Operation rules of the Vesdre reservoir revisited

Speaker: Benjamin Dewals

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The Vesdre reservoir is primarily used for drinking water (55,000 m³/day)

Other purposes include flood and low-flow control, as well as hydropower (2.6 MW).
Available data include time series of daily inflows to the reservoir over the period 1995-2014.
Problem formulation: *receding horizon control*

Find minimum reservoir level for each time step (e.g. daily or weekly), so that ...

... whatever the reservoir inflows over the next two years, water supply can be ensured.
The computation of the rule curve is performed in three steps

1. Multiple scenarios of reservoir inflows are generated, to account for the uncertainty arising from natural variability in the flow.

2. Each scenario is simulated independently, leading to scenario-specific minimum reservoir levels for each month.

3. The computed rule curve is determined as the upper envelope of the solutions obtained for the individual scenarios.
Two approaches were considered for generating the *scenarios*, defined by a set of inflow discharge inflow discharge inflow discharge:

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<thead>
<tr>
<th>Merging</th>
<th>Mixing</th>
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<tbody>
<tr>
<td>1 2 3</td>
<td>3 1 2</td>
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<td>2 1 3</td>
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</tbody>
</table>

- **17 scenarios** and **inter-annual correlations**: ✓
- **8,000 scenarios** and **inter-annual correlations**: ✗
This ends up with an optimization model, involving *linear* objective function and constraints

\[
\begin{align*}
\min & \quad \sum_t \text{ruleStorage}_t \\
\text{subject to} & \quad \text{storage}^s_t \leq \text{ruleStorage}_t, \quad \forall t, \forall s, \\
& \quad \text{storage}^s_{t+1} = \text{storage}^s_t - \text{output}^s_t + \text{input}^s_t, \quad \forall t, \forall s, \\
& \quad \text{input}^s_t = \sum_{r \in \text{tributaries}} \text{flow}^s_{t,r} + \sum_{r \in \text{diverted}} \text{diverted}^s_{t,r}, \quad \forall t, \forall s, \\
& \quad \text{output}^s_t = \text{drinkingWater}_t + \text{environmentalFlow}_t + \text{release}^s_t, \quad \forall t, \forall s, \\
& \quad \text{minStorage} \leq \text{storage}^s_t \leq \text{maxStorage}, \quad \forall t, \forall s, \\
& \quad \text{diverted}^s_{t,r} \leq \text{maxDischarge}_r, \quad \forall t, \forall s, \forall r \in \text{diverted}, \\
& \quad \text{diverted}^s_{t,r} \leq \text{flow}^s_{t,r} - \text{environmentalFlow}_r, \quad \forall t, \forall s, \forall r \in \text{diverted}, \\
& \quad \text{release}^s_t \leq \text{penstockHydropower} + \text{bottomOutlet}, \quad \forall t, \forall s, \\
& \quad \text{ruleStorage}_t \geq 0, \quad \forall t, \\
& \quad \text{storage}^s_t \geq 0, \quad \text{output}^s_t \geq 0, \quad \forall t, \forall s, \\
& \quad \text{input}^s_t \geq 0, \quad \text{release}^s_t \geq 0, \quad \forall t, \forall s, \\
& \quad \text{diverted}^s_{t,r} \geq 0, \quad \forall t, \forall s, \forall r \in \text{diverted}.
\end{align*}
\]
The computed rule curves strongly depend on how uncertainty is handled.

Slightly “too safe”

“unsafe”

Existing rule curve

Mixing
Support scenarios do not simply correspond to the driest years

Yearly average discharge (10^6 m³/day):

- **non-support** scenarios 0.857
- **support** scenarios 0.981

Instead, the years containing the **driest months / seasons** on record correspond mostly to the support scenarios.
Conclusion

The historical rule curve of the Vesdre reservoir and the computed rule curve based on recent data show a similar overall pattern, despite some differences.

However, the computed rule curves strongly depend on how uncertainty in reservoir inflows is handled.

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