Sharing learning from the Cumbrian NFM & Pioneer Catchment projects – 22/06/2020 @ 1330 – 1530

NFM monitoring (with analysis) approaches to evidence impact

Nick Chappell

Environment Agency

Lancaster University

UKRI Natural Environment Research Council

NFM monitoring (with analysis) approaches to evidence impact

Cumbria-focused research

Q-NFM

NATURAL FLOOD MANAGEMENT RESEARCH PROGRAMME

Natural Environment Research Council

With Keith Beven, Trev Page, John Quinton, Phil Haygarth, Barry Hankin Rob Lamb, David Johnson, Ann Kretzschmar and end-user partners

Primarily physics-based modelling (with some field monitoring)

C-NFM

Cumbrian NFM Effectiveness Monitoring Network

defra Department for Environment Food & Rural Affairs

Environment Agency

With Dave Kennedy and end-user partners

Primarily field monitoring (with some dynamic systems modelling)

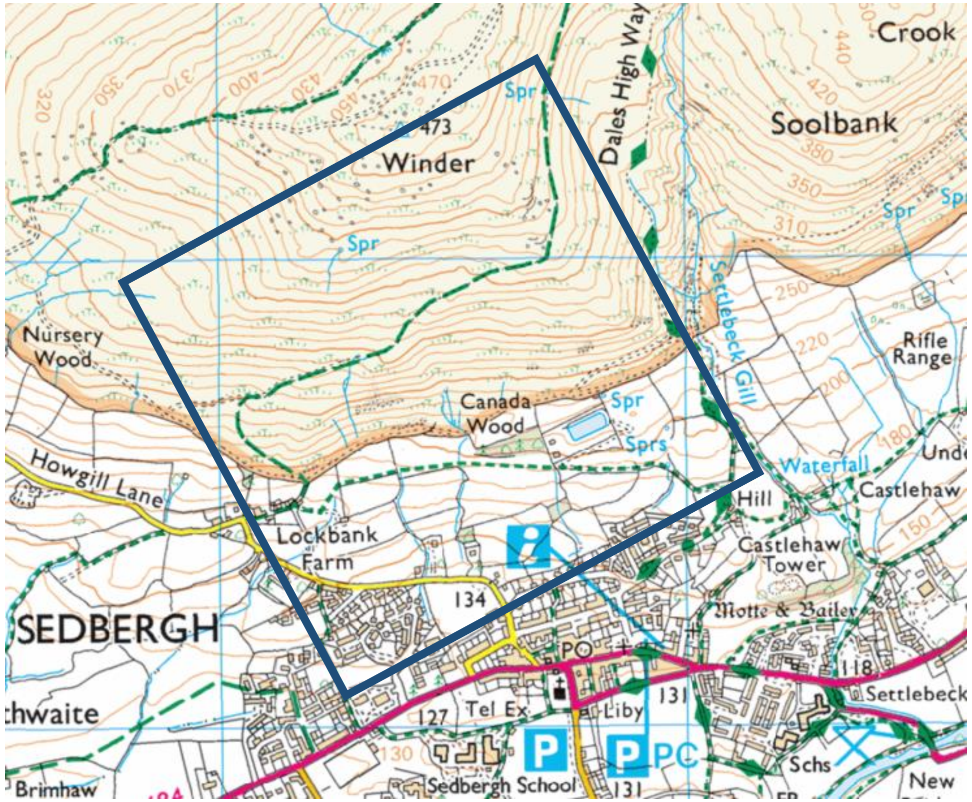
Our underpinning rationale:

Gain observational evidence (with analysis of these data) required to justify levels of implementation that would make a difference to flood peaks

For a traditional flood mitigation scheme ~ 1,000,000 m^3 per 100 km^2 contributory area

e.g., 1,300,000 m^3 Garstang flood basin downstream of 114 km^2 catchment (11,400 m^3 per 1 km^2)

Ref: Rydal Water 1.6M m^3



If res 2.5m (x100x40)=10,000m^3

10,000 m^3 per every 1 km^2 of contributory area

one blue square on OS 1:25,000 map

100x100x1m total storage

substantial investment of public money

Most of NFM-related interventions we are measuring at pilot sites are individually much smaller than this…

Need to know how these function during flood peaks

– to know *how many* such features needed for full implementation

If individual ‘NFM features’ are storage features[1]

Q1: How much additional in-storm storage (m^3) available?

Q2: When is the storage gain (m^3 per 5-mins) delivered? – ideally all at the peak

Flimby flume micro-catchment
© Dave Kennedy, EA 31 Jan 2020

Or How much freeboard?

[1] opportunity to discuss later where component measurements used to give other variables or parameters (e.g., wet-canopy evaporation, roughness or infiltration capacity) before storage

West Cumbria Rivers Trust
Caring for our Lakes and Rivers

Measure water-level continuously[2]

Pressure transducer / transmitter
gauge – needs air pipe
absolute – need barometric correction e.g.

Shaft encoder
Capacitance wire
Ultrasonic or radar

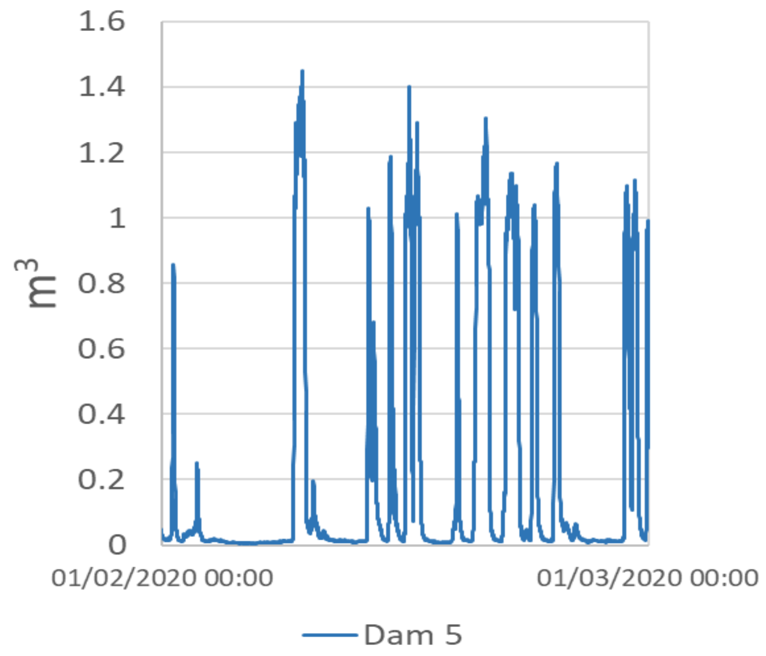
Measure dimensions of storage feature

Differential GPS
Total Station
Erosion bridge
Optical drone with GPS points

Level every 5mins[2]

Level - volume relation

Volume (m^3) time-series



Tebay peatland series

Effectiveness for a series of 'NFM storage features'

Q1: How much additional in-storm storage (m^3) per area draining to community (m^2)?

noting 100mm rainstorm over 1 km^2 = 100,000 m^3

Q2: When is the storage gain (m^3 per 5-mins) delivered?

Is the feature full before stream (or river) peaks?

Is feature able to hold back a peak in 1-in-1 yr event (important to some communities) but already full before peak of 1-in-30 yr or 1-in-100 yr event?

…to answer need observed flood hydrograph of stream affected

Measure water-level continuously[2]

Pressure transducer / transmitter
gauge – needs air pipe e.g.,

absolute – need barometric correction
Shaft encoder
Capacitance wire
Ultrasonic or radar

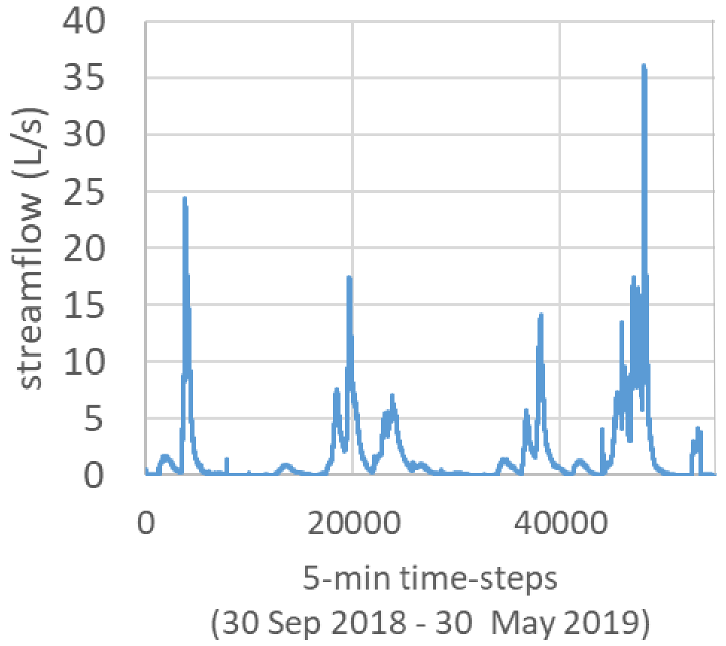
Measure level-discharge relation

Current meter
Dilution gauging
Pre-calibrated structure
etc.

