JBA group

Early GPU adoption within an SME company

EMIT, Manchester, 11 April 2014

Rob Lamb

Chief Scientist, JBA Group

Honorary Professor,
Lancaster Environment Centre

Consultants of the Year 2010
Winner

Who are we?

JBA group

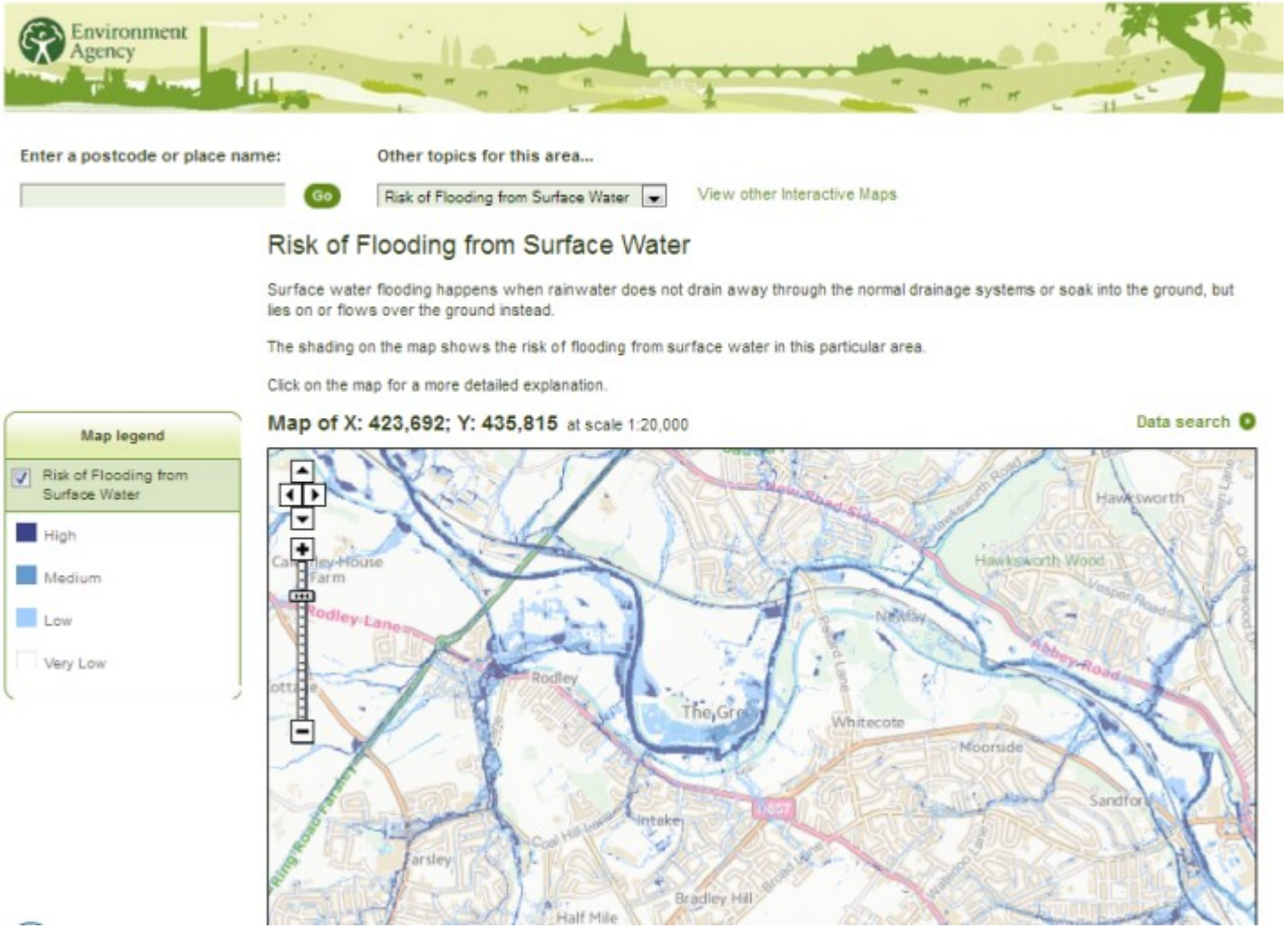
JBA consulting — Environmental and engineering consultancy

JBA risk management — Risk Management (re/insurance sector)

JBA trust — Science
Knowledge Exchange
Education

www.jbatrust.org

What do we do?



