PrimeWater

Australian End-Users Workshop: HAB’s Early Warning Tools

Thursday 20th April 2023 | 11:30 am – 2:30 pm AEST
Dep. of Civil Eng., Monash University, Melbourne

EMVIS
WATER RESOURCES & ENVIRONMENT MANAGEMENT

Towards a multi-objective Water Quality Forecasting Service - The watershed digital twin concept implementation in Mulargia – Fulmendosa Reservoirs

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Organized by:

IWA
the international water association

In collaboration with:
Monash University & CSIRO

CSIRO

…ENAS needs to identify Hydro-ecological Risks in the Mulargia Reservoir at an early stage and…

About ENAS

Ente Acque della Sardegna (ENAS), is Italy's largest public water utility based on multipurpose dams. ENAS was established to construct and manage a freshwater supply system for the sustainable and rational use of water resources on the regional scale. The supply system comprises works and infrastructure for the collection, storage and conveyance of water.

ENAS Sardegna

…Pro-act instead of Re-act

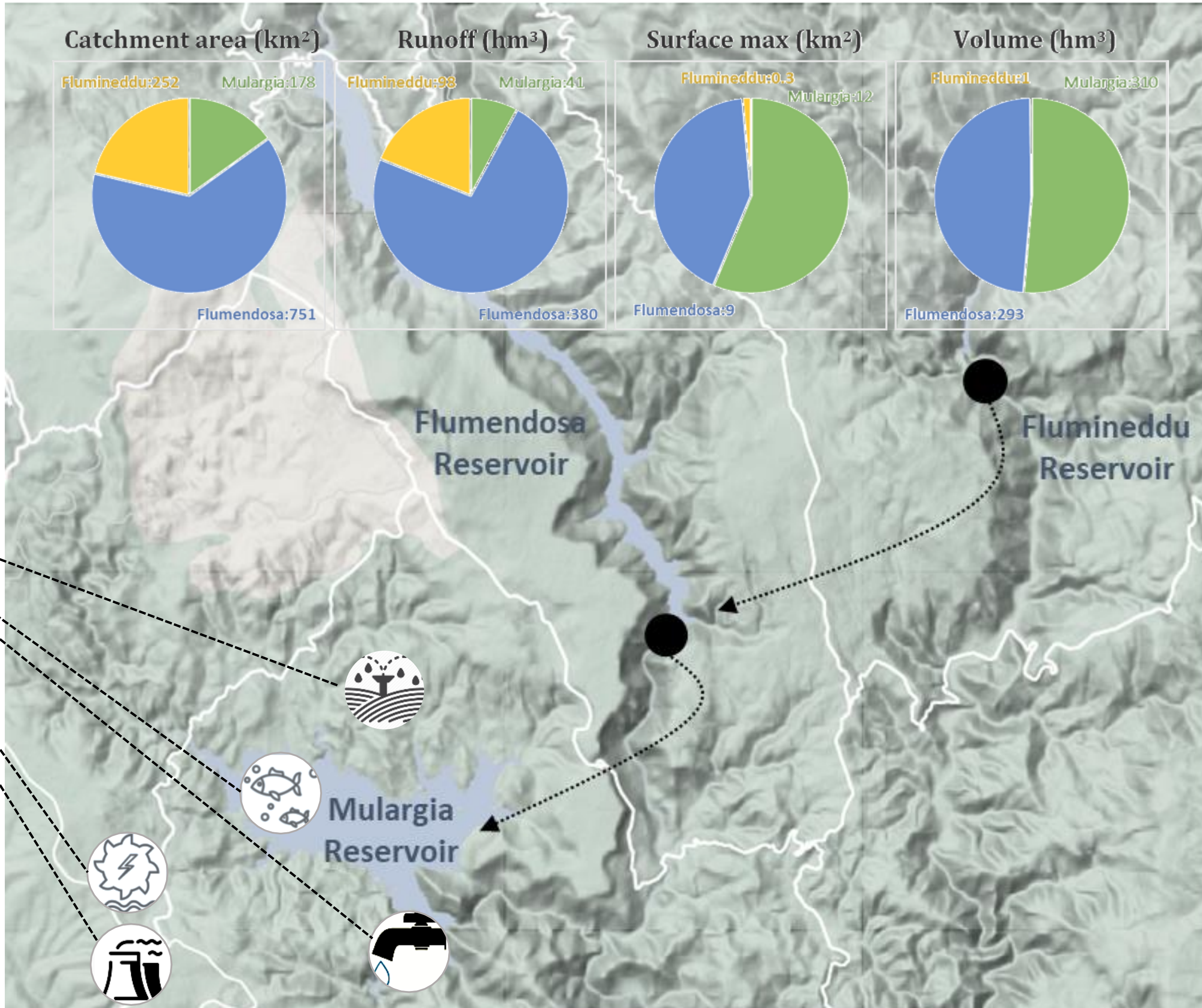
The Mulargia Watershed Digital Twin

A quick overview of the area

Water Dependent Activities

- Potable Water Treatment Operations
- Irrigation
- Amenity and Recreation
- Hydropower Production
- Petrochemical Industry

