data points. GWSDAT users are already enjoying this benefit.
  - New PhD student started at University of Glasgow, Oct 2021: Implementation of cost-effective spatiotemporal approaches to optimize groundwater monitoring network design and data analysis.
  - **Version 3.1 is the beginning of the journey in incorporating Network Optimisation tools into GWSDAT.**

GWSDAT V3.1 – New Features and Enhancements

- **Well Redundancy Analysis:** allows user to very conveniently drop a well or a combination of wells from analysis and investigate resultant impact.
- **Updated user manual:** http://gwsdat.net/gwsdat_manual/. Completely overhauled and updated.
- **Excel Add-in:** Updated technology to avoid frequently reported issue of the GWSDAT Excel Add-in menu not being displayed.
- **Updated branding:** Excel data input templates updated with more contemporary colour schemes which align with branding here: www.gwsdat.net.
- **Custom Colour Key:** In response to user feedback added functionality to customise colour key in main GWSDAT spatial plot.
- **Export Contours to ArcGIS**: Export of GWSDAT solute concentrations contours via "tiff" output format.
- Other minor bug fixes and enhancements.

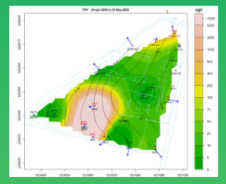
GWSDAT V3.1

Demonstration

WWW.GWSDAT.NET

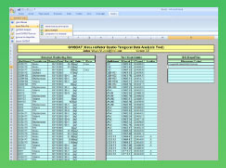
GWSDAT

An open source, user-friendly, software application for the visualisation and interpretation of groundwater monitoring data.

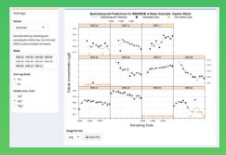


A spatiotemporal model provides a more powerful analysis than spatial modelling at isolated time points or temporal modelling at isolated locations.

Visualisation of site-wide trends in solute concentrations, with interactive control. Trend and threshold matrices can be constructed as summary indicators.



Ease of data entry through a MS Excel spreadsheet containing well co ordinates and solute concentrations at specific times. Wells can be grouped into separate aquifers. Site maps can be added as GIS shapefiles.



Automatic report generation tools, including site reports and spatial plots at user specified times with groundwater and NAPL data overlaid. Plots can be exported directly to MS PowerPoint.

The simplest form of access to GWSDAT is through the on-line tool.

GWSDAT on-line

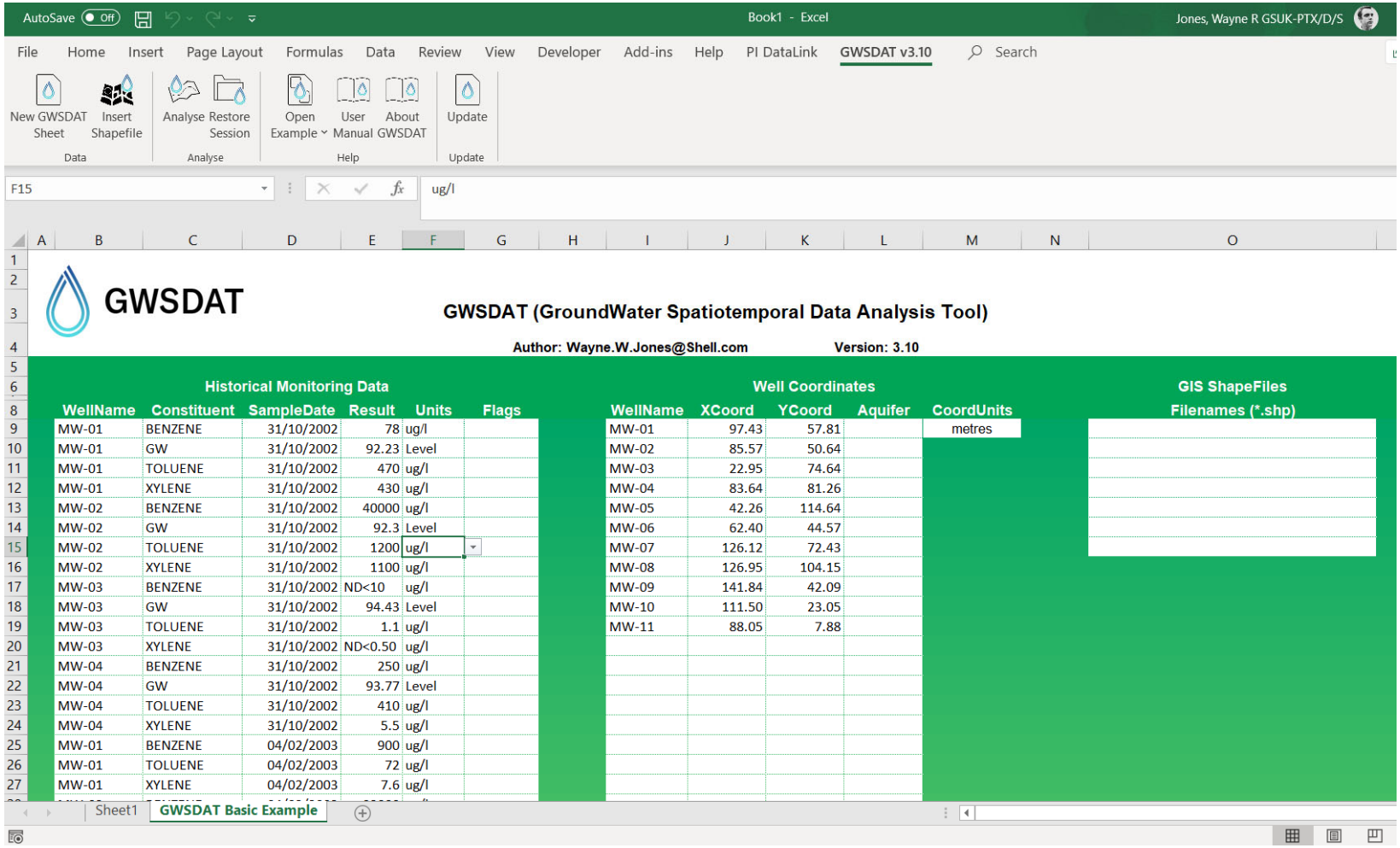
Guidance on use of the tool is available in the Getting Started page.

A version of the tool which can be installed locally is available either as an R package from CRAN or as an Excel interface from the API and CL:aire.