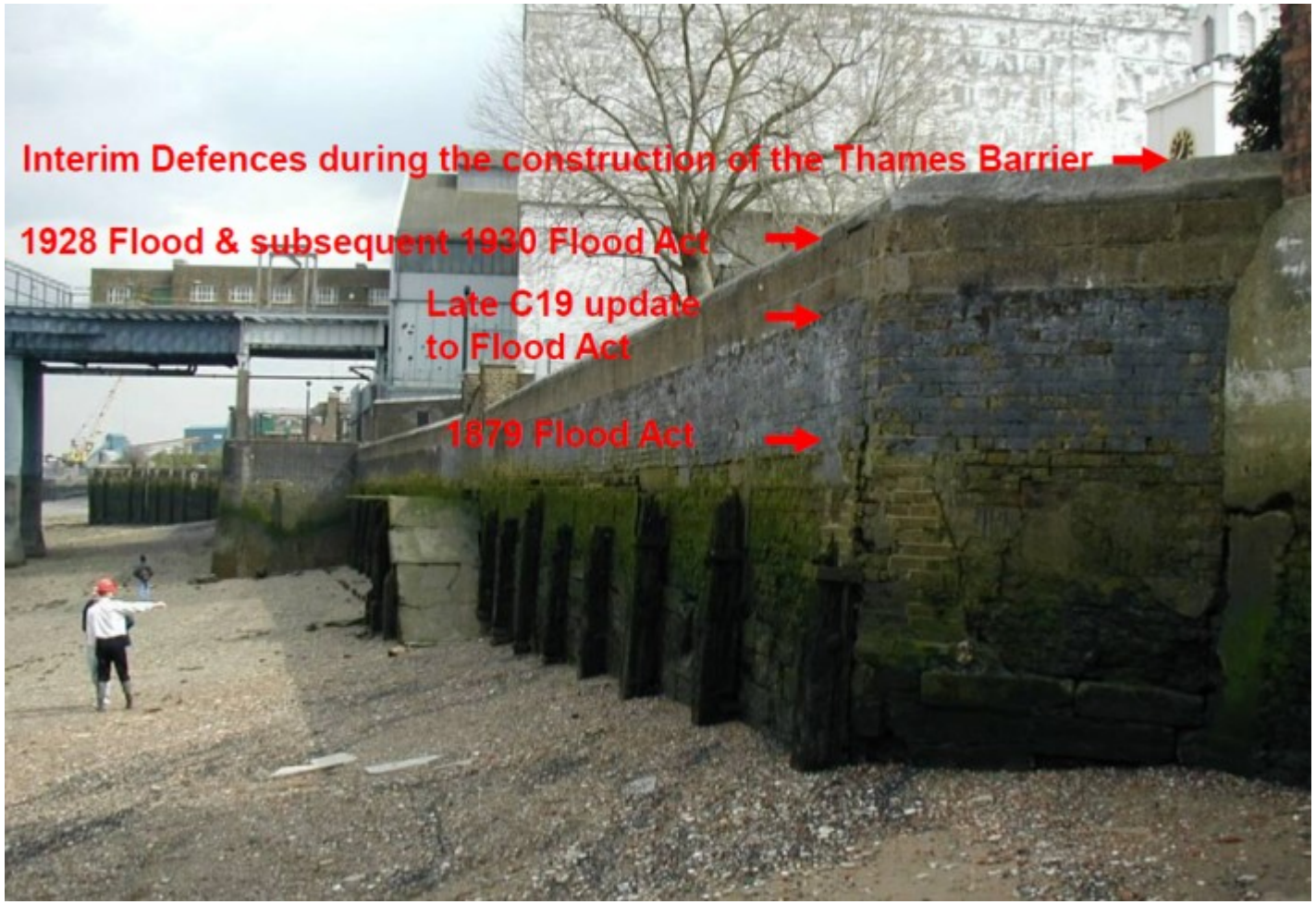
- Climate Change and Adaptation
- Coastal Risk Management
- Development Planning and Design
- Ecology
- Energy and Water Optimisation (Ewtops)
- Engineering
- Environment
- Fisheries
- Flood Consequence Assessment
- Flood Emergency Management
- Flood Risk Assessment
- Flood Risk Management
- Funding and Bid Writing
- GIS and Software Development
- Groundwater / Hydrogeology
- Hydrology
- Hydrometry
- Landscape Architecture

Flood risk economics

- Annual average cost ~£1bn
- Summer 2007 floods ~£3bn
- One in six properties at risk
- Climate change and development ►increasing risk

How much should we invest in flood protection?

- Historically based on reaction to events



How much should we invest in flood protection?

- Economic case linked to reduction in risk ► **need models**

Ingredients of a flood model

- How does the ground slope?
  - Terrain data
- How much water are we dealing with?
  - Precipitation data, river level data, sea level and wave data
  - Statistical models
- Where does the water end up?
  - Computational hydraulics code

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Terrain data

- Large scale data from RADAR and LIDAR (laser) surveys
- Used to develop **Digital Terrain Models** (DTMs), i.e. height maps)
- ±15 cm or better vertical accuracy

Mathematical model

- Flood flow is controlled by ground slope, gravity and friction

$$\mathbf{U}_t + \mathbf{F}_x + \mathbf{G}_y = \mathbf{R}$$

rate of change over time

rate of change over space

"source terms" for external forces

$$\mathbf{U} = \begin{pmatrix} h \\ hu \\ hv \end{pmatrix}, \quad \mathbf{F} = \begin{pmatrix} hu \\ hu^2 + \frac{1}{2}gh^2 \\ huv \end{pmatrix}, \quad \mathbf{G} = \begin{pmatrix} hv \\ huv \\ hv^2 + \frac{1}{2}gh^2 \end{pmatrix} \text{ and } \mathbf{R} = \begin{pmatrix} 0 \\ gh(S_{0_x} - S_{f_x}) \\ gh(S_{0_y} - S_{f_y}) \end{pmatrix}$$