The System



DYNAMIC MULTI-RESERVOIR WATER BLENDING AS A SERVICE

Preventing the evolution of an algae bloom by combining different sources of water

Challenge

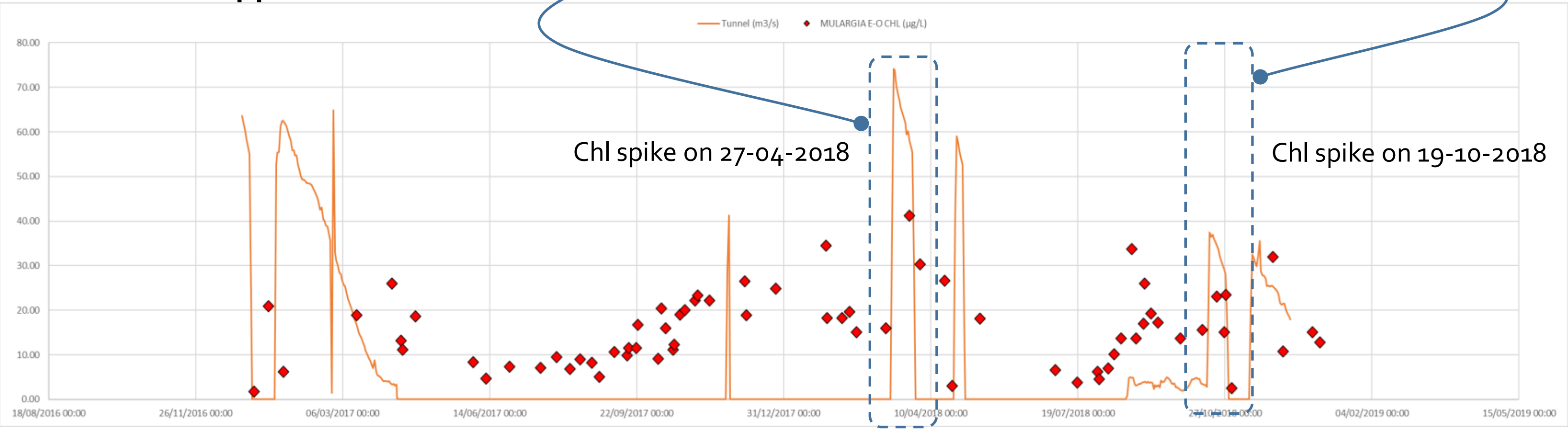
Managing interconnected reservoirs under water quality stress is a complex and multi-parametric problem which requires advanced tools.

When it comes to Water Quality

- ❑ Transferring water from Flumendosa to Mulargia might not have always the same effect…
- ❑ Also the rate of removing water from Flumendosa reservoir should not cause any adverse ecological effects.

…or it can have no effect or even the opposite result

…it can reduce chl-a concentrations…



Chl-a concentrations from EO data at the abstraction point in Mulargia vs water transfers from Flumendosa.

Dynamic Multi-reservoir Water Blending as a Service

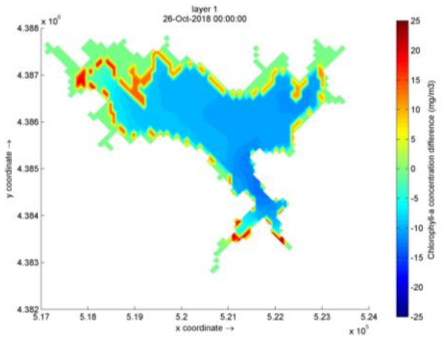
Preventing the evolution of an algae bloom by combining different sources of water