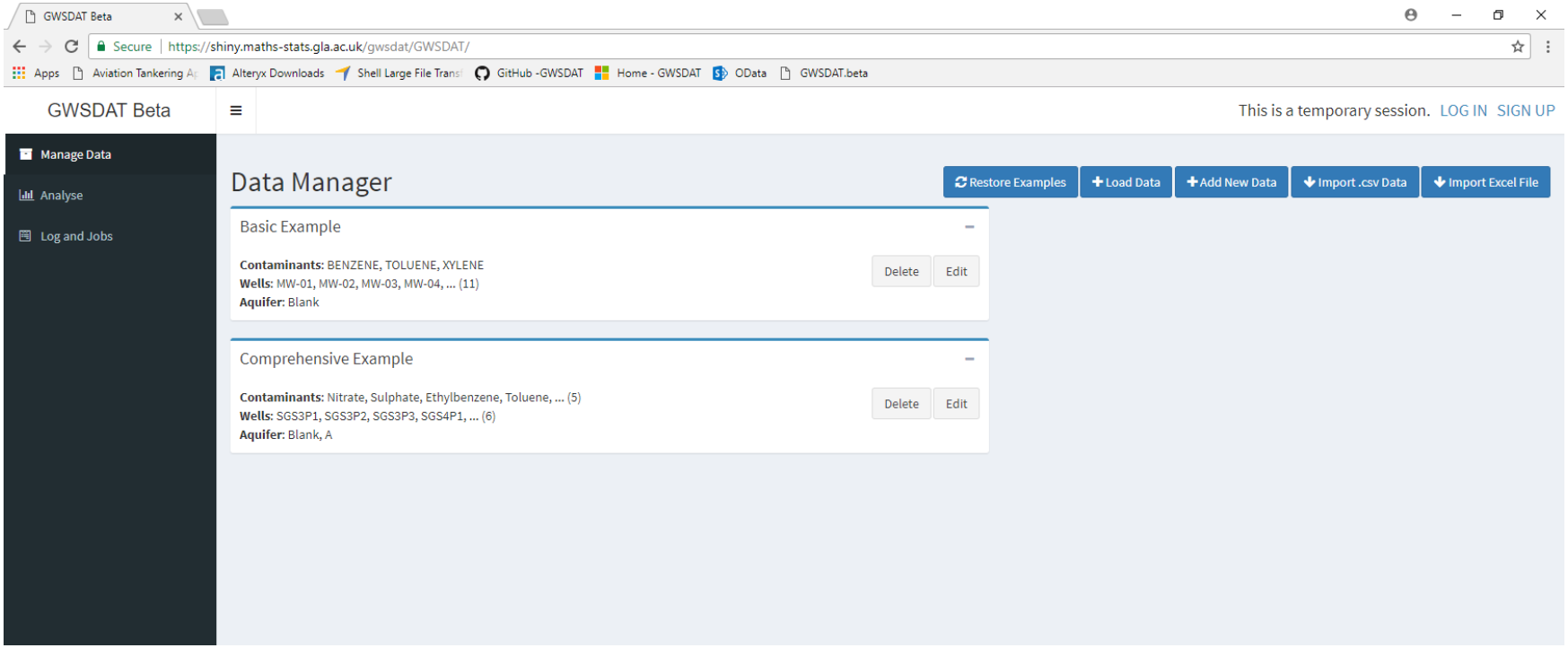
GWSDAT

Ground**W**ater **S**patiotemporal **D**ata **A**nalysis **T**ool

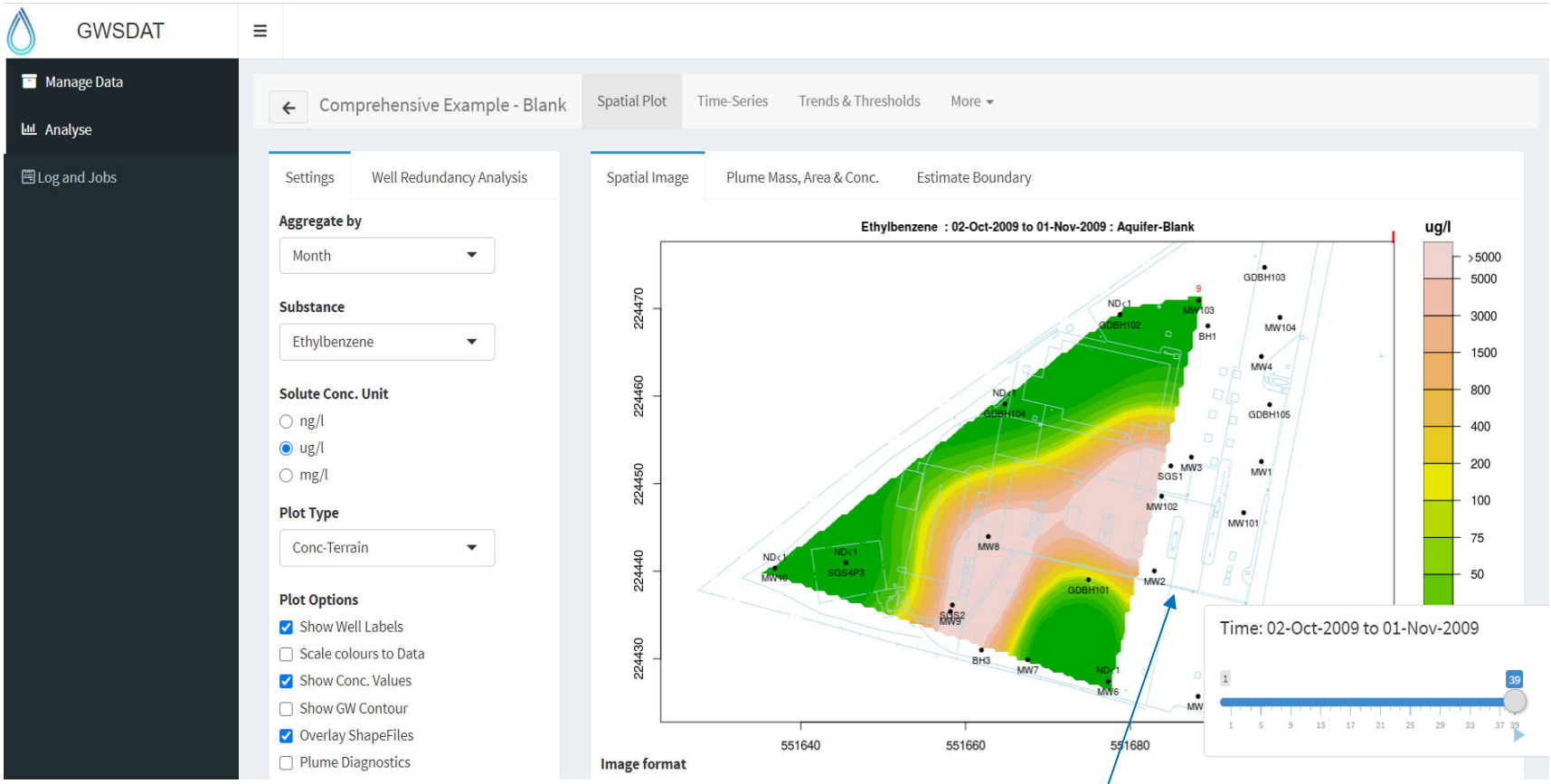
GWSDAT V3.1 – Updated Add-in menu and branding.



GWSDAT V3.1 – Screenshot - Data Management Page (online version)