depth, velocity, momentum

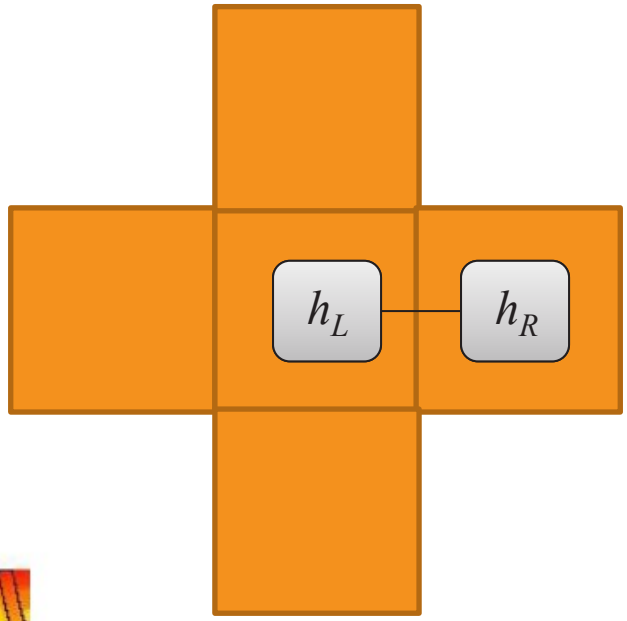
fluxes (momentum and pressure)

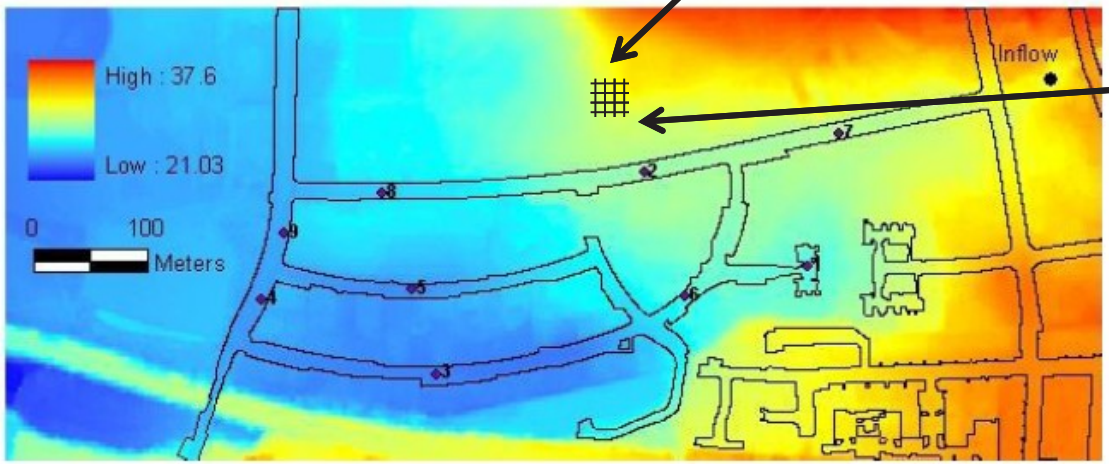
slope, friction

Computational implementation

- Explicit solver depends on iteratively computing functions of data in adjacent cells