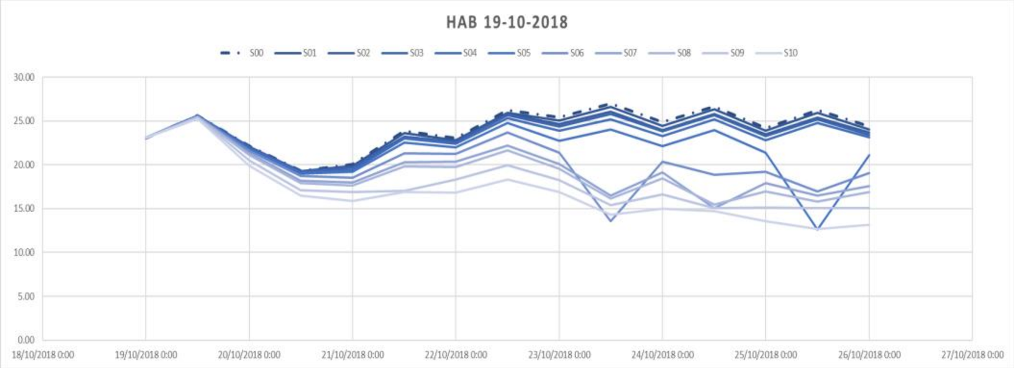
Differences in chlorophyll a concentrations between the scenario of Flumendosa contribution (S10) and the reference scenario at day +7 for the top layer.

Chlorophyll a concentrations for the baseline scenario and the scenarios of Flumentosa contribution (S1 – S10) at the abstraction point.

Chl spike on 19-10-2018

- Additional water from Flumendosa reduces chl-a values by up to 13 µg/L.
- Higher reduction is observed near the area of the Flumendosa tunnel entrance and the north part of the reservoir

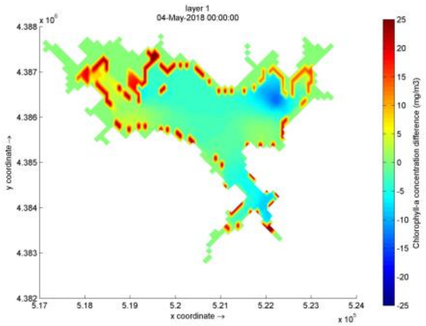


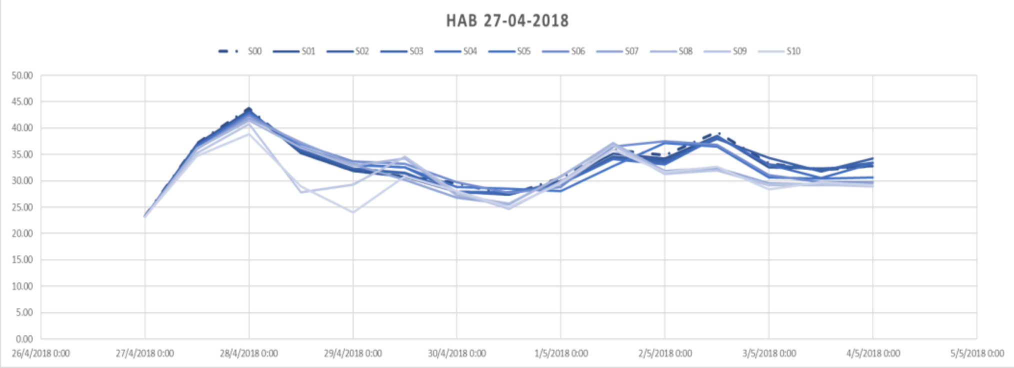


	Percentage improvement of chlorophyll on a 7 - days average	Maximum improvement of daily chlorophyll on a 7 – days period
S1	0.98%	0.46
S2	2.12%	0.92
S3	2.66%	1.21
S4	3.84%	1.80
S5	10.01%	13.60
S6	16.32%	13.40
S7	19.45%	11.57
S8	21.09%	11.17
S9	25.76%	11.61
S10	30.16%	13.57

Chl spike on 27-04-2018

- Additional water from Flumendosa reduces chl-a values by up to 7 µg/L in the north part but has little effect or increases chl-a in the rest of the reservoir.