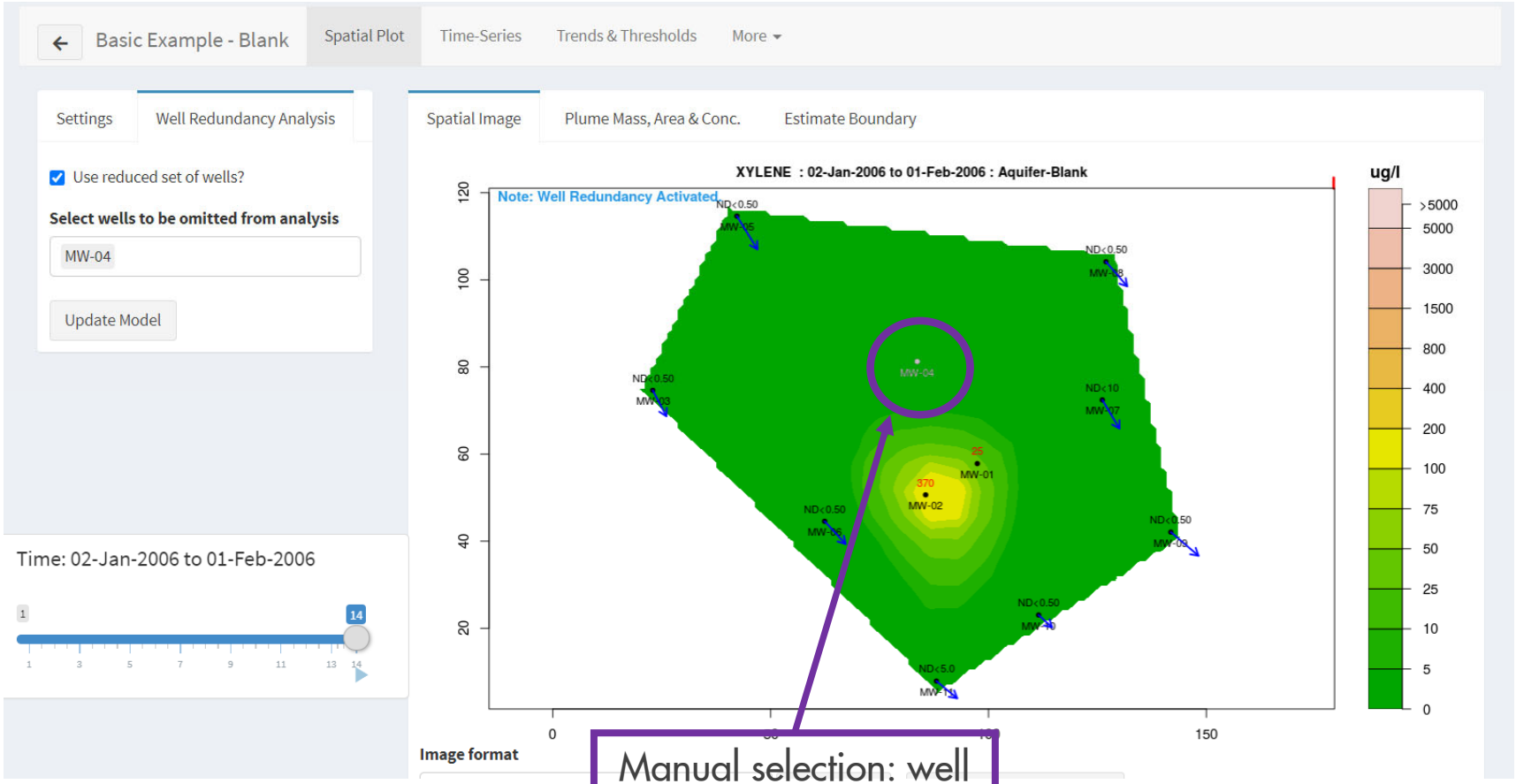


GWSDAT V3.1 – Screenshot - Spatial Plot

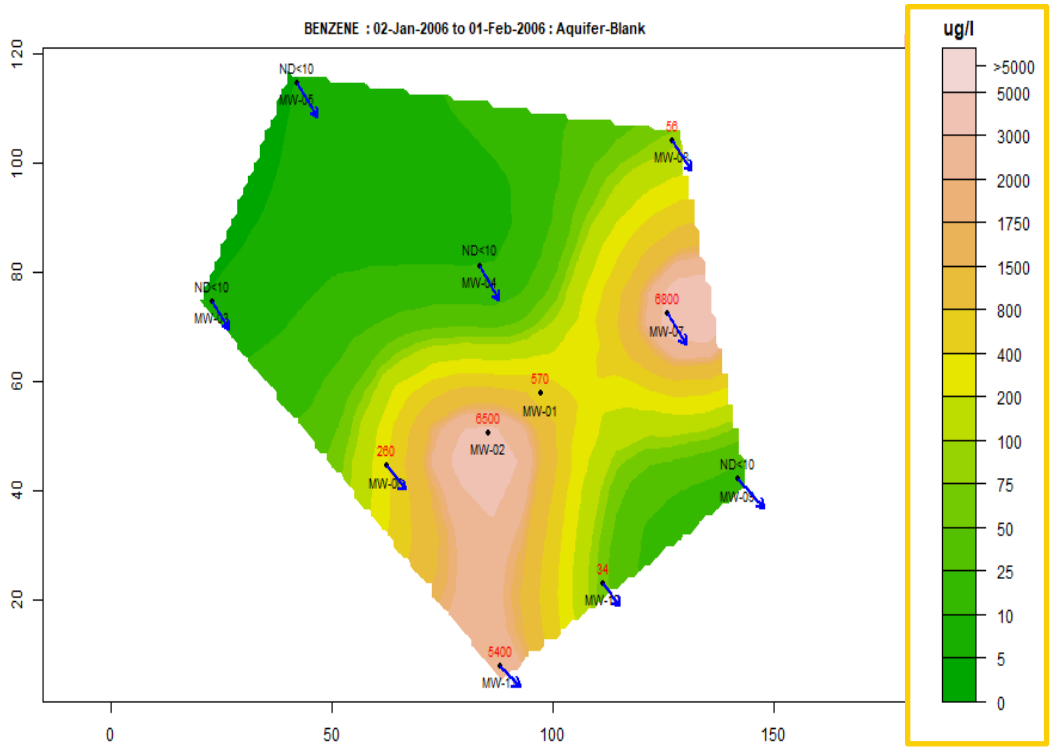


➤ Option to add map of site infrastructure

Well Redundancy – Spatial Image
(Toggle between full model and model with well MW-04 removed)



Ability to customise Spatial plot Colour Key.



Customise the Spatial Plot Colour Key

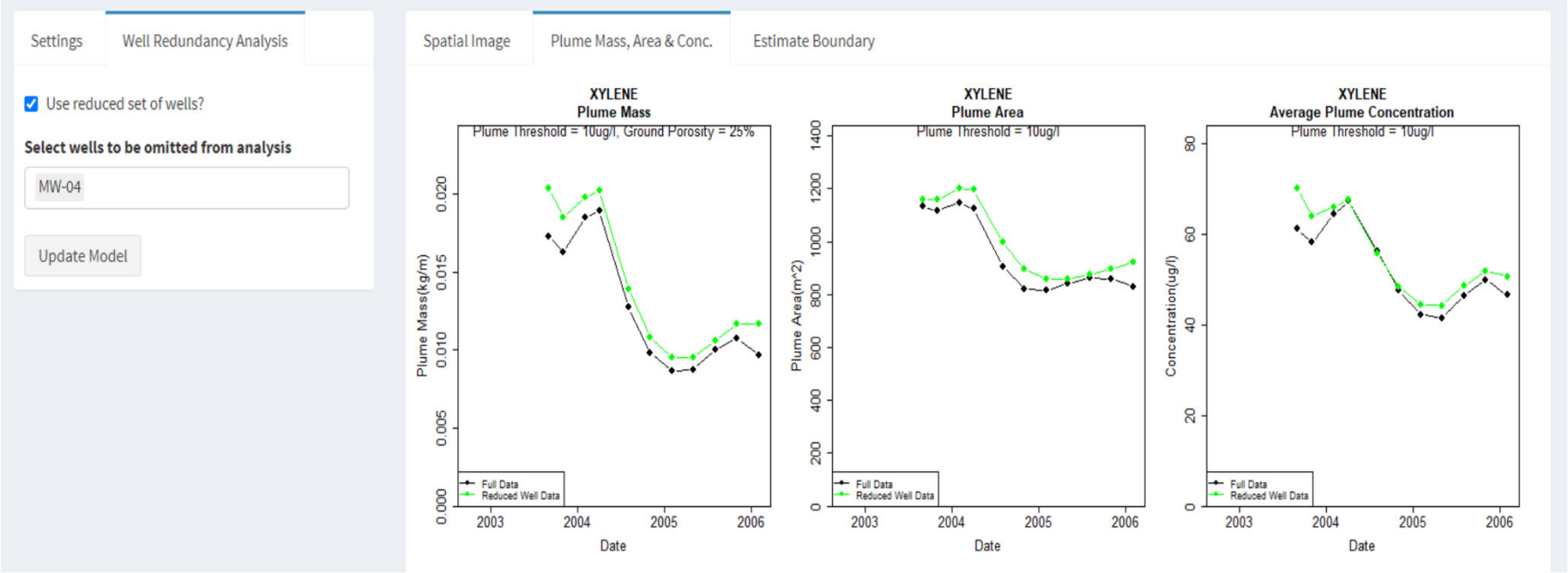
Specify the contouring intervals for each solute in ug/l.