e.g. $\tilde{h} = \frac{1}{2}(h_L + h_R)$

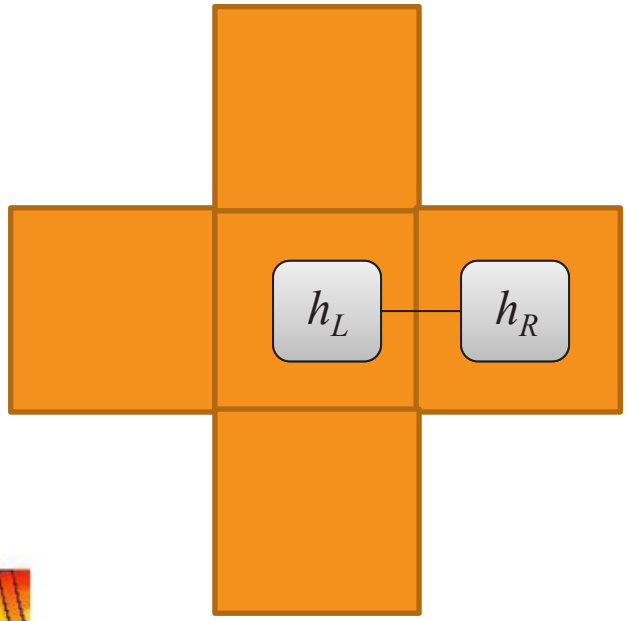


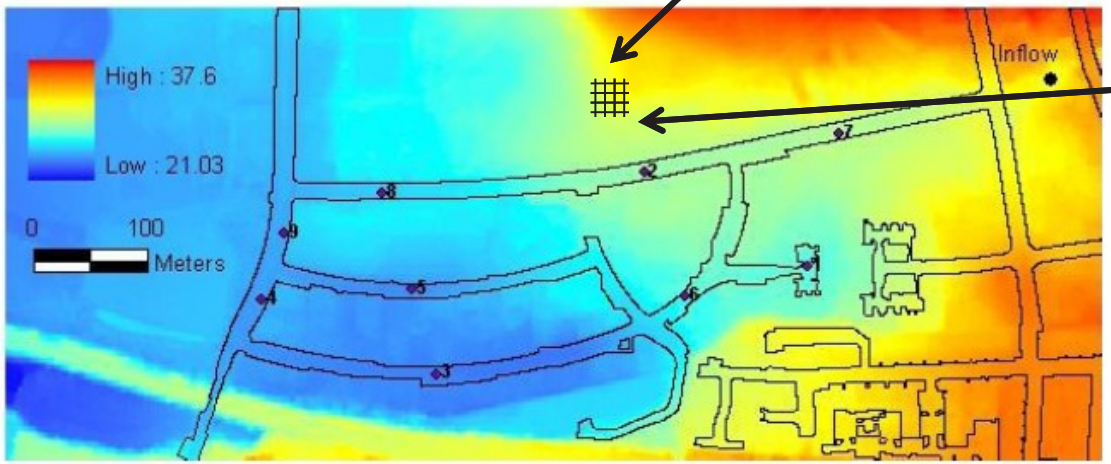


Computational implementation

- Structured 2D data
- Repeated data access pattern and arithmetic operations

  ► **good for parallel processing**





Scaling: physical domain ►model ► GPU

- Typical calculation grid ~1000 x ~1000 cells

- Quasi-independent domains

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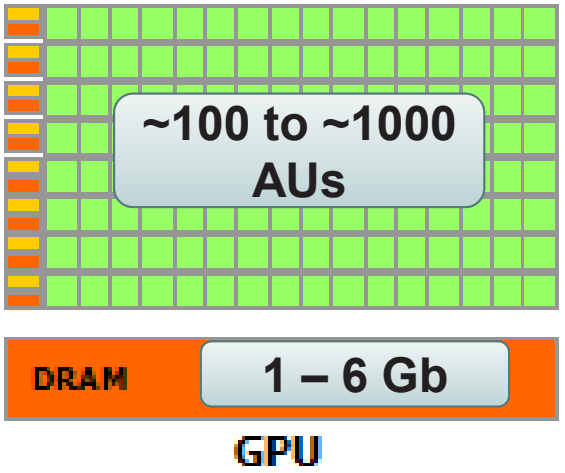

- Quasi-independent
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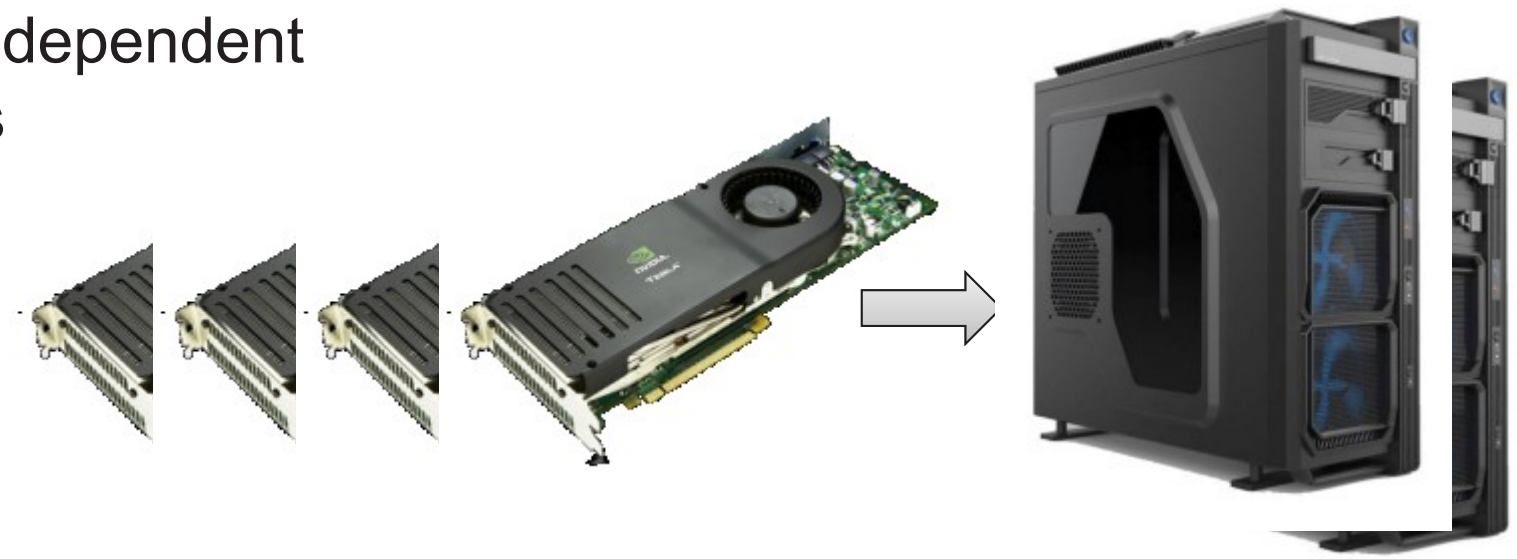

JFlow software evolution

- 2002 first prototype 2D flood inundation model (VBA)
- 2003 – 2005 code runs on distributed network of PCs, x86 CPUs
- 2005 first GPU code built in C, .Net and Direct X
- 2009 GPU code built in C++ and CUDA
- 2013 large GPU grid, multi-GPU nodes

Performance

Proceedings of the Institution of Civil Engineers
Water Management 162
December 2009 Issue WM6
Pages 363–370
doi: 10.1680/wama.2009.162.6.363

Paper 800062
Received 29/05/2008
Accepted 16/10/2008

Keywords: floods & floodworks/ information technology/ mathematical modelling

Rob Lamb
Technical Director, JBA Consulting, Skipton, UK

Mandy Crossley
Senior Numerical Analyst, JBA Consulting, Skipton, UK

Simon Waller
Director, JBA Consulting, Skipton, UK

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A fast two-dimensional floodplain inundation model