Level every 5mins[2]

Level - discharge relation

Discharge (m^3/s per 5min) time-series[3]



Sedbergh flume

[3] or L per 5min or mm/5min

Measure level-discharge relation

Current meter
Dilution gauging

very difficult without huge time/cost commitment
otherwise highly inaccurate, why…

1/ Coarse sediment piles downstream control level, & change during storms, shifting the level-discharge relation

2/ Channel may be wide & shallow so discharge very sensitive to small changes in level

3/ Flow regime likely to change through a storm (sub-critical to supercritical) – very noisy level-discharge relation

4/ Requires continuous storm tracking & rushing to field at night in hope of gauging peakflow (dangerous)

Solution – build a control structure (weir or flume) & ensure installed in hydraulically correction location

see e.g. Chapter 7 Shaw *et al*. (2010) Hydrology in Practice

Pre-calibrated structure (right)

we choose to use

Telemetry system

not required for judging NFM effectiveness

Our reasons:

1/ Access our data on demand

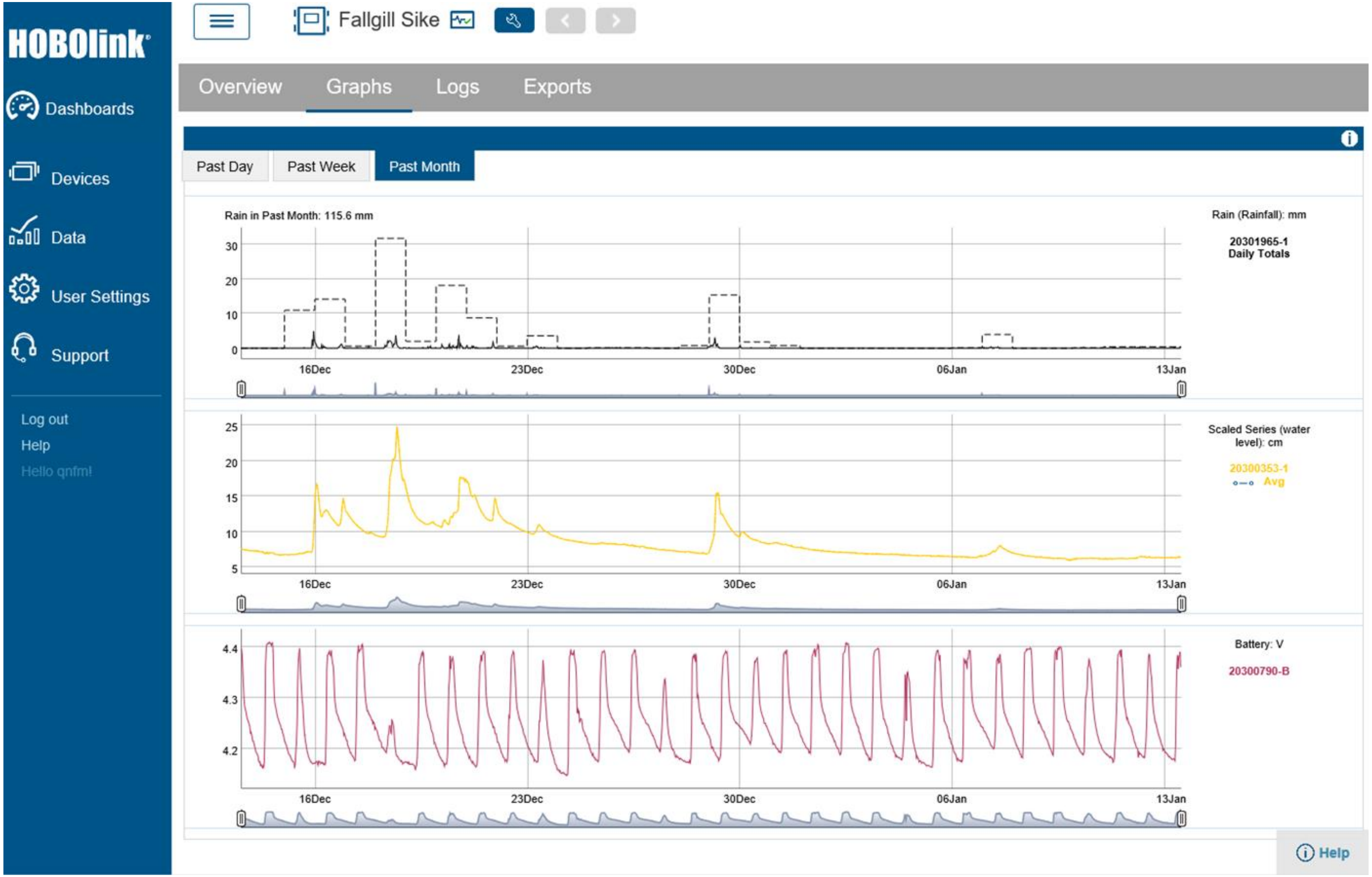
2/ Identify sensor/station problems quickly – know what needs fixing & fix quickly

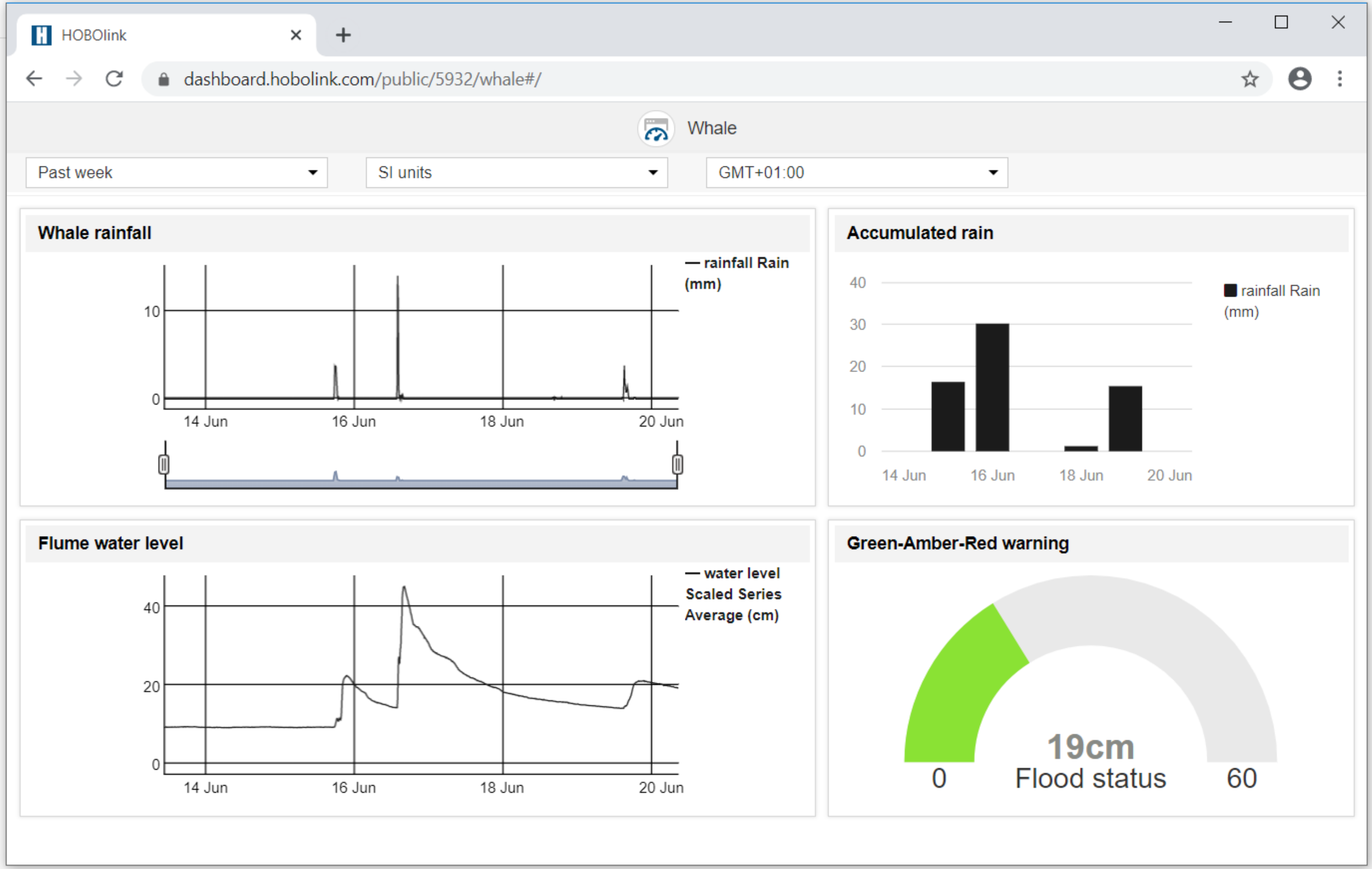
3/ Share live information with landowner & funder