BENZENE	TOLUENE	XYLENE
0.00	0.00	0.00
5.00	5.00	5.00
10.00	10.00	10.00
25.00	25.00	25.00
50.00	50.00	50.00
75.00	75.00	75.00
100.00	100.00	100.00
200.00	200.00	200.00
400.00	400.00	400.00
800.00	800.00	800.00
1500.00	1500.00	1500.00
1750.00		
2000.00		
3000.00	3000.00	3000.00
5000.00	5000.00	5000.00

(Double-click on cells to edit)

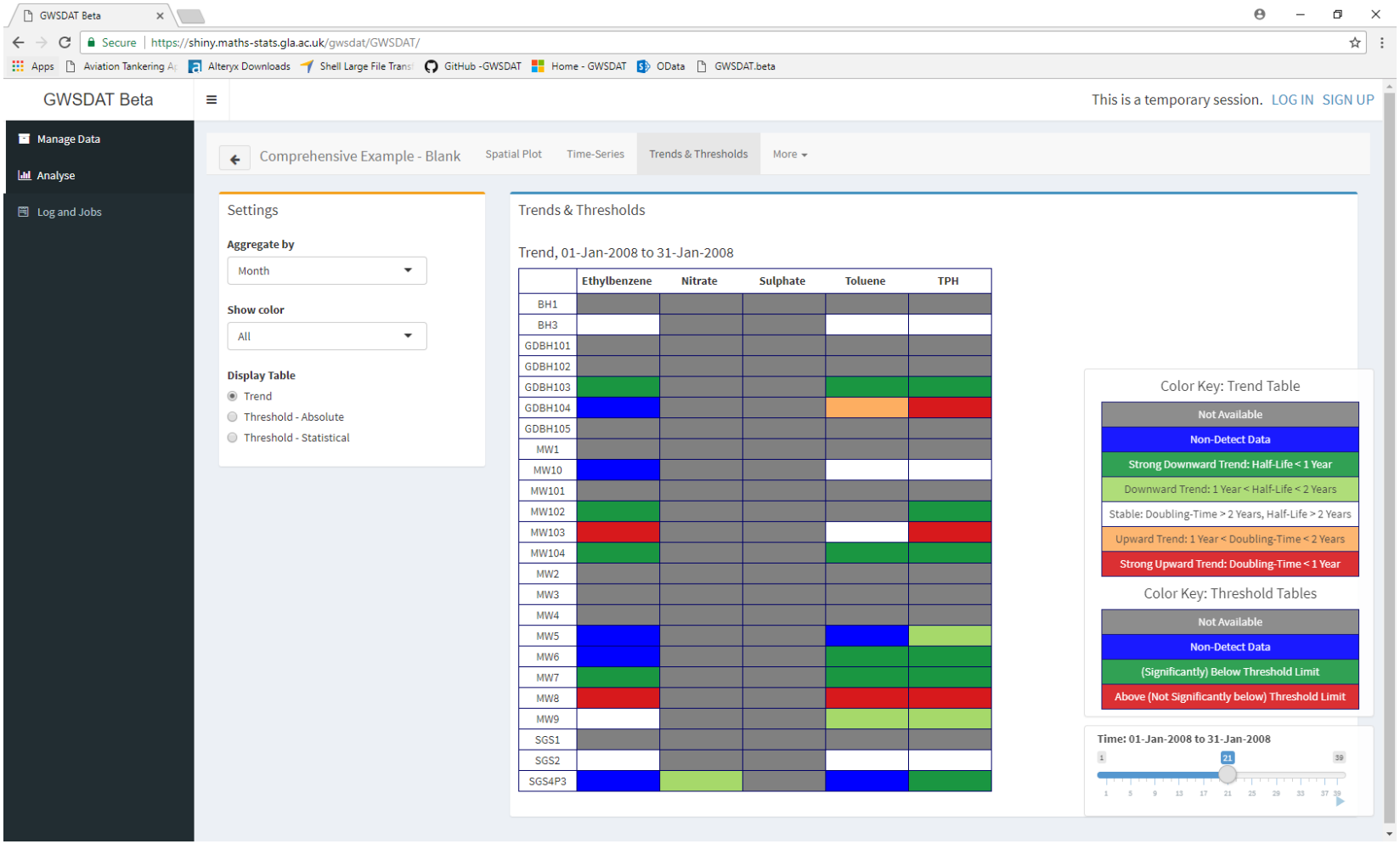
(Right-click on cells to add or delete rows)

Well Redundancy
(Comparing Plume metrics with well MW-04 removed)