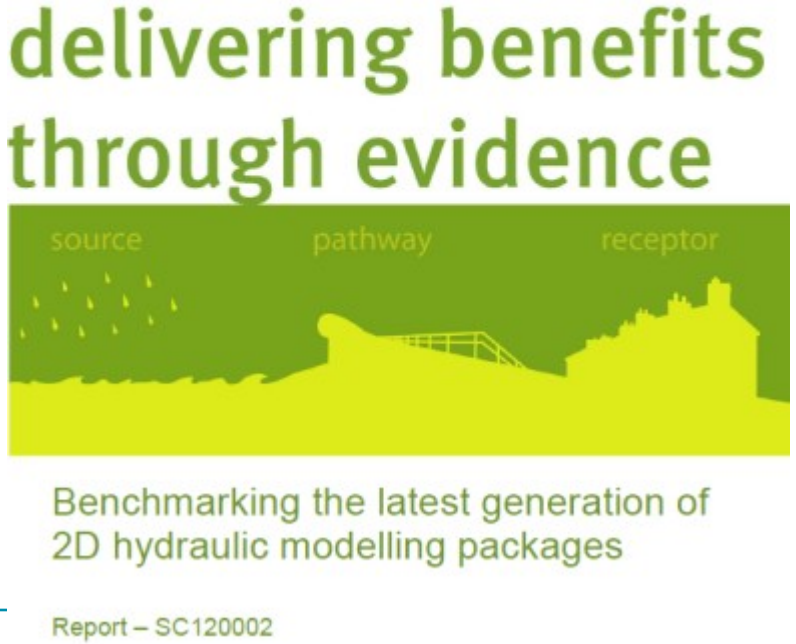
R. Lamb MA, PhD, M. Crossley MSc, PhD and S. Waller BEng, CEng

Two-dimensional (2D) flood inundation modelling is now modelling,[3–5] which often involve Monte Carlo simulation

Department for Environment Food & Rural Affairs

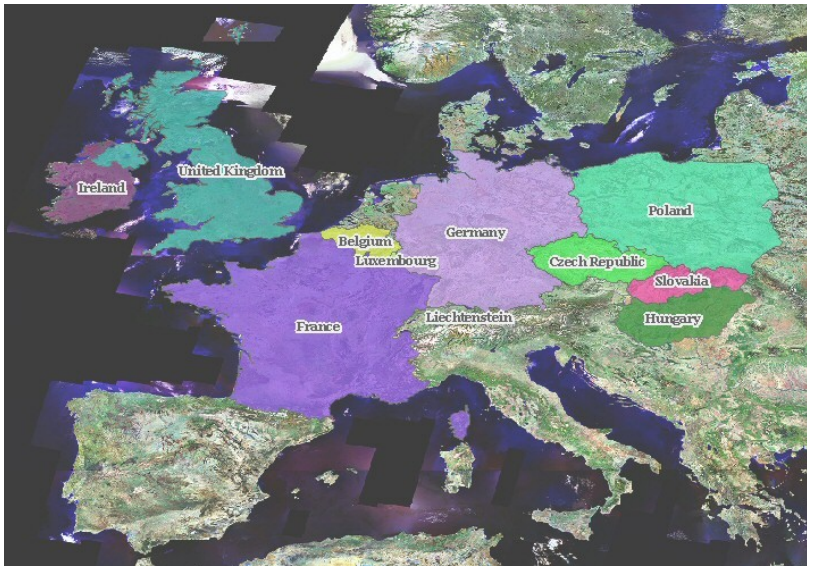
Environment Agency

- Benchmark results published
- Typically x10 or better performance
- Sometimes up to x100



Large scale river floodplain models

- UK national river flood mapping
  - 80,000 miles of river network length
- France
  - 50,000 miles river network