4/ Share live information with community at risk – support flood warning

Note: we attach a **raingauge** to same system (for gross or net rainfall measurement)

for our characterisation of basin-integrated rainfall-streamflow response (systems & physics-based modelling)

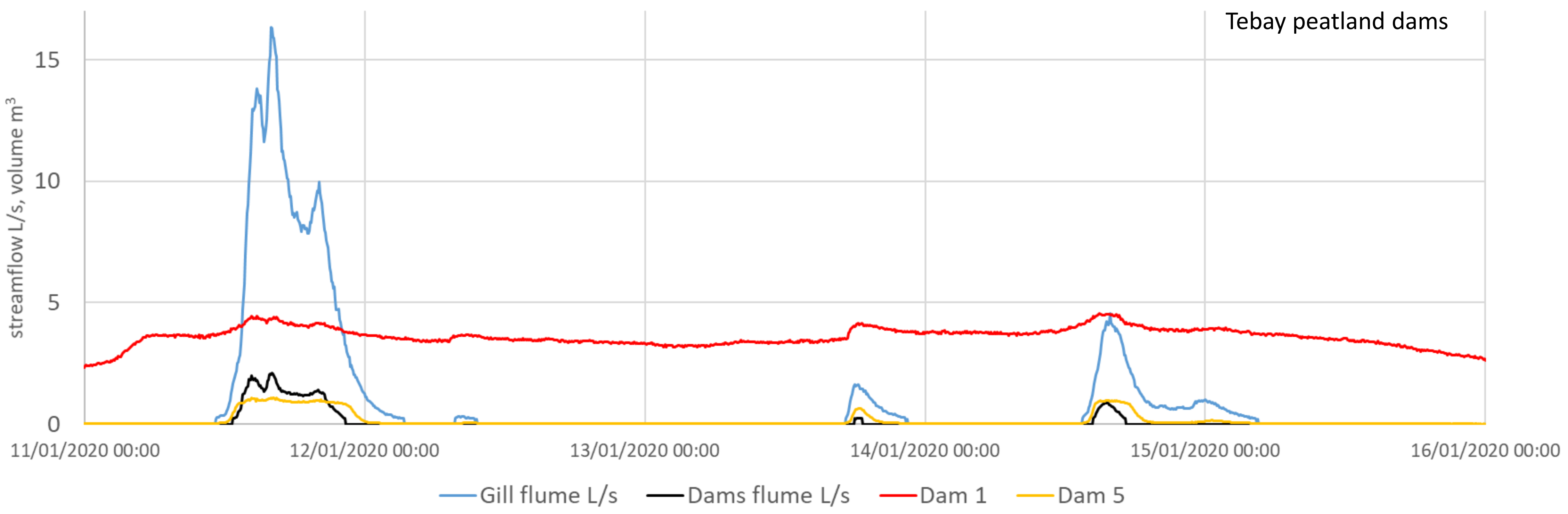

HOBOlink
Dashboards
Devices
Data
User Settings
Support
Log out
Help
Hello qnfm!
Fallgill Sike
Overview
Graphs
Logs
Exports
Past Day
Past Week
Past Month
Rain in Past Month: 115.6 mm
Rain (Rainfall): mm
20301965-1
Daily Totals
Scaled Series (water level): cm
20300353-1
Avg
Battery: V
20300790-B
16Dec
23Dec
30Dec
06Jan
13Jan
Help

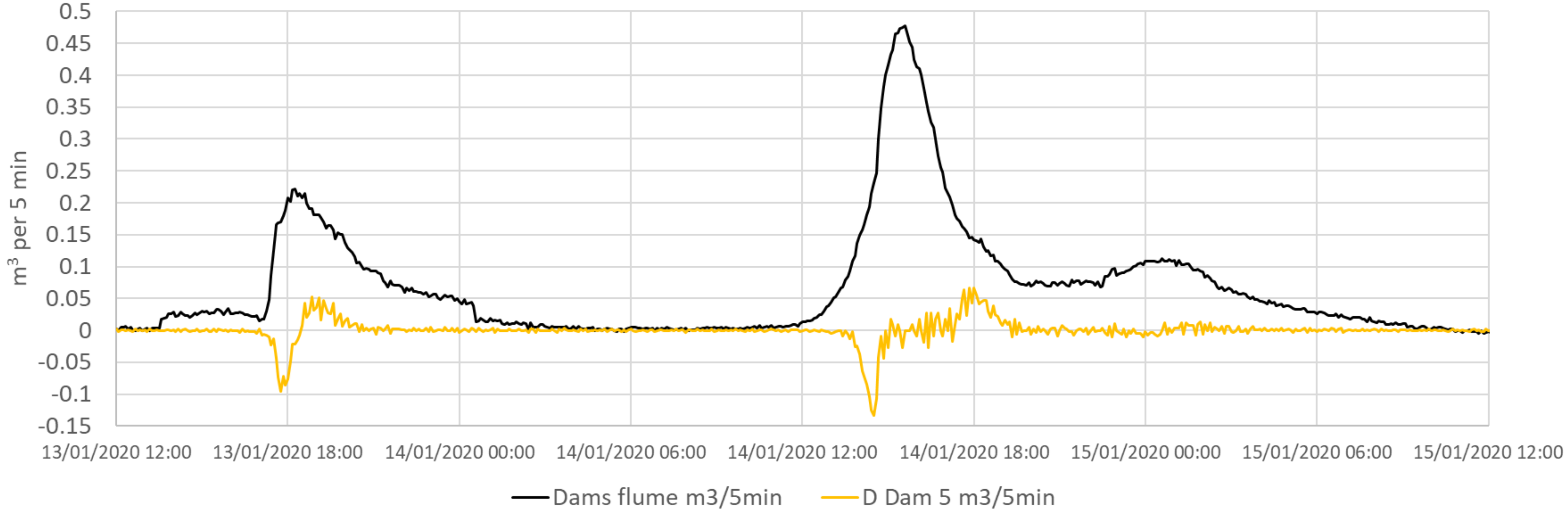

HOBOlink
dashboard.hobolink.com/public/5932/whale#/
Whale
Past week
SI units
GMT+01:00
Whale rainfall
— rainfall Rain (mm)
10
0
14 Jun
16 Jun
18 Jun
20 Jun
Accumulated rain
rainfall Rain (mm)
40
30
20
10
0
14 Jun
16 Jun
18 Jun
20 Jun
Flume water level
— water level Scaled Series Average (cm)
40
20
0
14 Jun
16 Jun
18 Jun
20 Jun
Green-Amber-Red warning
19cm
0
Flood status
60

Linking storage dynamics (m^3) with local stream discharge (m^3/s or L/s) e.g.,

Peatland dams on Tebay Fell

Linking storage dynamics (m^3) with local stream discharge (m^3/s or L/s) e.g.,





and storage gain, ΔS (m^3 per 5min) directly with local stream discharge (m^3 per 5min) allowing even one flume (up or downstream) to be used to quantify storage effectiveness

