Flow Gauging Strategy for Water Resource Assessment in Scotland

Owen Bramwell, Charles Malcolm & Paul Rodgers
Introduction

- Water Resources Hydrology in Scottish Water
- Historical Context and the Current Network
- Scottish Water SR15 Flow Gauging Strategy
- Climate Change
- Benefits and Conclusions
Water Resources Hydrology in Scottish Water
194 Water Resource Zones
238 Water Treatment Works
450 Sources
Source Types

- Rivers
- Lochs
- Reservoirs
1) HYSIM
Rainfall-Runoff Model

2) Hysim Calibration

3) Aquator Water Resource Simulation
Lack of data and model limitations

- Both HYSIM and Aquator require reliable inflow and storage data to validate and calibrate models.

- Lack of hydrological data can lead to large uncertainties in model outputs (evidence base) which underpin our investment decisions.

- In certain parts of Scotland the coverage of river flow gauging network is very sparse.
Analogue Gauges

• Analogue flow gauges are flow gauges that are near an ungauged catchment of interest and have similar (analogous) hydrological characteristics to the catchment of interest and more than 7 years of data.

• Analogue gauges can provide valuable hydrological information about SW sources that they are analogous to.

• But...the reliability of that information is proportional to the similarity of the analogue catchment to the catchment of interest.
The current hydrometric network
Current hydrometric network

- 396 river gauging stations
- Flood warning stations
- Poor quality data
- Influenced flows
- Approximately 225 suitable for water resource use
Current hydrometric network in relation to water sources

All Analogue (Water Resource) Gauges and Operational Sources
Scottish Water SR15
Flow Gauging Strategy
SR15 flow gauging strategy

• Installation of river flow gauges to reduce uncertainty and improve long term evidence base for investment decisions

• Working from basis of existing SEPA hydrometric network
Options for ‘plugging the gaps’ in the hydrometric network

- Permanent flow gauges at every source
- Permanent gauges at all sources except very small sources
  
  *Both these options very expensive and would generate unnecessary data (poor value for money)*

- Temporary flow gauging at all sources except very small sources
  
  *Expensive, would not pick up on long term trends*

- Preferred option = combination of long term analogue gauges and temporary gauges prioritised by locations where uncertainty in hydrology thought to be high.

**Preferred option allows both yield improvement and climate change/trend detection**
SEPA Analogue Selector Tool

- Score for all 4 components calculated based on similarity to target catchment

- Weighted total calculated using different weightings for each component

- Total Confidence score calculated for each analogue gauge (100= best, 0 = worst)

- Best analogues ranked. Scores >70 selected
Sources with existing analogues

Availability of Analogue Gauges

- Sites without SEPA analogue
- Sites with SEPA analogue

Scottish Water
Trusted to serve Scotland
Analogue Site Selection

• Identify sources with no analogue which could act as an analogue for other target sites if gauge installed

• Rank sources according to the number of target sites they could serve

• Final selection based on rank, location/site suitability, and alignment with other investment projects

• Whole process aimed to maximise the hydrological (and financial) value of analogues by situating them in the optimal locations.
Sources with analogues before and after

Availability of Analogue Gauges

Sites without SEPA analogue
Sites with SEPA analogue
Availability of Analogue Gauges
Sites without SEPA or SW analogue
Sites with SEPA or SW analogue
All SR15 flow gauging activities

- Five long term analogue flow gauges
- 13 temporary gauges
- Support investment projects (need to include growth driver)
- Improve our understanding of hydrology at sources where hydrological uncertainty deemed to be high and perceived supply demand balance is marginal
Flow measurement methods

- Hydraulic Control
- Level sensor, logger and telemetry
- Gauge board
- Gauging Section

<table>
<thead>
<tr>
<th>Stage [m]</th>
<th>Q [m³/s]</th>
<th>Q Measured (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>Rated Flow</td>
</tr>
<tr>
<td>100.000</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>200.000</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>300.000</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Hydraulic Control
- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section

- Flow measurement methods

- Level sensor, logger and telemetry
- Gauging Section
<table>
<thead>
<tr>
<th>Flow estimation method</th>
<th>Uncertainty in yield (+/- %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogue upstream of source</td>
<td>10%</td>
</tr>
<tr>
<td>Good analogue and local temporary gauge</td>
<td>15 - 20%</td>
</tr>
<tr>
<td>Local temporary gauge only</td>
<td>25%</td>
</tr>
<tr>
<td>No flow data (desk-top methods only)</td>
<td>30 - 40%</td>
</tr>
</tbody>
</table>
Climate Change
Vulnerability to Climate Change

- Initial assessment using UKCP09 Future Flows data
- Identified where changes to river flow would have impact on Deployable Output
- Classified as High, Medium or Low based on change to central estimate and Range of uncertainty
- 57 zones High or Medium requiring further analysis

[Map of vulnerability to climate change with indicators for high and medium vulnerability.]
Rain Gauges for long term monitoring

• Identified Scottish Water sites which were >5km from nearest Met Office rain gauge
• Aim also for reasonable coverage of Scotland
• Secure locations to minimise vandalism
• 50 sites identified
• Exact locations to be confirmed by site visits
Benefits and Conclusions
Benefits

• Hydrological data collection results in greater certainty in our understanding of the quantity of water resources we can utilise for supply which contributes to greater certainty in our supply-demand balance methodology.

• In turn our evidence base which underpins water resource investment is more robust.

• Vital contribution to our aim that no customers will exercise long term supply interruptions by 2027 (all zones in surplus). In the mean time, data is essential for producing robust drought plans.

• Detection of long term trends, climate change analysis etc.

• Contribution to the wider field of hydrology.
Conclusions

• Scotland has a long pedigree of hydrological monitoring and survey, but despite this it is still a ‘data sparse environment’ from a water resource perspective

• Lack of data can hamper our efforts to reliably quantify the water resource that is available for supply. This means that the operation of our assets and investment decisions is underpinned by an uncertain evidence base

• Carefully targeted data collection can significantly reduce hydrological uncertainty

• Expansion of the existing hydrometric network will also increase our ability to assess and monitor climate change impacts on the water supply network
Thank You