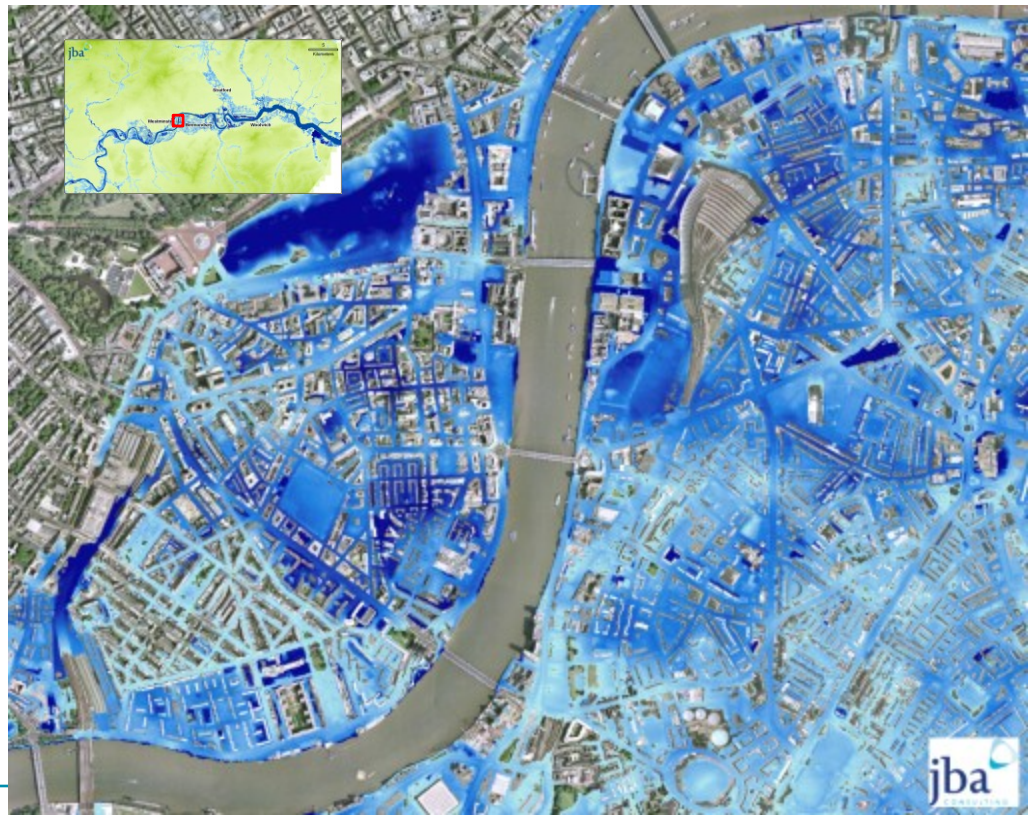


- UK dam-break flood risk analysis for over 1,000 dams in UK

Ulley Reservoir, 2007

London ‘worst case’ flood

- Highly detailed (2m x 2m) flood exposure “envelope”
- 949 flood wall breaches or overtopping scenario models
- Model domains ≈ 4,150 Km^2 in total



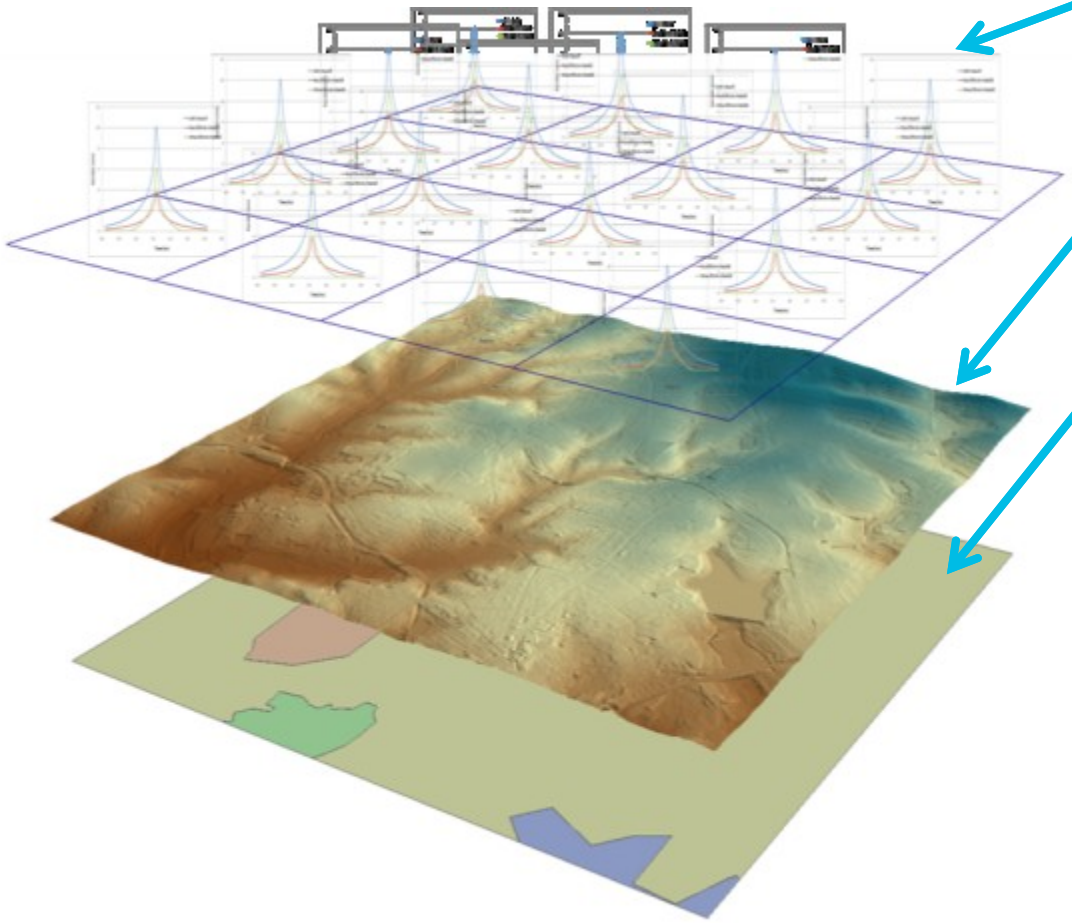
London (Westminster area detail)
2m resolution model for 1/250 year storm surge and defence failure scenario with tidal barrier and flood walls breached.