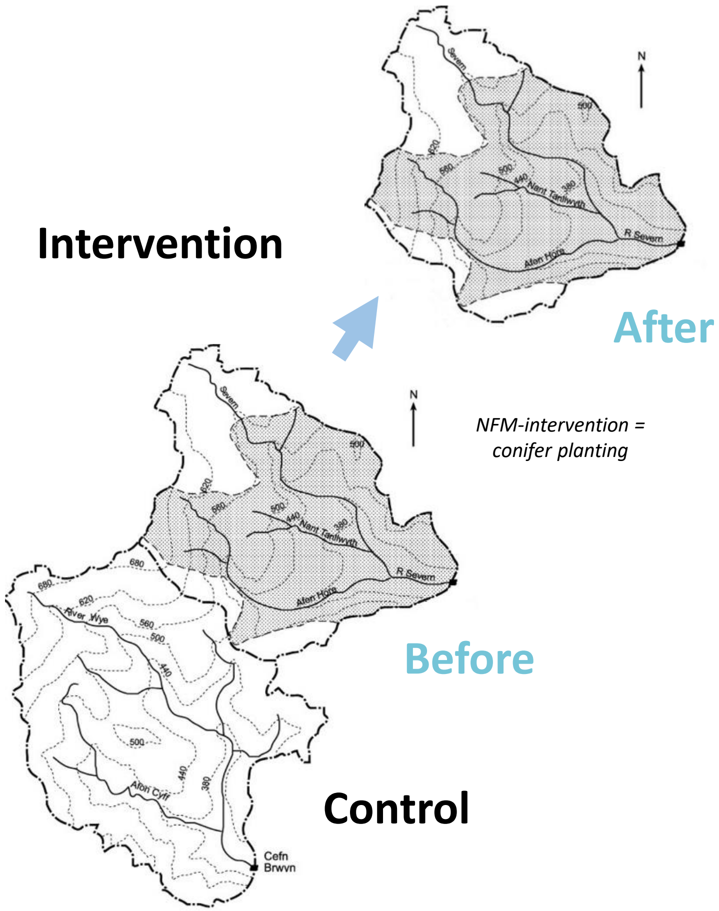
Different experiment designs for our flumes:

Type 1: Gauging station **immediately upstream and downstream** (with no major channel flows entering) eg bracketing a series of in-channel woody dams

Type 2: An **adjacent basin** (also gauged) lacking the extensive NFM features (e.g., reference moorland basin next to forested basin – emulating optimal state after tree planting)

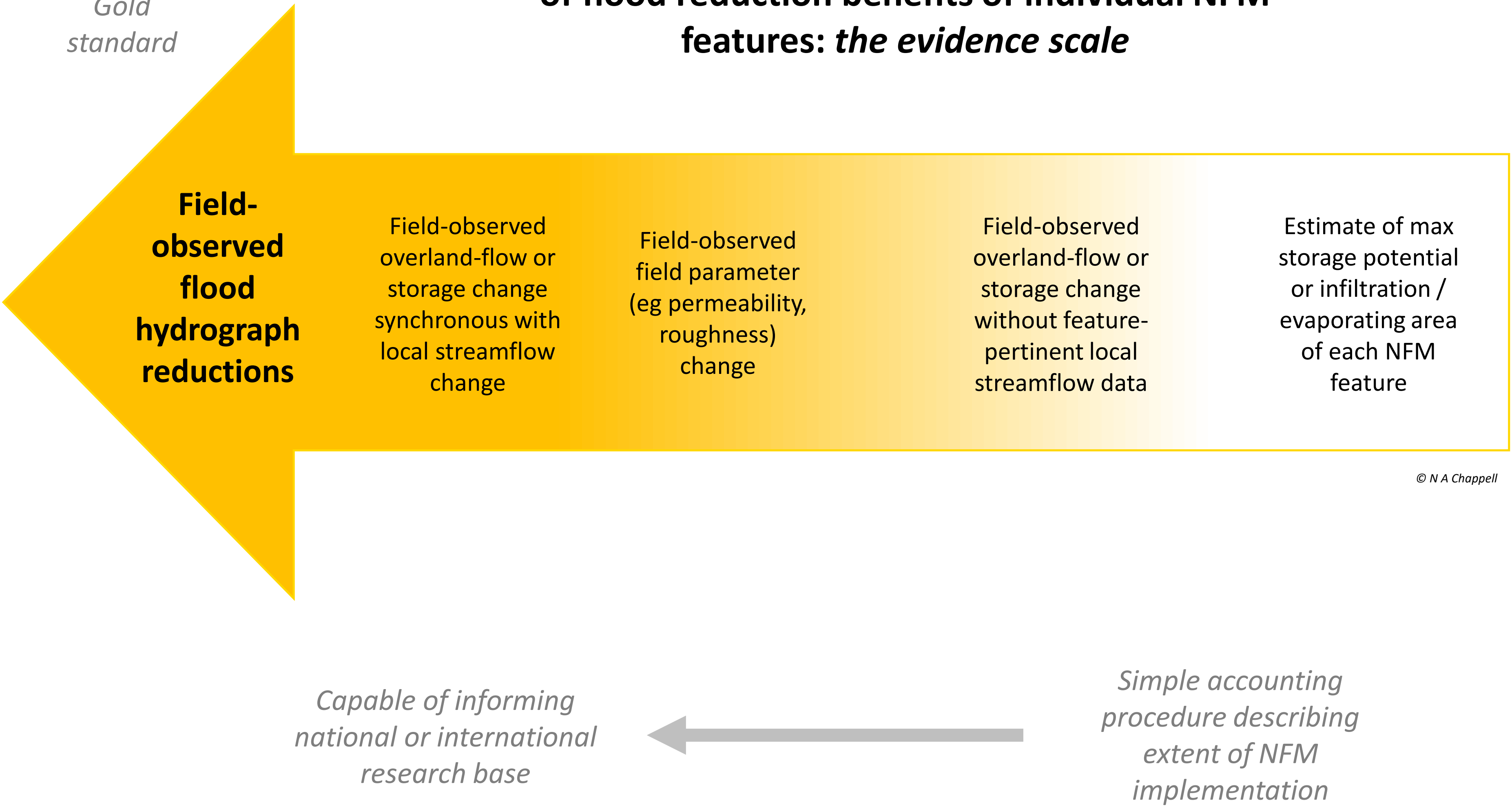
Type 3: A **single reference gauging station** eg where change in storage during storm (m^3 /5min) is a significant proportion of peak channel flow (m^3/5min)

Type 4: A single gauging station monitored **before and after** an intervention added *(if not surface storage - requires exceptional Time Series Analysis to capture changing rain-flow dynamics with minimal uncertainty)*

