A multi-objective optimisation framework for scheduling environmental flow management alternatives in a river reach of the SA River Murray

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Capability and expertise in water addressing water management issues of national significance.
Background Information

- Rivers, wetlands and floodplains have been altered
  - Land conversions
  - Over-allocation of water
  - Construction of barriers (e.g. dams, weirs)

- Altered hydrological regime $\rightarrow$ reduced connectivity
  $\rightarrow$ changed ecology and caused poor health

- Environmental flow management
  - Schedule alternatives (e.g. flow releases)
  - Mimic natural flow regime
  - Key to maintaining ecological integrity

- Timing
- Frequency
- Magnitude
- Duration
- Rate of change
Problem: Scheduling Environmental Flow

- Scheduling environmental flow management alternatives is not an easy task

**OPTIMISATION**
- Timing
- Frequency
- Magnitude
- Duration
- Rate of change

**Management Alternatives**
(e.g. flow releases & regulators)

**Fixed amount of Environmental Water**

**System Constraints**
(e.g. Qmax)
Optimisation

- Selecting the best solution based on objectives and constraints
- Can solve complex problems with competing objectives and develop a trade-off curve

Optimisation Algorithm (e.g. Ant Colony Algorithm) → Simulation Model (e.g. Hydrological)

Water Research Centre

- Least water allocation solution
- Ecological Outcomes (maximise)
- Water Allocation (minimise)

Dominated solution
Non-dominated solution

Best ecological outcomes solution
Trade-off
Understand the system
Transparency
Presentation Outline

- Optimisation Framework

- Case Study
  - South Australian River Murray
  - Lock 1 and 2

- Analysis Conducted
  - Trade-off
  - Different system constraints
  - Key Results
Framework

Problem Formulation

Select Objective Functions and Identify Constraints

Develop EFMA Schedule

Calculate Objective Function/s

Termination Criteria met?

Optimisation

Yes

Final set of EFMA Schedules

No
Problem Formulation

Murray Flow Assessment Tool

5 year schedule
Monthly

SA Border flow releases
Wetland regulators

Duration and Magnitude

Identify wetlands and floodplains

Identify ecological indicator

Identify time period and interval

Identify Management Alternatives

Identify sub-options
Framework

- Objective Functions
  - Maximise ecological outcomes (MFAT)
  - Minimise water allocation

- Constraints
  - Maximum flow rate at the SA border

- Environmental Flow Management Schedule Development
  - Decision tree graph
  - Sequential nature and conditional dependencies
Framework

- Calculate Objective Functions
  - Simple water balance model for river, wetlands and floodplains
    - Backwater curves
    - Area vs. depth curves (DEM, baseline survey and wetland management plans)
  - Coupled with MFAT

- Selection of Optimisation Algorithm
  - Pareto Ant Colony Optimisation (Doerner et al. 2007)
  - Based on foraging behaviour of ants
  - Can solve non-linear complex problems
  - Construction of solution using a graph
Analysis Conducted

- Two studies conducted

1. Impact of system constraints
   - Maximum flow rate at the border (1,200-3,000 GL/month)

2. Impact of additional regulators
   - Increasing the number of operational wetland regulators

- Impact on optimal trade-off curve
- Impact of effectiveness of various allocations
Impact of system constraints

Temporary wetlands and floodplains are inundated

Breakpoint
Impact of system constraints

- 4000 GL/yr
- 3200 GL/yr
- 2750 GL/yr
- Current
Impact of additional regulators

- 1,200 GL/mth
- 1,800 GL/mth
Impact of additional regulators

- Investigation 1
- Investigation 6
- Investigation 7
- Investigation 3
- Investigation 8
- Investigation 9

Environment (GL/yr) vs. MFAT Score

- 4000 GL/yr
- 3200 GL/yr
- 2750 GL/yr
- Current
Summary

- Scheduling environmental flow management alternatives is a complex problem

- Multi-objective optimisation framework

- Demonstrated using case study in Murray River

- Two studies conducted
  - Maximum flow rates have significant impact
  - Additional regulators reduce the water allocation

- Inform decision making
THANK YOU
• Ecological Response of the wetland and floodplain
  - Murray Flow Assessment Tool (Young et al, 2003)
  - A score given from 0 (poor) to 1 (good)

\[
WVHC = x_1 AHC_w + x_2 RHC_w
\]

where:

\(WVHC\) = Annual Wetland Vegetation Habitat index

\(AHC_w\) = Adult Habitat Condition

\(RHC_w\) = Recruitment Habitat Condition

\(x_1\) and \(x_2\) are normalized weights = 0.5
- Adult Habitat Condition ($AHC_w$)

$$AHC_w = ID^3 \sqrt{FT_w \times PD \times RD}$$

where:

$ID$ = Inundation Depth

$FT_w$ = Inundation Timing

$PD$ = Depth Duration

$RD$ = Rate of Depth Change