Scaling up per GPU node

- GPU workstation now supports >100 million cells
- Equates to 21 x 21 km (13 mi) on 2m LIDAR, enough to model a city

Large systems: Fully 2D channel/floodplain model for California Central Valley

National surface water flood risk maps

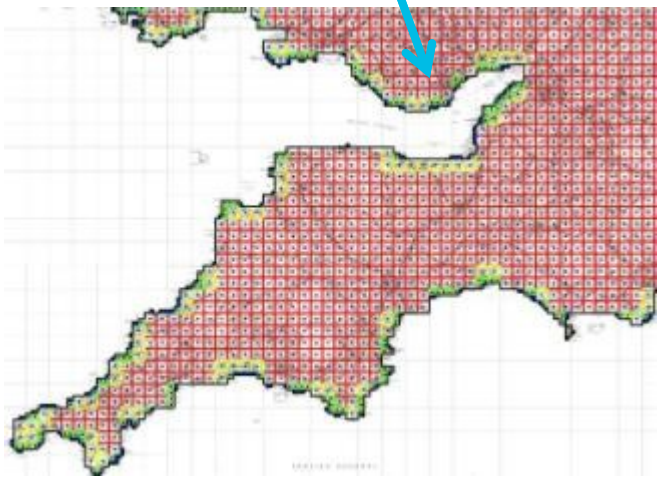


Rain storm data from statistical models

DTM

Spatially variable infiltration

Mosaic of 6 x 6 km model domains



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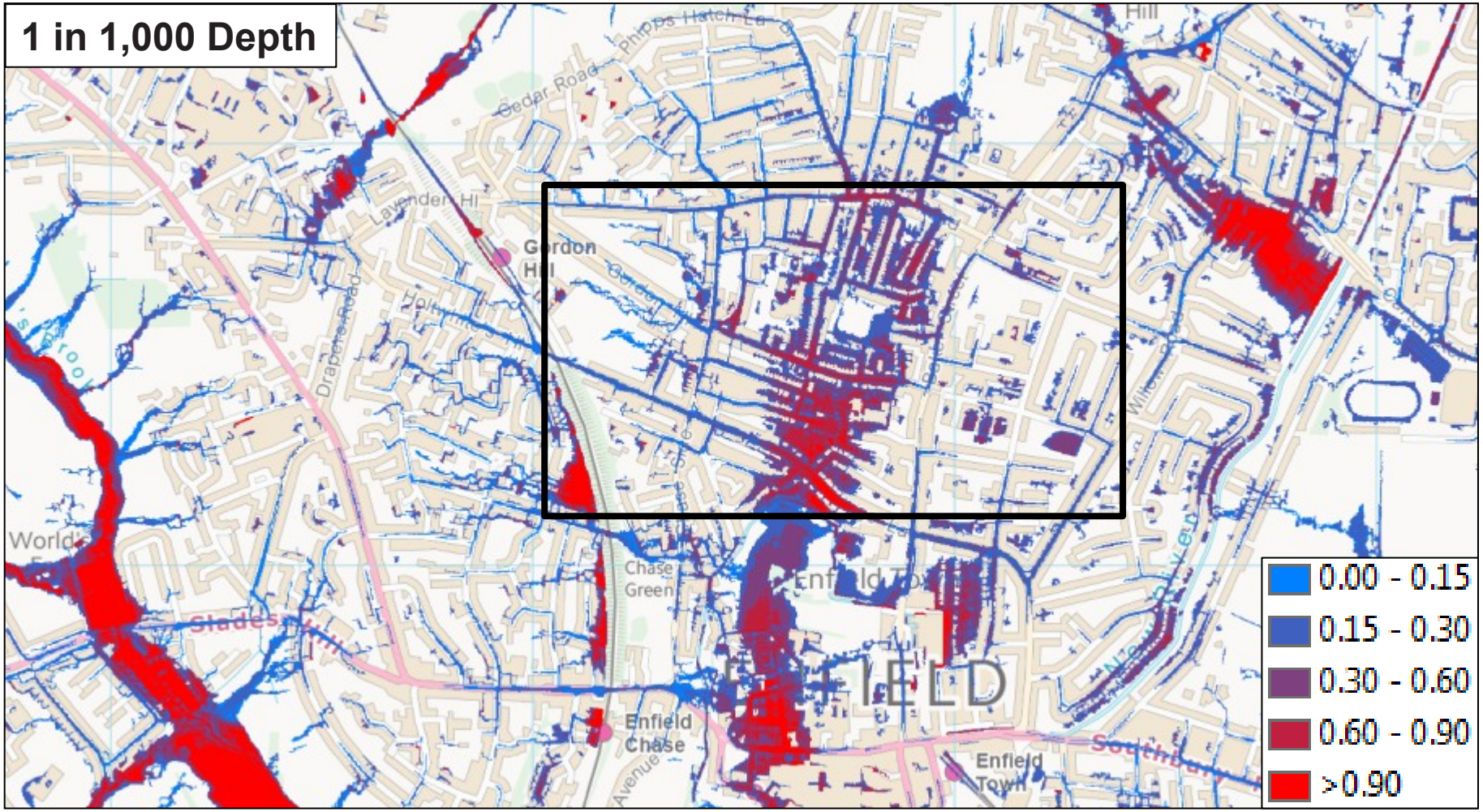