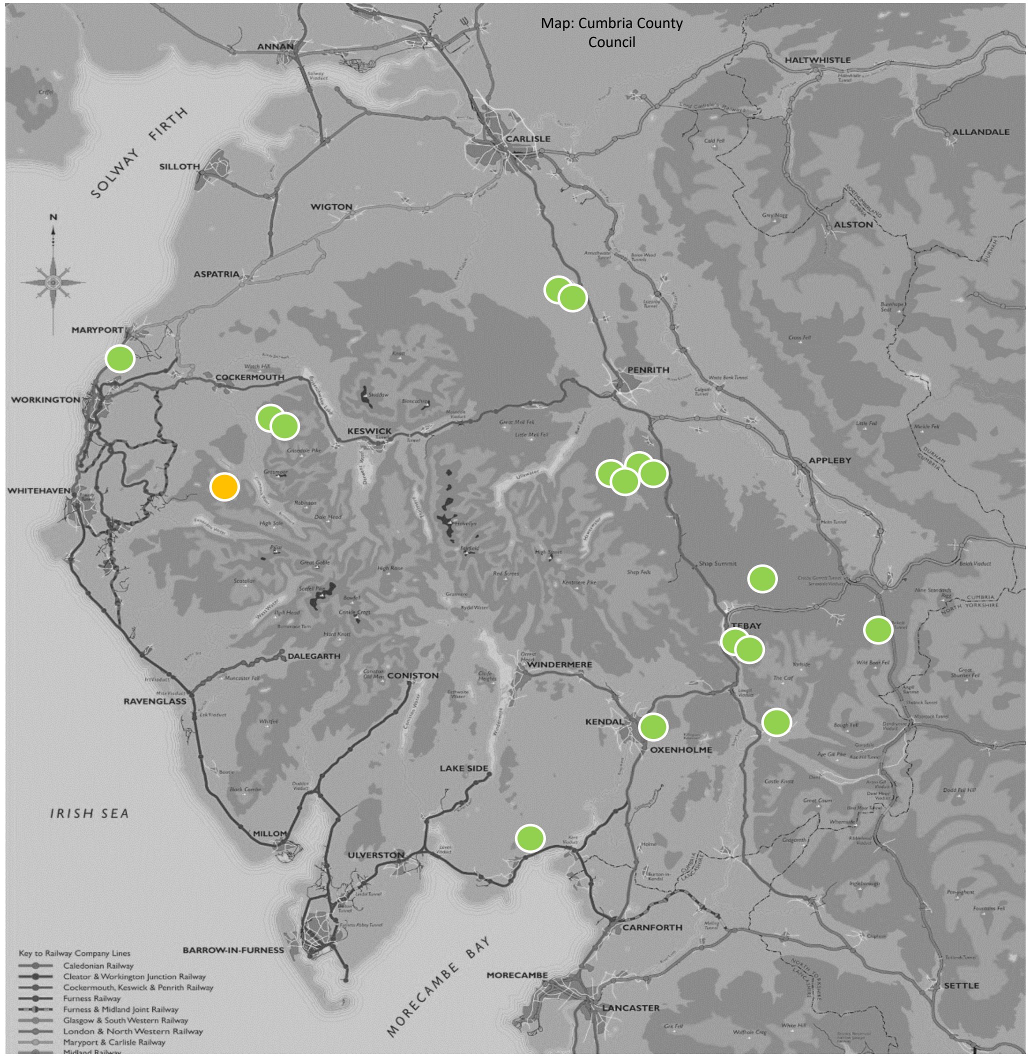


Combining 2 & 4 = BACI design
(Before-After Control-Intervention)

Strength of field-observed evidence for delivery of flood reduction benefits of individual NFM features: *the evidence scale*

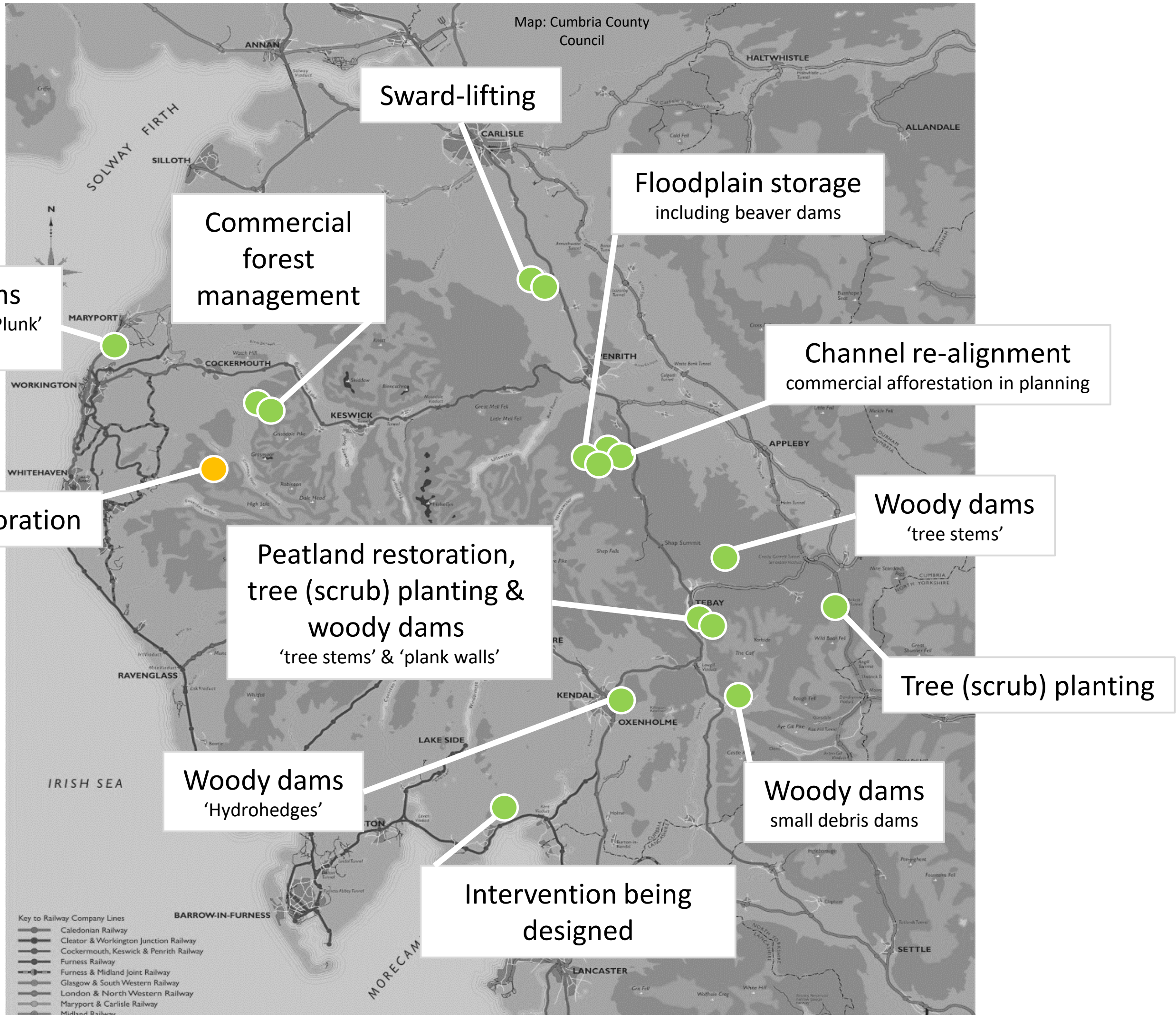


Micro-basins (< 1 km²)

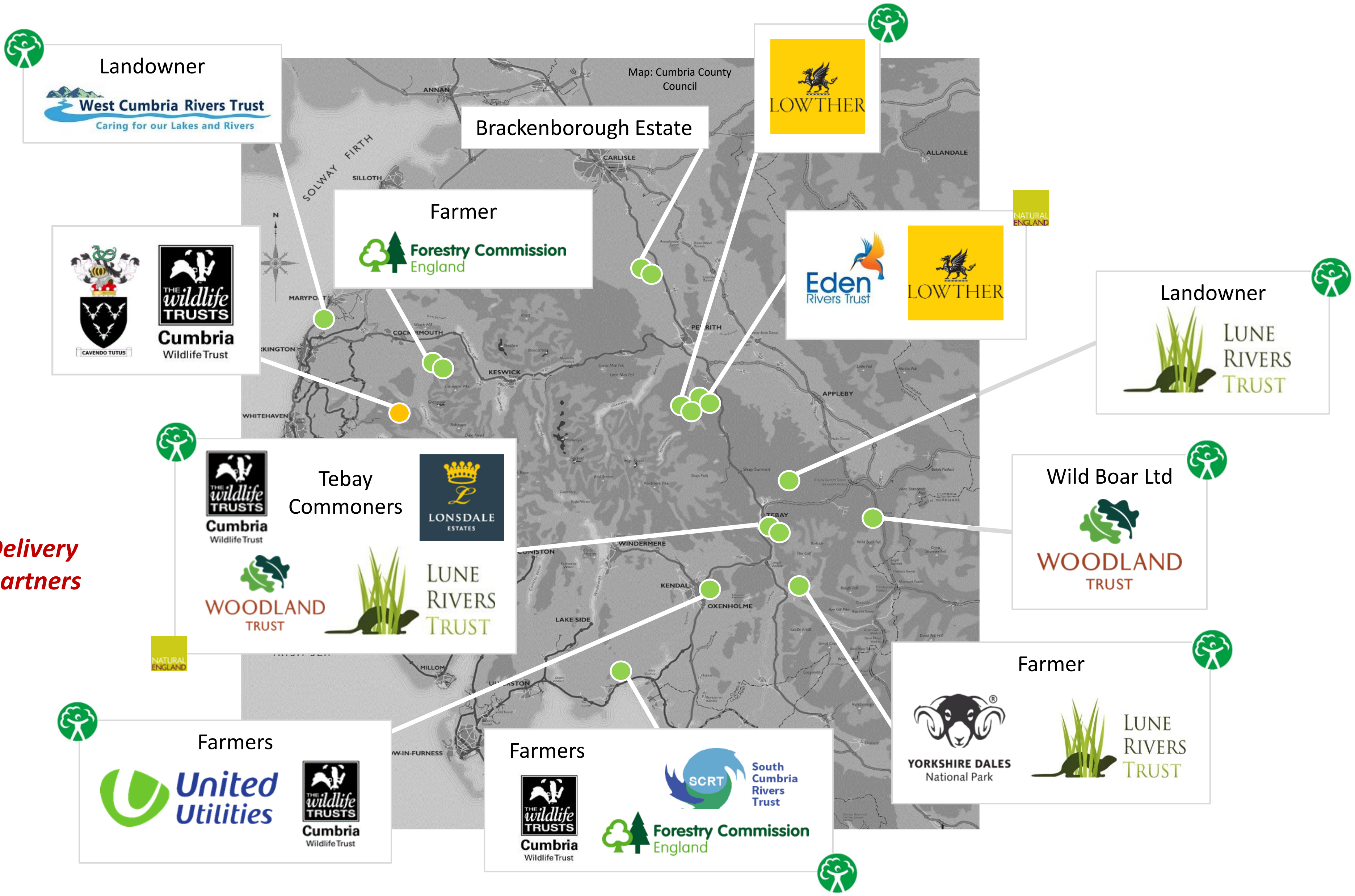


Operational status (Jun 2020):
fully (green), structure present
(orange), to be installed (red)