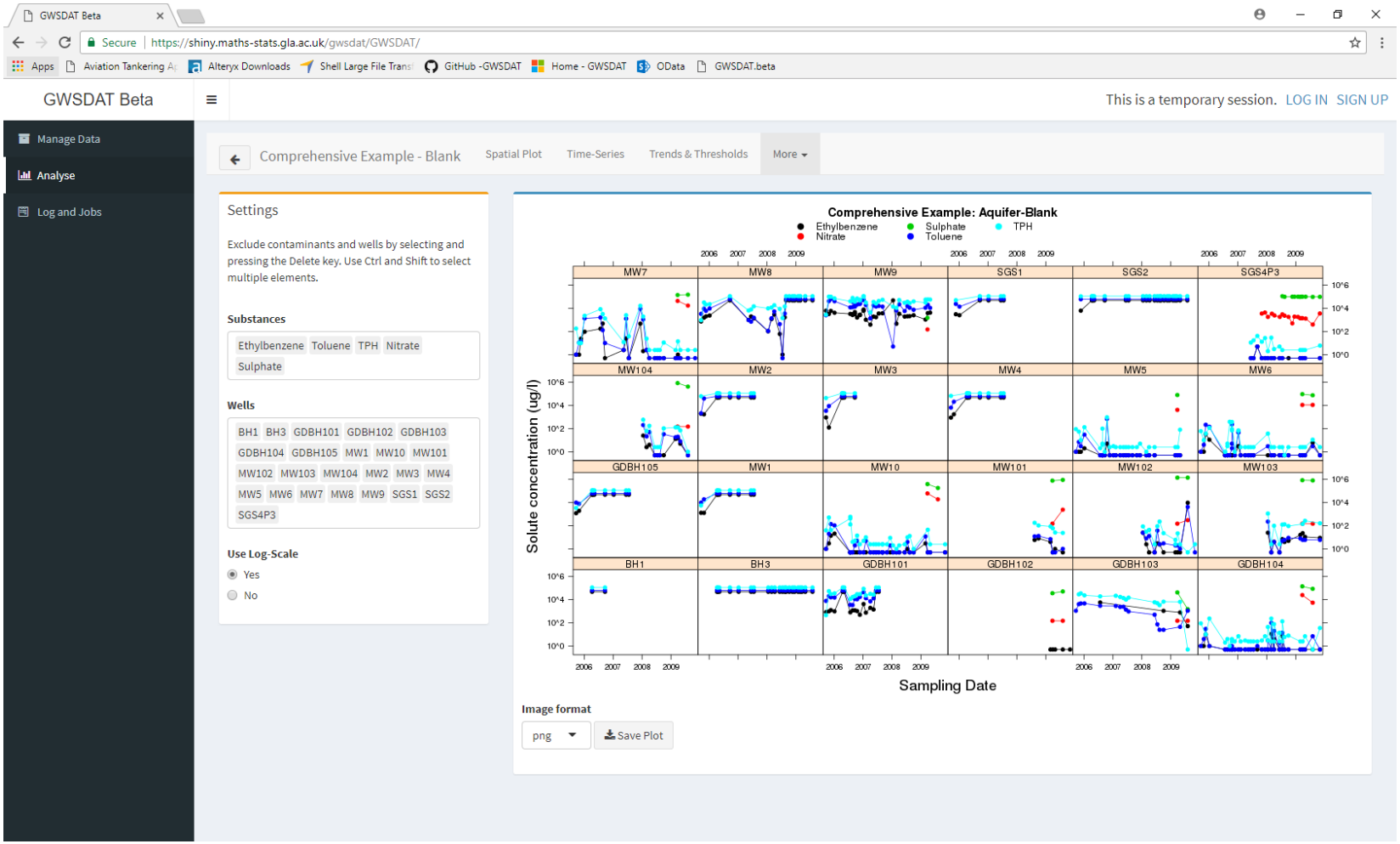


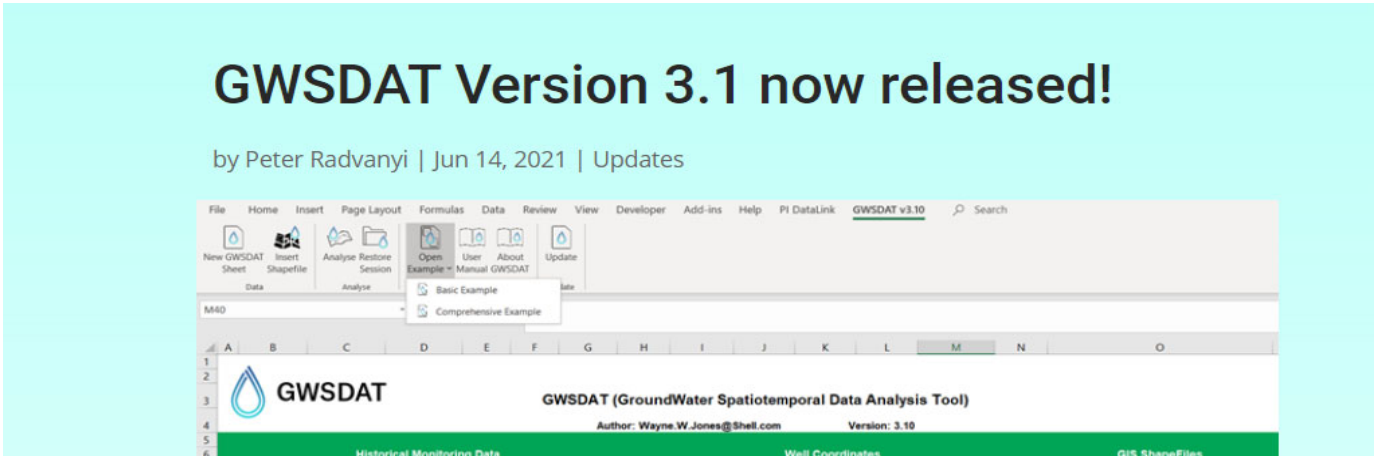
- Black line: original dataset
- Green line: reduced dataset

GWSDAT V3.1 – Screenshot - Traffic Light Plot



GWSDAT V3.1 – Screenshot - Well Time Series Reporting





- GWSDAT V3.1 released in August.
- Available to download from: www.api.org/GWSDAT , www.claire.co.uk/GWSDAT and www.gwsdat.net.
- On a longer term basis, we are interested to hear ideas about features related to Well Network Optimisation, e.g. New well placement, Well sampling schemes/strategies, etc.

GWSDAT - Case studies: “Plume stability”

Background on case studies

- **Data source**: real, anonymized from 2 sites
- **Geological setting**: non-fractured siliciclastic
- **Site general information**:

Site	Objective	Site setting
#1	Plume stability – optimization in sampling interval	residential commercial
#2	Plume stability – gap in monitoring network, earlier adoption of tool	residential commercial recreational

- **Support**: Gratefully acknowledge B. Kautsch (Shell); A. Wesch, E. Marzusch (Arcadis)

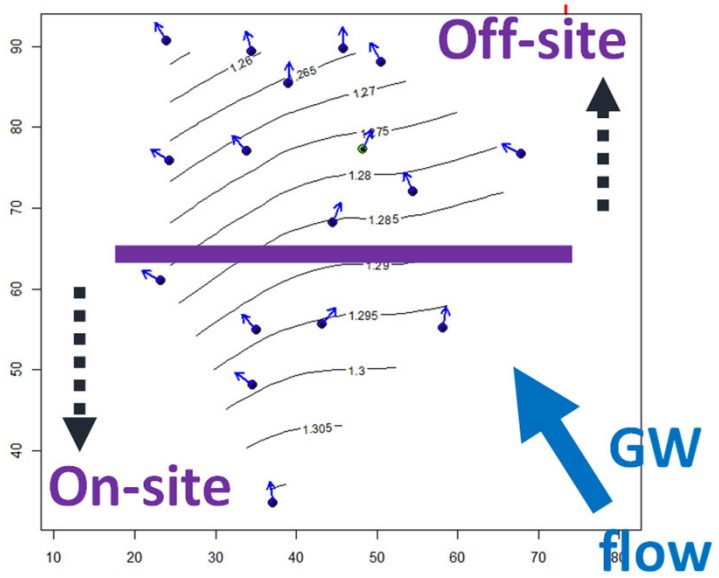
Case study – Site #1

- **Objective**:

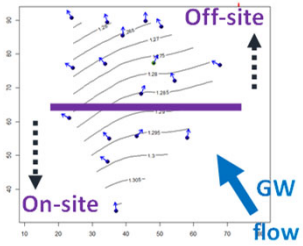
Demonstrate plume stability with the aim to optimize sampling frequency interval

- **Site history**:
  - Mid 1990's: impact observed, primarily BTEX, partial remediation soil excavation
  - Early 2000's: GW monitoring implemented
  - Plume beyond site boundary
- **GW sampling**:
  - Frequency varied - quarterly to bi-annual
  - Over 15 locations