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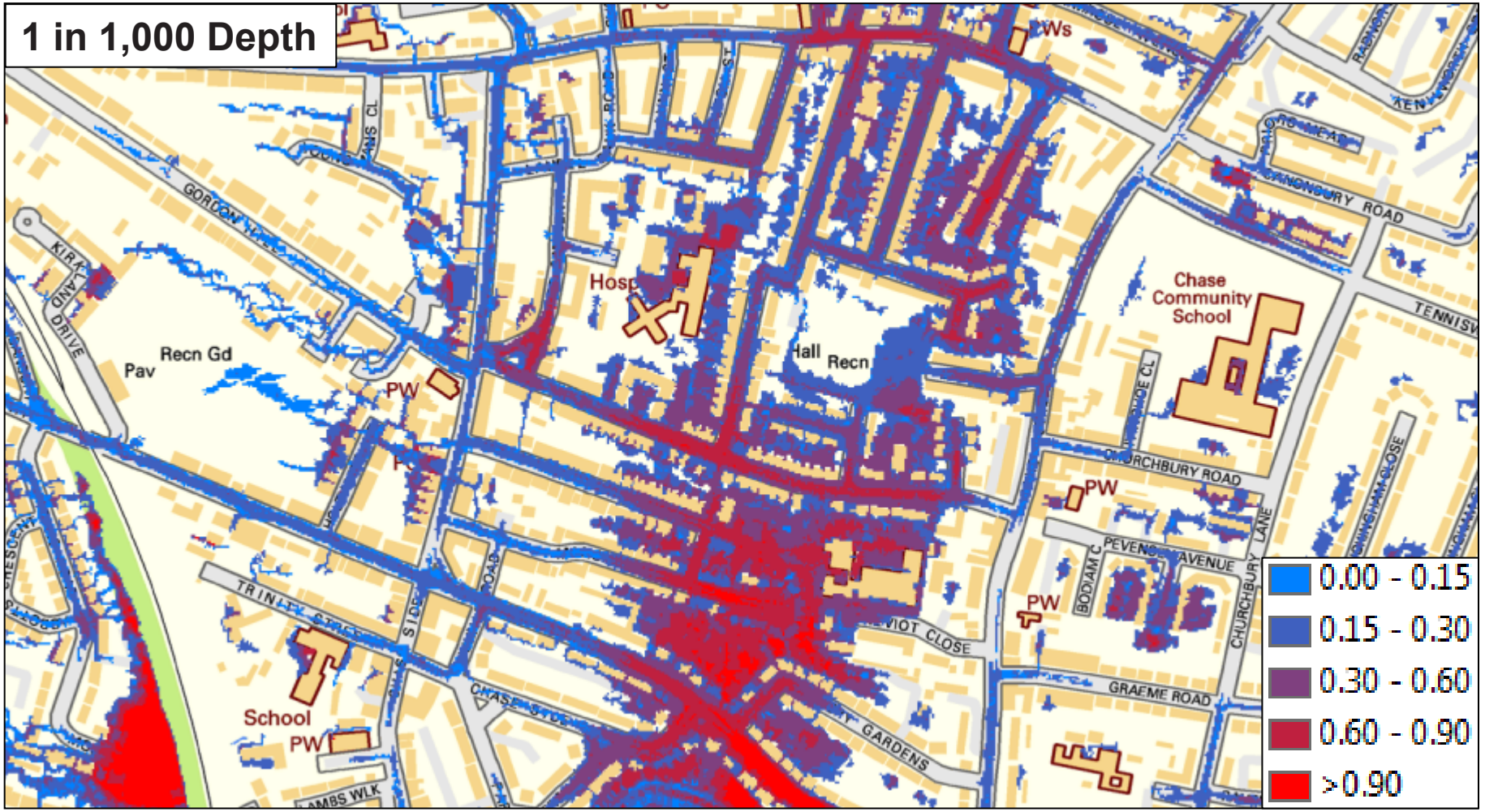

Some headline numbers...

- Data preparation: 7 months

- **Flood modelling: ~105,000 x 6Km x 6Km tiles modelled at 2m x 2m grid resolution in less than 6 months including QA**

- Post-processing: Flood maps produced from ~320,000 merged model outputs

Royal Academy of Engineering

- Finalists of 2012 RAEng *MacRobert Award* for innovation in engineering

JBA's **JFlow** technology uses unique algorithms to produce some of the world's most detailed 2D hydrodynamic maps on a national scale. In the UK, these are used by national and local government agencies, the top five insurance companies (accounting for 60% of the data), and civil engineering firms to help understand the hydrology, plan flood defences, set premiums and develop rescue plans.

Ireland, France, Germany, Poland, Czech Republic, Slovakia, Hungary, Belgium, Luxembourg and India are among the countries using the **JFlow** product.

Producing detailed maps of this nature usually demands immense processing power, only available from extremely expensive super-computers. JBA Consulting's key innovation was to create software that could run on 'off the shelf' graphics cards and processors, which could be easily and cost-effectively up-scaled according to demand. Yorkshire-based JBA now operates the world's largest dedicated flood modelling grid, using, in essence, a super-computer made up of over 50,000 processor cores.

Team members: Chief Scientist - Dr Rob Lamb, Director - Simon Waller, Principal Analyst - Dr Amanda Crossley, Technical Director - Dr Kate Bradbrook, all based at JBA Consulting in Skipton, North Yorkshire.

Future needs from industry

- Need to continue scaling up – bigger and more detailed models
- Power efficiency is an issue
- Need for cost effective multi-GPU infrastructure

Recruitment

Hydraulic Model Developer

JBA Consulting is an environmental, engineering and risk company committed to exceptional client service and helping to improve the environment, business, and infrastructure. Our software teams develop mobile and browser based asset management software for client and internal use.

Job Description

We are seeking a Hydraulic Model Developer to work on the continued development of JFlow, our two-dimensional flow routing model. This would suit a postgraduate student in the engineering, mathematics or environmental sciences with a numerical background and knowledge of the two-dimensional shallow water equations. The successful candidate will be required to develop

Current Vacancies

KTP Associate

A956
Skipton
Closing Date: 9 May 2014

Hydraulic Model Developer

RSK14-01
Skipton
Closing Date: On-going

Senior Analyst-Engineer