	Percentage improvement of chlorophyll on a 7 - days average	Maximum improvement of daily chlorophyll on a 7 – days period
S1	1.13%	1.69
S2	0.75%	1.73
S3	1.16%	1.78
S4	1.21%	1.80
S5	2.01%	3.12
S6	0.93%	3.11
S7	4.65%	6.81
S8	4.30%	7.26
S9	7.41%	7.58
S10	9.48%	7.90

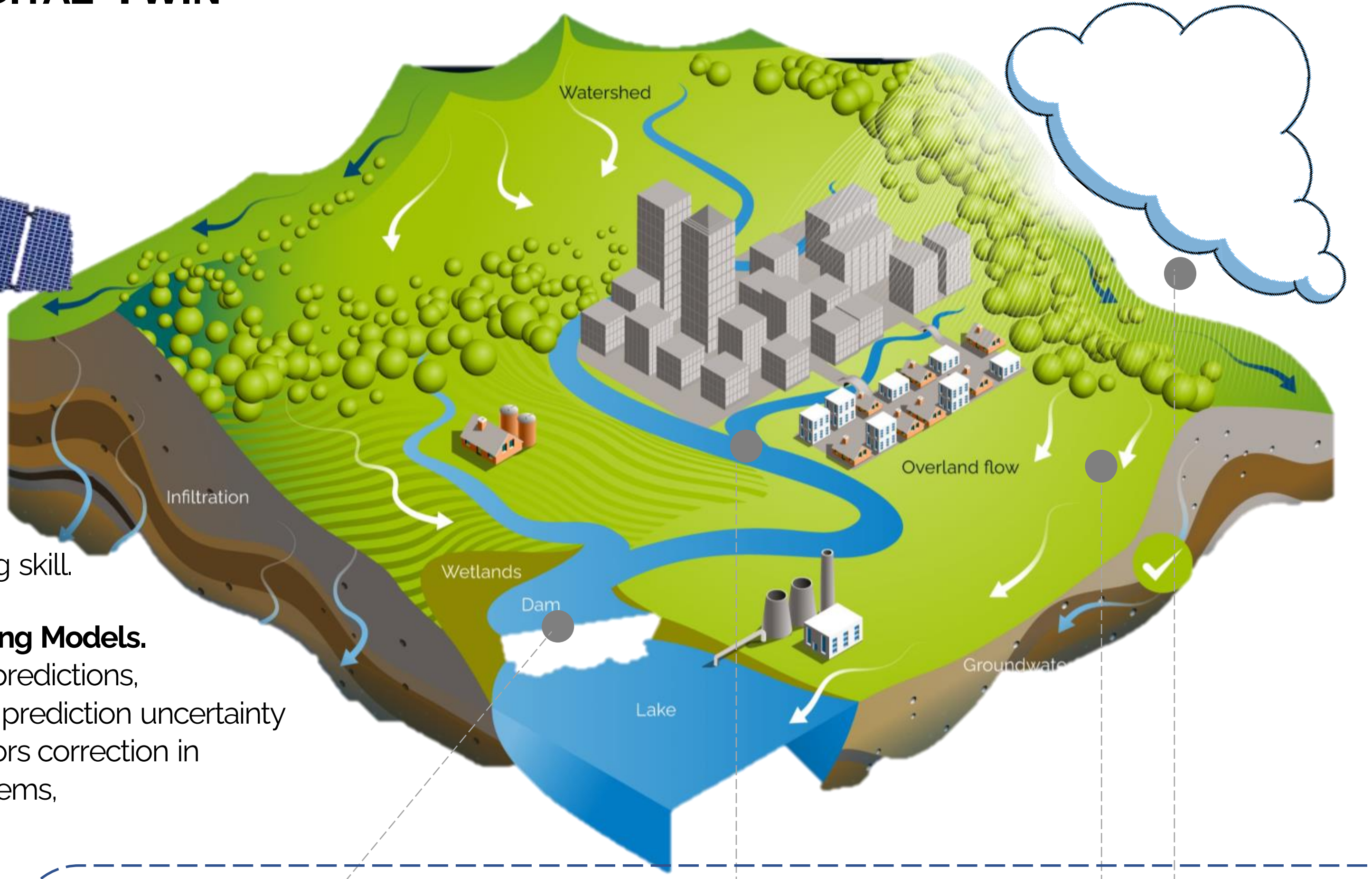
S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
4,5	8,0	10,0	15,0	20,0	30,0	40,0	45,0	55,0	65,0

Flumendosa water transfer scenarios (m3/sec) for 7 days

The Mulargia Watershed Digital Twin

…from Satellites Imagery to high reliability water forecasts

EO is used to improve forecasting



Automated Scientific workflows

Operationalizing the science

Data Assimilation
-Improve forecasting skill.