Key intervention per micro-basin



Delivery partners



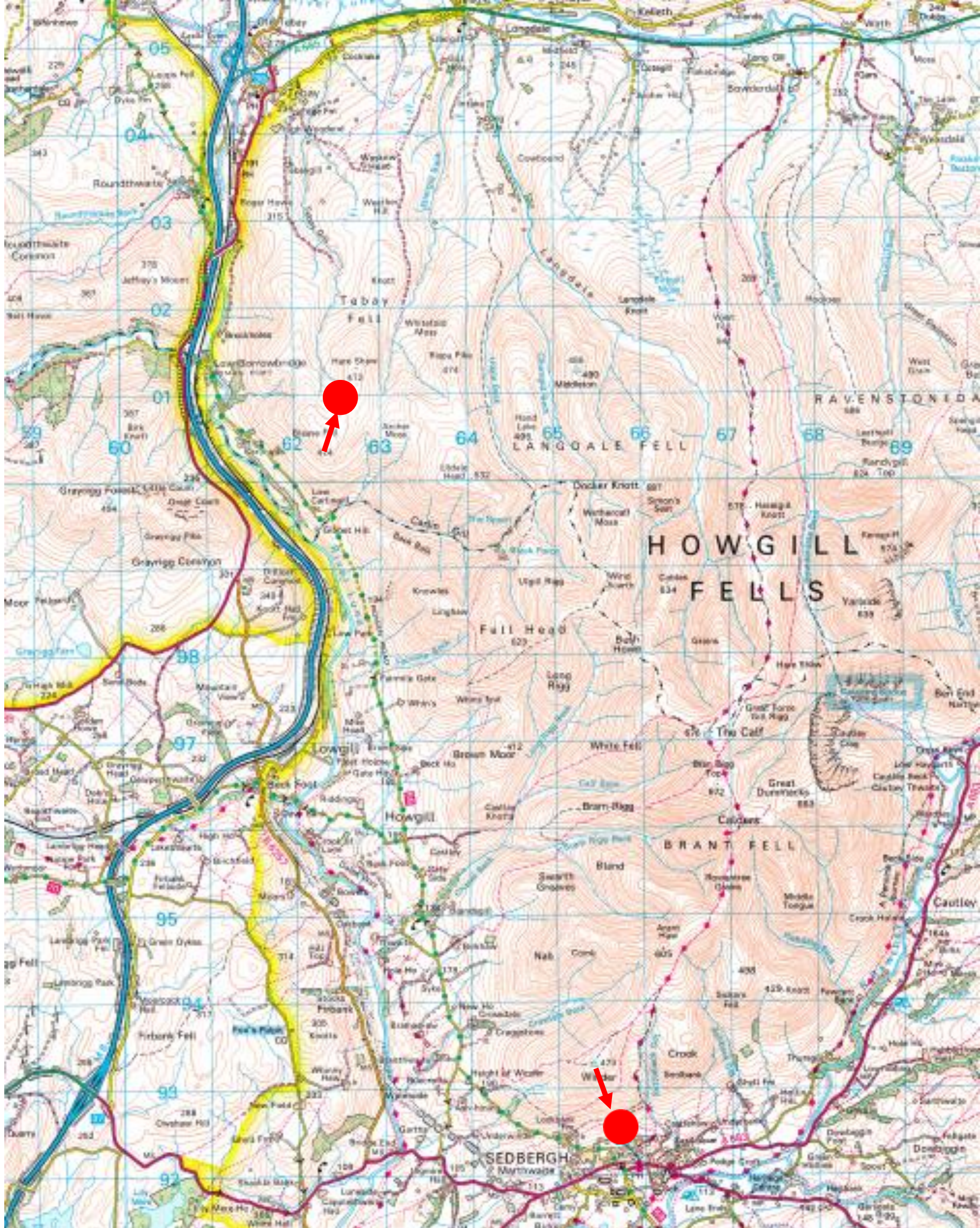
A further reason why accurate discharge observations important near some NFM pilot sites

way small headwater streams (scale of many 'NFM pilots') behave in response to rainfall

- **very different to that of large rivers**
- **very different to nearby micro-basins**
- **not very predictable without observed streamflow data**

e.g., Tebay Gill micro-basin vs Sedbergh micro-basin (both largely draining Wenlock Rocks)

1:50,000 OS map



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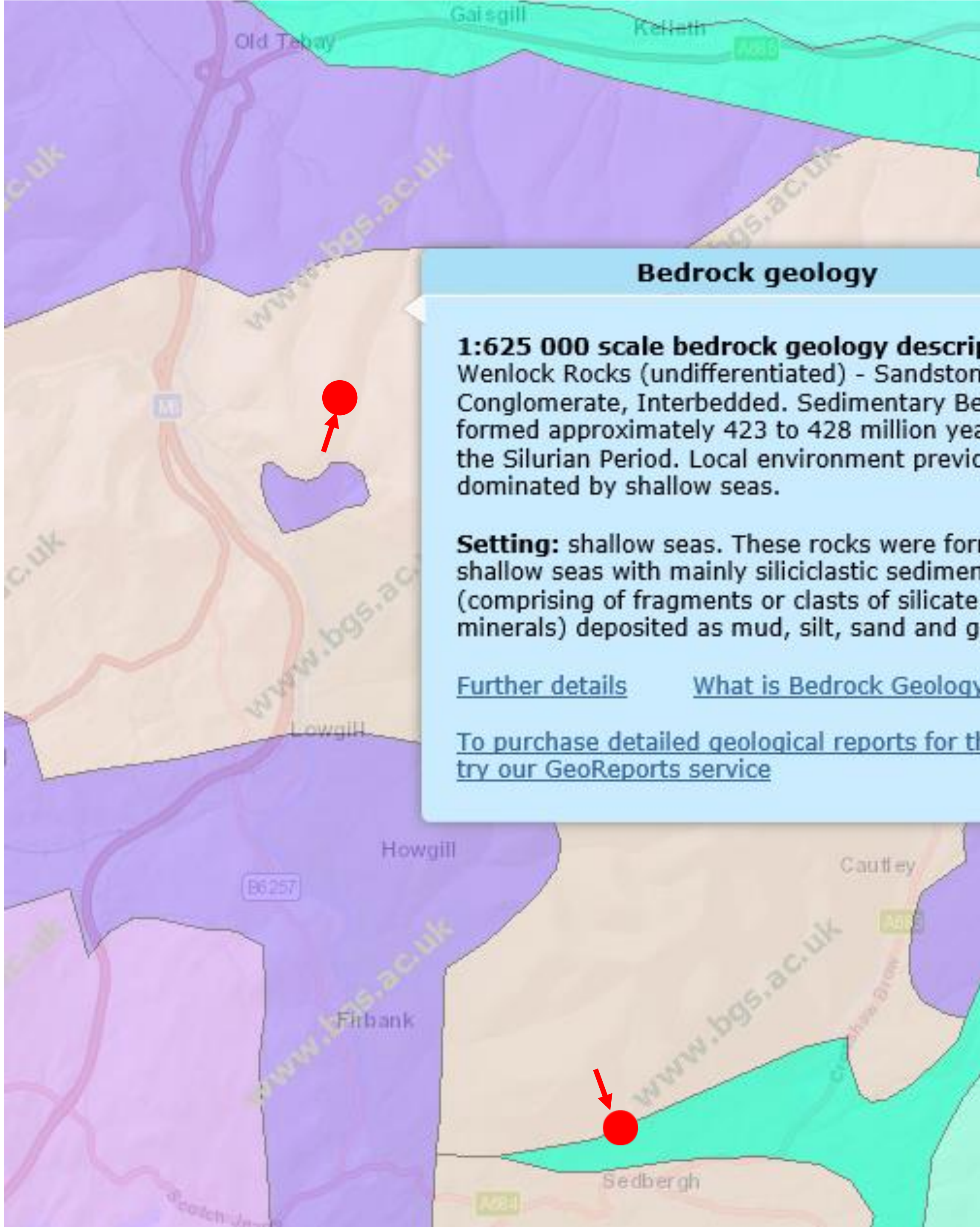
1:625,000 BGS solid geology map