→ Proposed change to annual after recent bi-annual sampling event



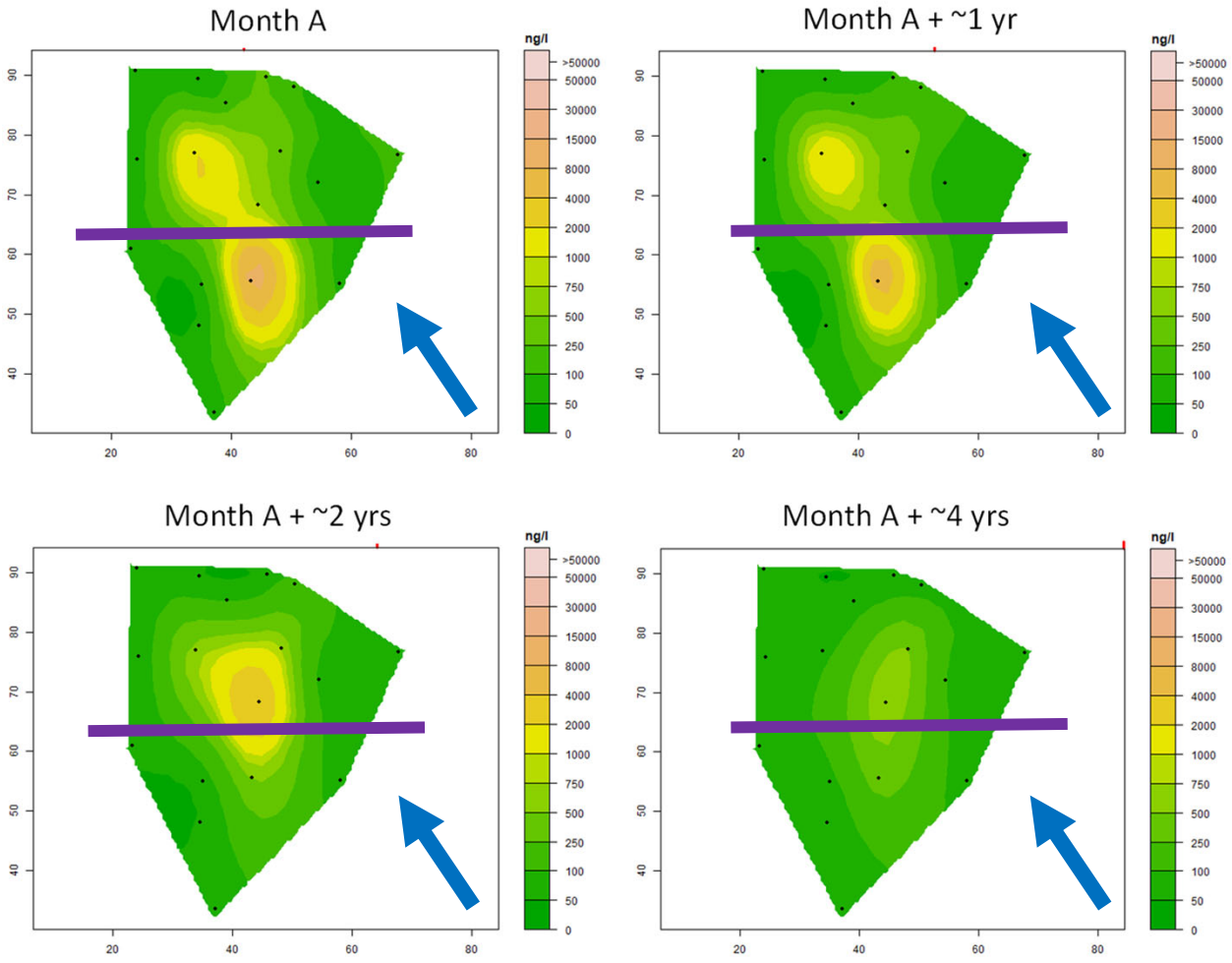
Case study – Site #1



Data shown

to most recent

- **Observations**:
  - Time slices of spatiotemporal plots showing part of historical BTEX plume evolution
  - **Plume**: stable and shrinking

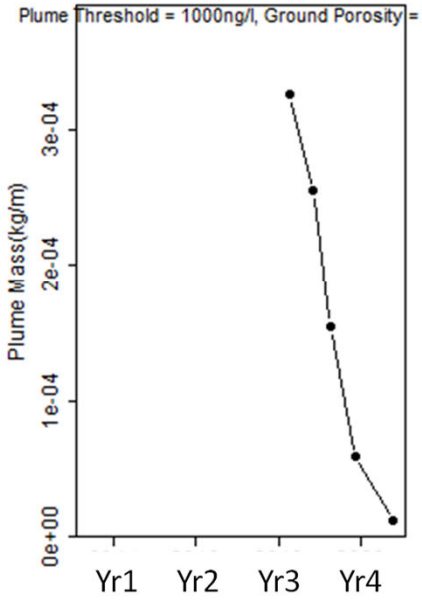


Case study – Site #1

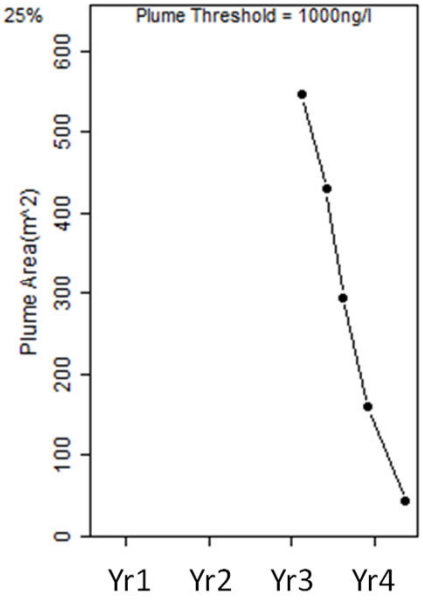
Benzene

- **Observation**:
  - Plume diagnostics functionality output for benzene
  - **Plume trends**: decreasing mass, area, & average concentration

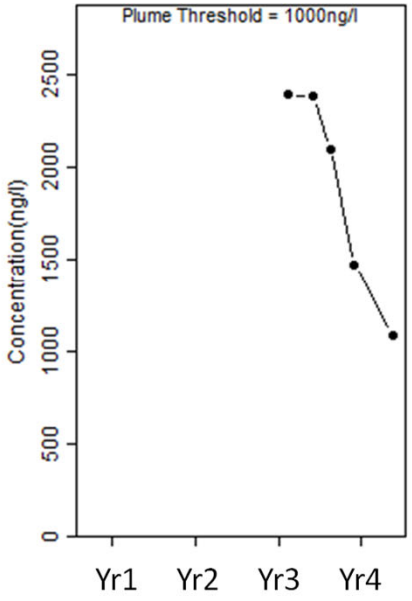
Plume Mass



Plume Area



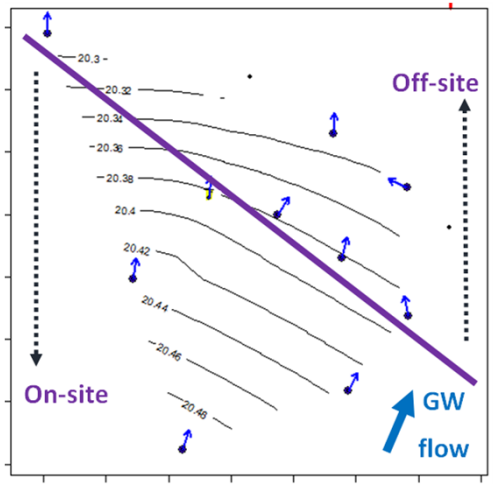
Average Plume Concentration



Benzene: threshold value of 1 ug/L

➢ **Outcome**: Regulator approved change in sampling frequency

Case study – Site #2



- **Objective**:

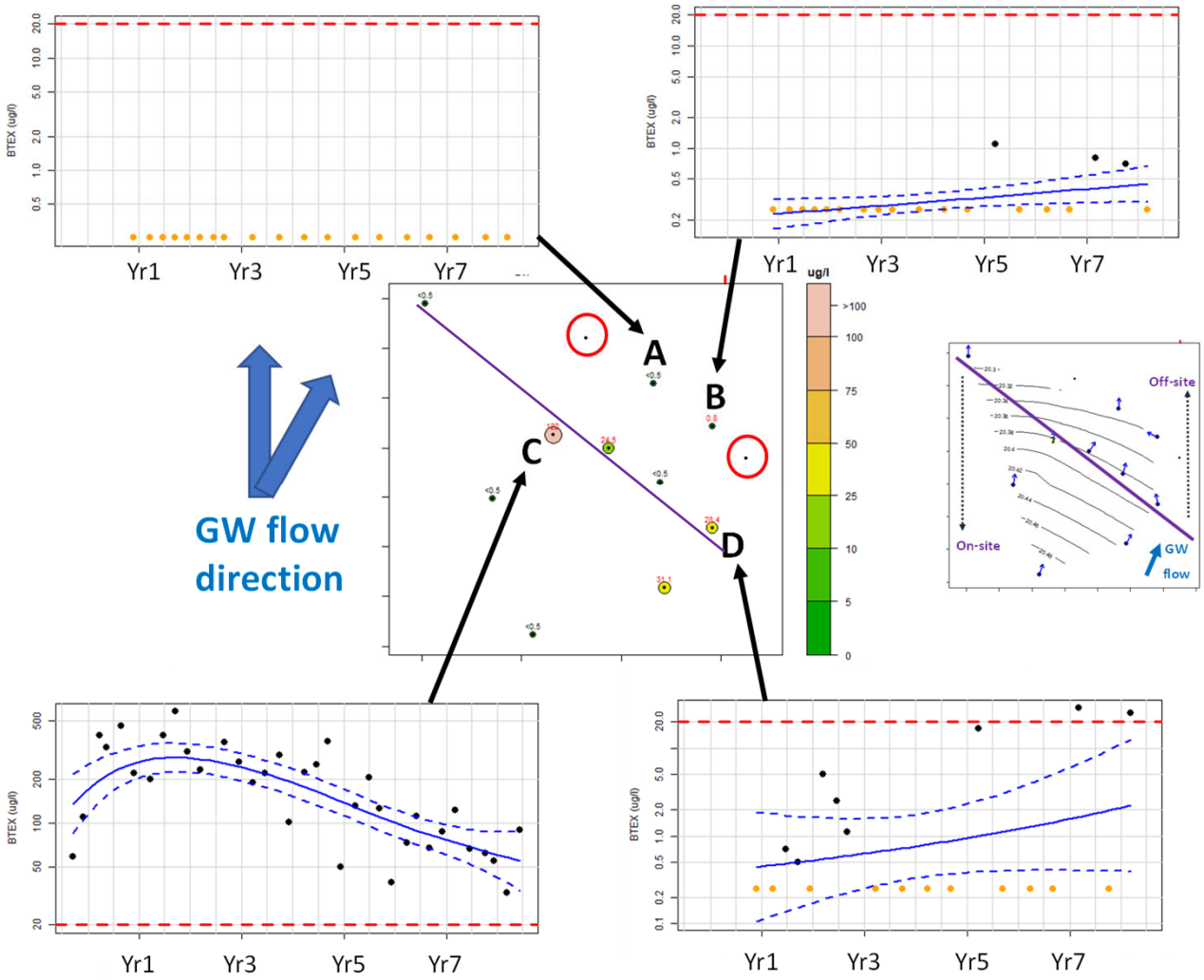
Assess plume stability and evaluation of monitoring network

- **Site history**:
  - In 1990's: several SGW investigations including remedial activities
  - Residual contamination remained
  - Since ~2012: regular GW monitoring to assess TPH, **BTEX**, MTBE
  - Plume at/beyond? site boundary
  - GWSDAT not part of data interpretation workflow process for many years
- **GW data**:
  - BTEX data over 8-year period presented
  - GWSDAT used 1st time for annual reporting of GW monitoring events related to years 6 and 7

→ Proposed additional wells for gap closure

Case study – Site #2

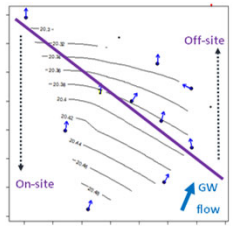
- **Observations**:
  - Existing downstream wells below threshold
  - Gap in monitoring network in downstream direction of wells with exceedances

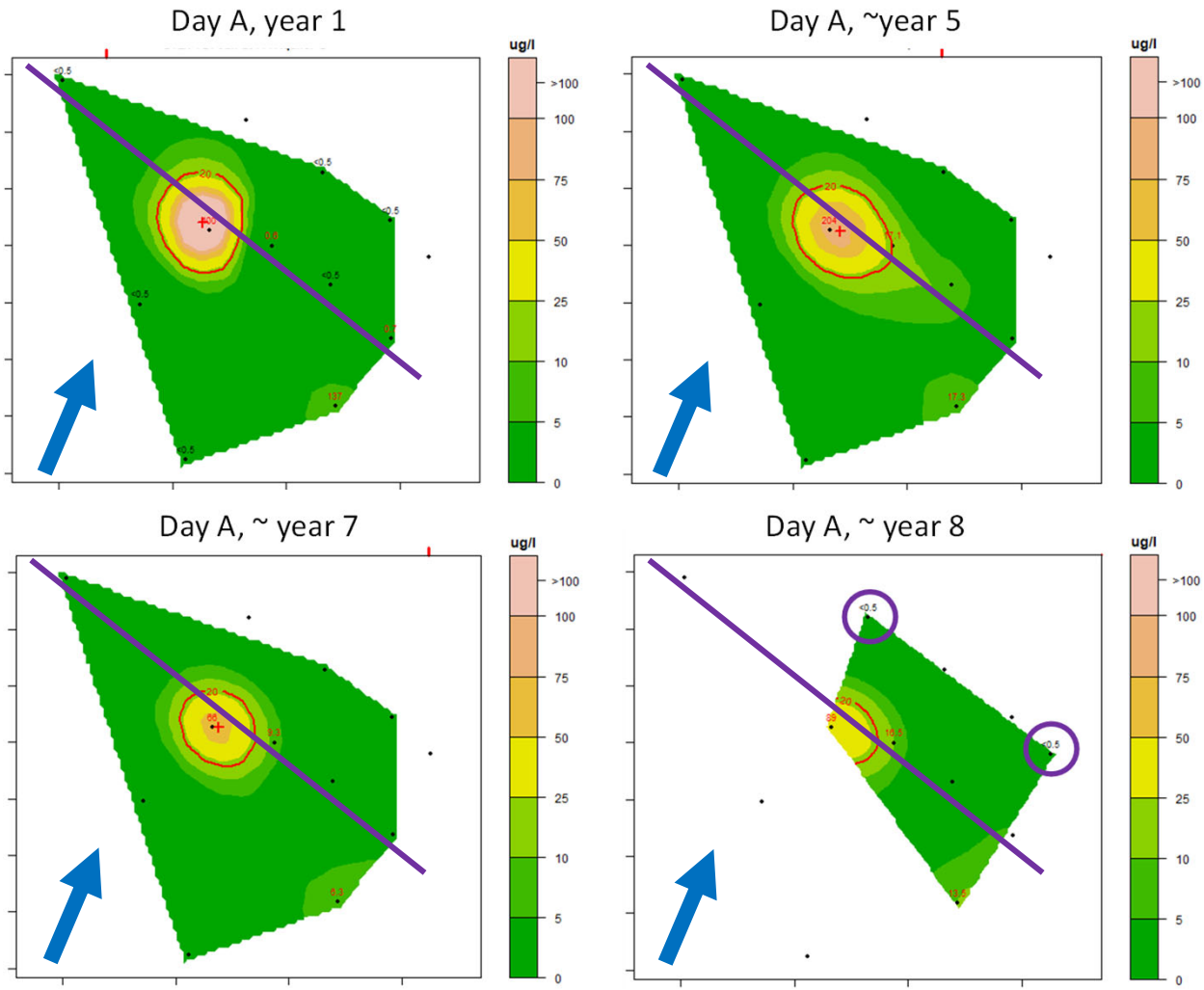


➢ **Outcome**: Regulator approved 2 new wells

Case study – Site #2

- **Observations**:
  - Time slices of spatiotemporal plots showing part of historical BTEX plume evolution
  - **GWSDAT model**: concentrations in 2 new wells will likely be below detection limit