Tebay Gill micro-basin

Dynamic response characteristics (DRCs) of rainfall to streamflow (5-min data)

Rainfall nonlinearity τ :

Pure time delay δ :

Residence time TC :

Steady-State Gain C :

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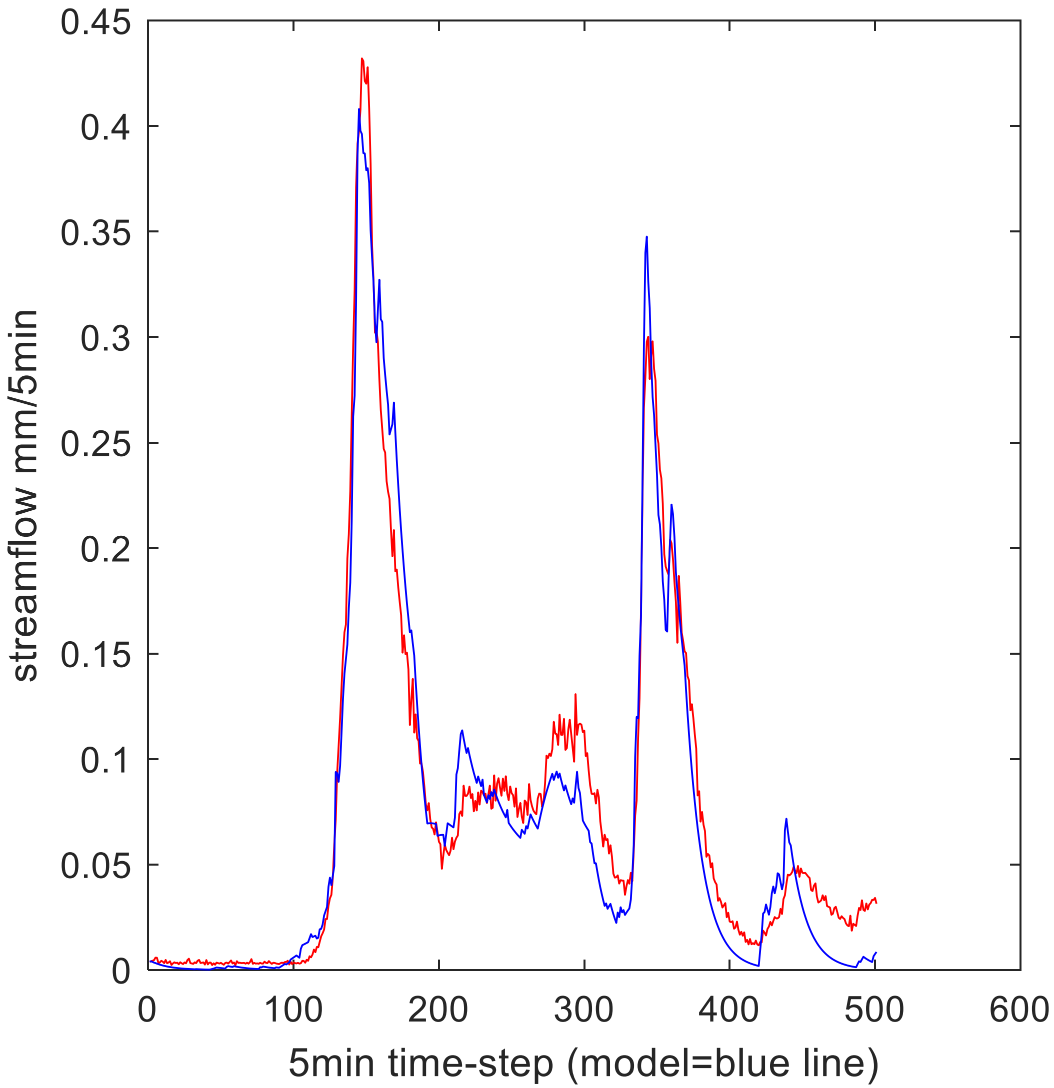
from first-order BOSM CAPTAIN RIV model

Efficiency (R_t^2) : YIC :



Tebay Gill micro-basin

Dynamic response characteristics (DRCs) of rainfall to streamflow (5-min data)

Rainfall nonlinearity τ : 275 min (4.58 hr)

Pure time delay δ : 5 min (0.08 hr)

Residence time TC : 59 min (0.98 hr)

Steady-State Gain C : 0.30

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from first-order BOSM CAPTAIN RIV model

Efficiency (R_t^2): 0.9501 YIC : -10.893

\tebg1.m 12-13 Oct 2018

Sedbergh micro-basin

Dynamic response characteristics (DRCs) of rainfall to streamflow (5-min data)

Rainfall nonlinearity τ : 850 min (14.2 hr)

Pure time delay δ : 480 min (8.00 hr)

Residence time TC : 2265 min (37.7 hr)

Steady-State Gain C : 0.17

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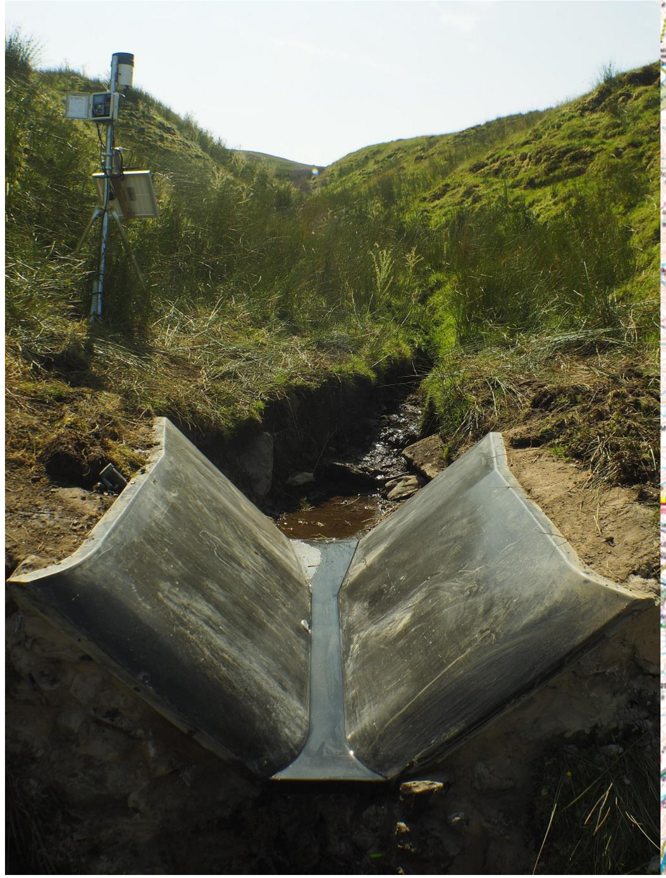
from first-order BOSM CAPTAIN RIV model

Efficiency (R_t^2): 0.9204 YIC : -12.769

\sedb1.m



5 min δ & 1 hr TC very flashy
NFM stores need to catch, fill & drain quickly

Why does this matter?

8 hr δ & 38 hr TC very slow & damped. NFM stores will fill very slowly but need to cope with very extended flood flows (at least long warning of flood!)

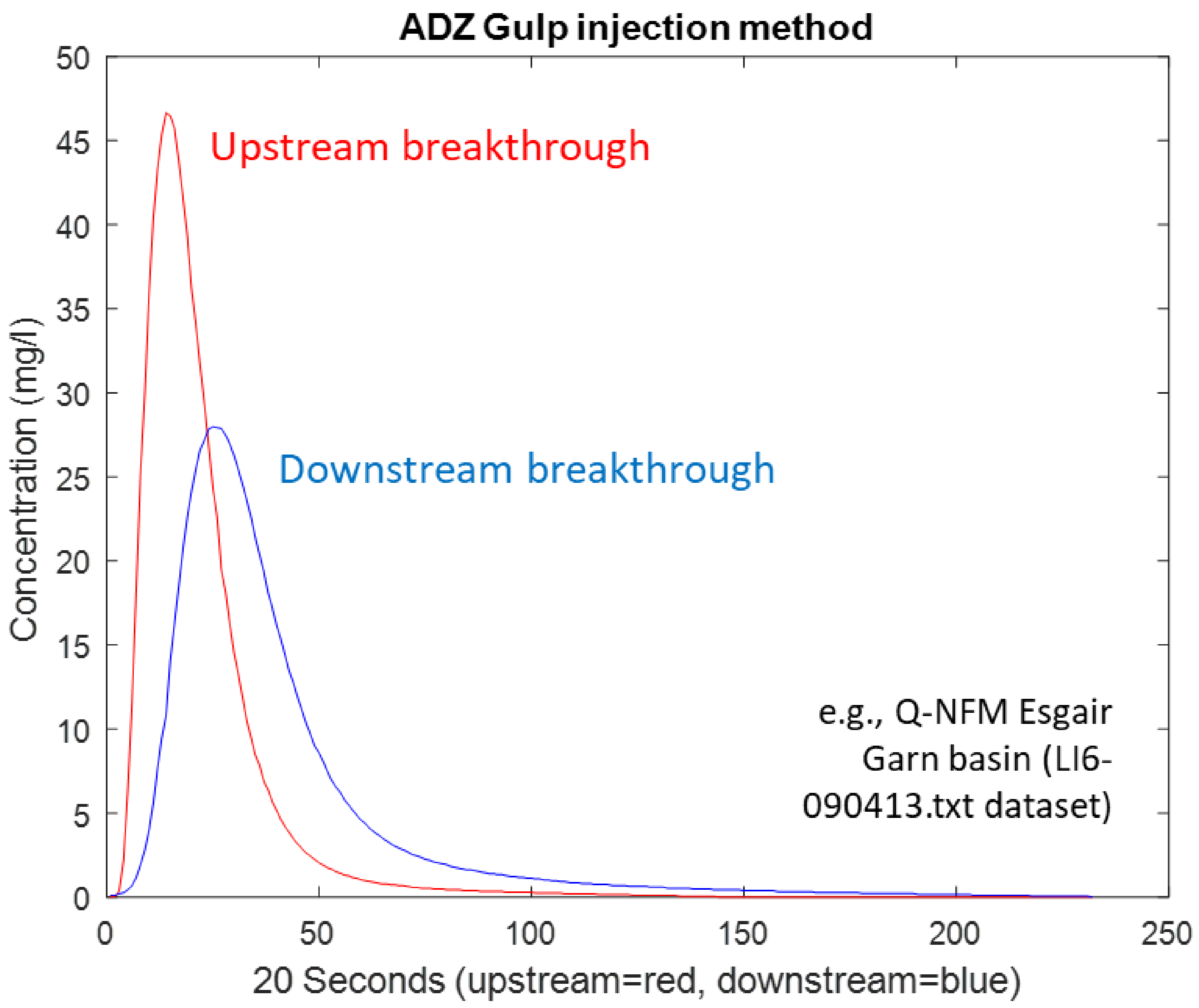
Next session opportunity to discuss measurement of **wet-canopy evaporation**, **roughness** or **topsoil permeability** (as more specialist)

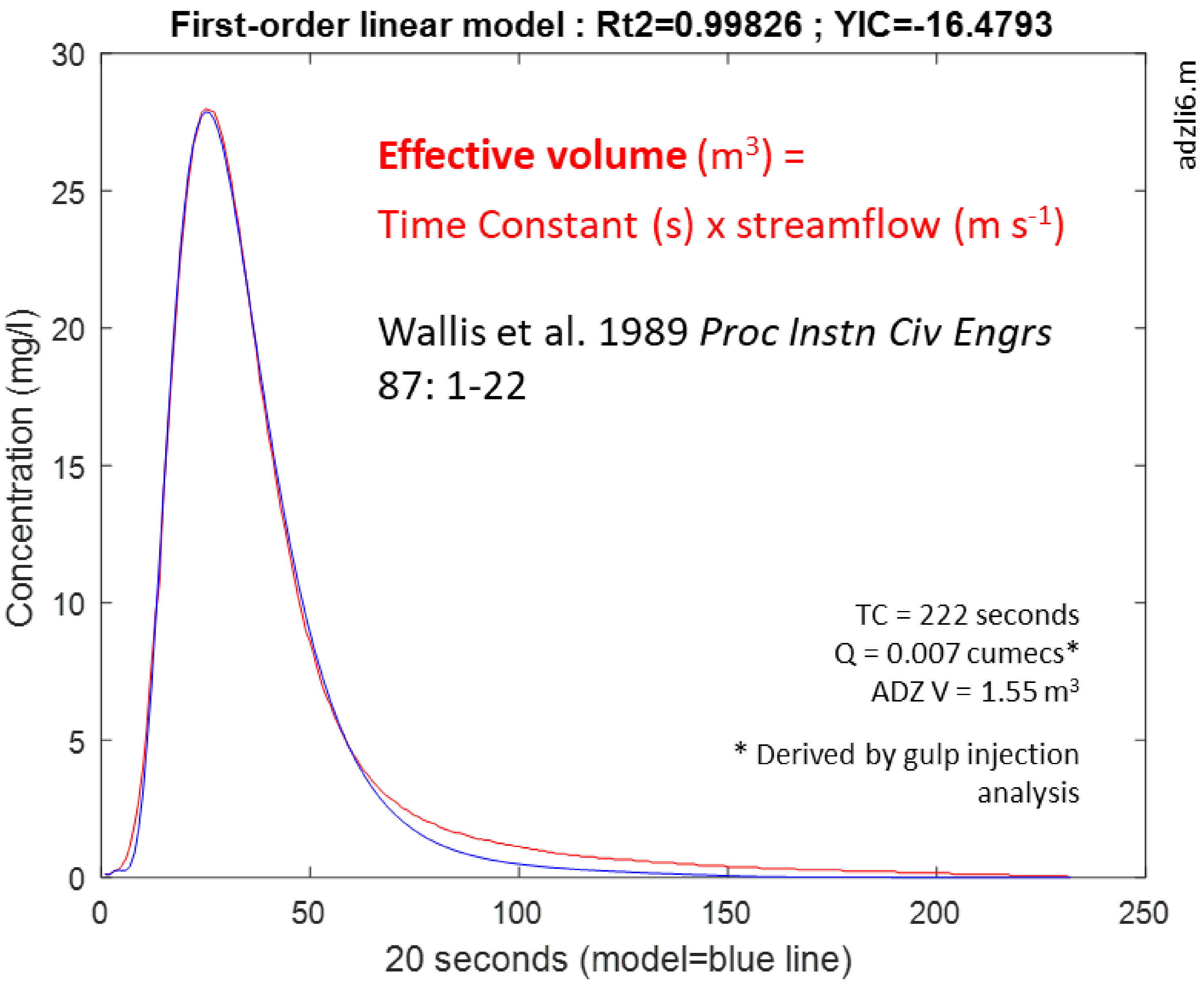
Not covered how we use dilution gauging to characterise **effective storage** in channels or through a series of NFM features (e.g., leaky dams) – see appendix

APPENDIX

Dilution gauging to characterise **<u>effective storage</u>** in channels or through a series of NFM features (e.g., leaky dams)

RhodamineWT dilution gauging
Bessy Gill flume 12 Jun 2020


ADZ Gulp injection method
Upstream breakthrough
Downstream breakthrough
e.g., Q-NFM Esgair
Garn basin (Ll6-
090413.txt dataset)
Concentration (mg/l)
20 Seconds (upstream=red, downstream=blue)
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250


First-order linear model : Rt2=0.99826 ; YIC=-16.4793
adzli6.m
Effective volume (m3) =
Time Constant (s) x streamflow (m s-1)
Wallis et al. 1989 Proc Instn Civ Engrs 87: 1-22
TC = 222 seconds
Q = 0.007 cumecs*
ADZ V = 1.55 m3
* Derived by gulp injection analysis
Concentration (mg/l)
20 seconds (model=blue line)
0
5
10
15
20
25
30
0
50
100
150
200
250