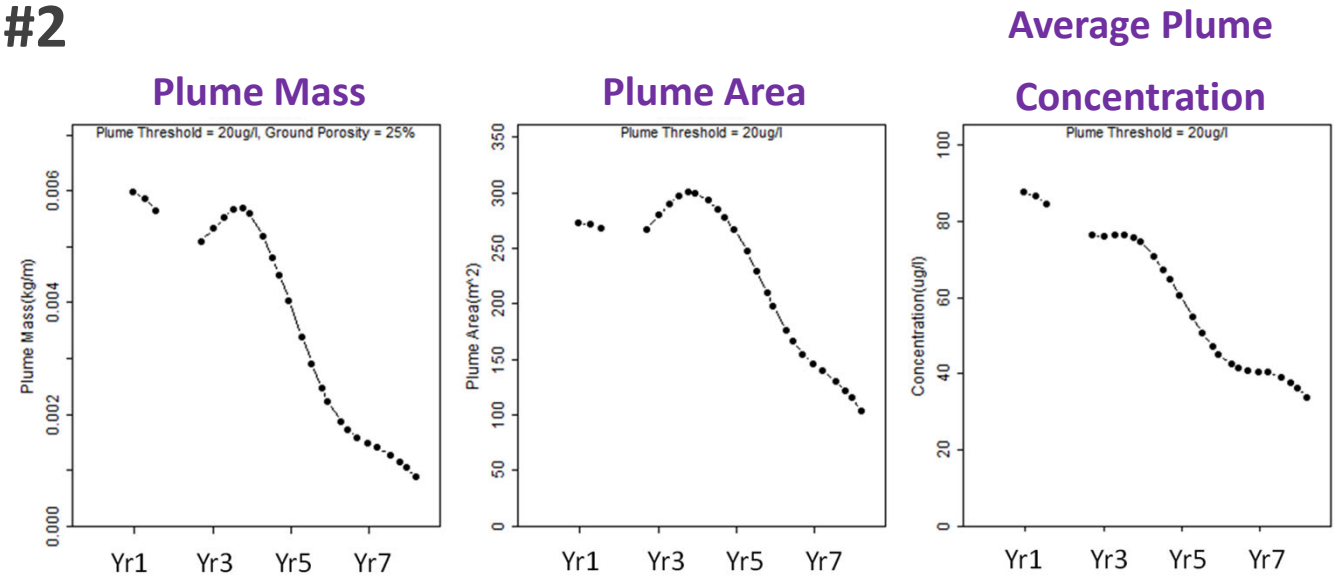


red circle: modelled BTEX plume outline based on threshold value of 20 ug/L; purple circles indicate location new wells

Case study – Site #2

- **Observation**:
  - Plume diagnostics functionality output for BTEX
  - **Plume trends**: decreasing mass, area, & average concentration

BTEX



BTEX: threshold value of 20 ug/L

➢ **Reflection**: earlier integration of GWSDAT could have optimized site understanding & decision making

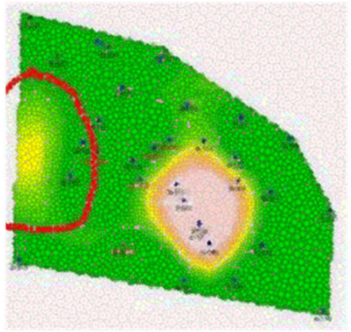
Q & A

Things to consider..

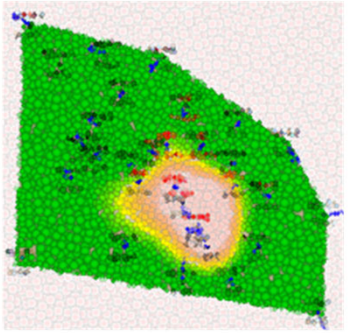
Ballooning..

- Ballooning is a statistical anomaly where where predictions can be high in areas where there are no data.

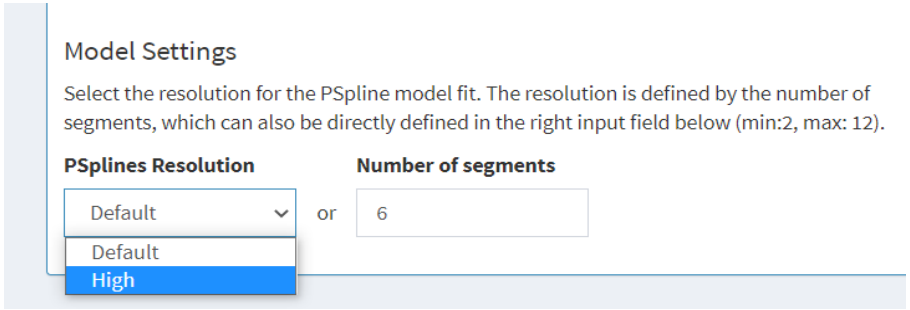
Modelling resolution:
Default & Higher Resolution



Modelling resolution:
10



Nb: data from actual site, figures anonymized

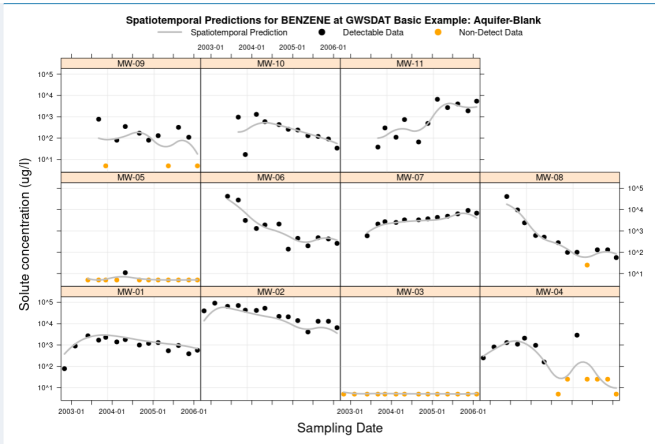


- The best way to improve the model is to up the model resolution…

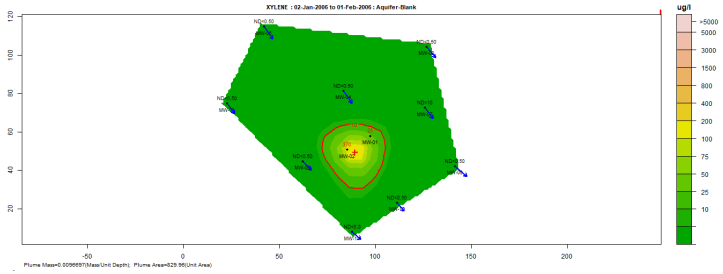
- See Evers, et al. , 2015. *Efficient and automatic methods for flexible regression on spatiotemporal data, with applications to groundwater monitoring*, Environmetrics.

Major Assumptions + Useful pointers

- Model Checking:
  - The Spatiotemporal prediction plot compares model output with lab results.



- Plume Diagnostics:
  - GWSDAT assumes a homogenous aquifer in depth and analyses the data on an aquifer-by-aquifer basis.
  - Plume mass calculated per unit depth. Multiply by aquifer depth to yield plume mass.



- See FAQ document – for answers to common technical questions.

References (open access articles)

- Molinari, D. A., 2014. Spatiotemporal modelling of groundwater contaminants, PhD Thesis (Glasgow).
- Jones, et al., 2014. A software tool for the spatiotemporal analysis and reporting of groundwater monitoring data. Environmental Modelling & Software.
- Evers, et al. , 2015. Efficient and automatic methods for flexible regression on spatiotemporal data, with applications to groundwater monitoring, Environmetrics.
- Jones, et al., 2015. Analyzing Groundwater Quality Data and Contamination Plumes with GWSDAT, Groundwater.
- Mclean, M. I., 2018. Spatiotemporal models for the analysis and optimisation of groundwater quality monitoring networks, PhD Thesis (Glasgow).
- Mclean et al.,2018 . Statistical modelling of groundwater contamination monitoring data: A comparison of spatial and spatiotemporal methods. Science of the Total Environment.
- User Manual: http://gwsdat.net/gwsdat_manual/