Machine Learning Models.
-Water Quality predictions,
-Assessment of prediction uncertainty
-Systematic errors correction in forecasting systems,

Downstream applications
Early warning systems

Proactive in-lake management of water-related hazards (e.g. algal blooms)

Optimization of water operations (e.g. treatment plants, aquaculture, energy production)

In-lake hydrodynamics
Forecasts of the water temperature, lake mixing and circulation patterns

In-lake water quality
Forecasts of chlorophyll-a, nutrients, sediments and dissolved oxygen

River flow forecasting
Forecasts of water depth and velocity

Hydrologic forecasting
Forecasts of river discharges, water temperature, sediment and nutrient loads into downstream lakes

Weather forecasts
Forecasts of wind, rainfull and other atmospheric variables

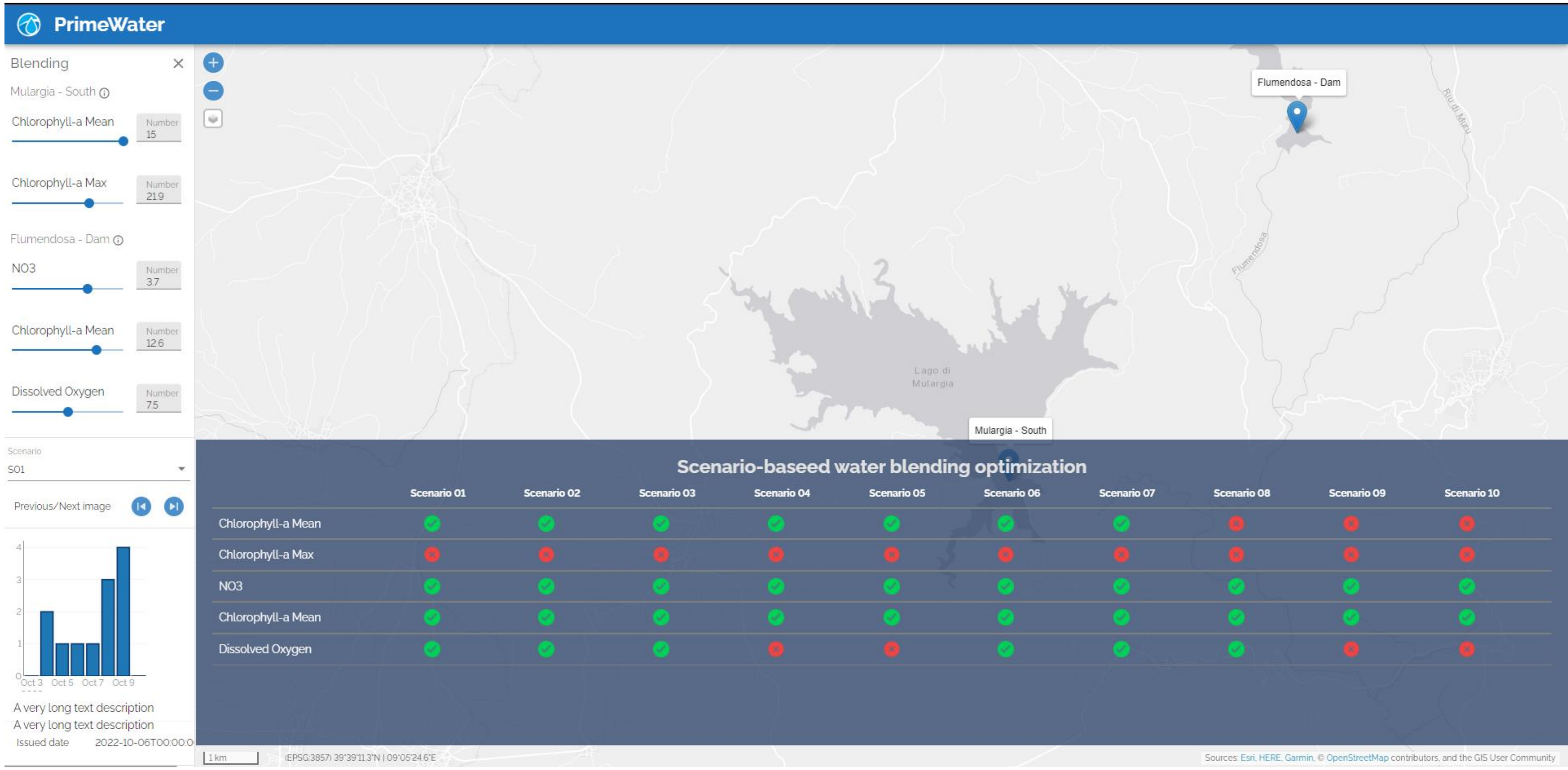
DYNAMIC MULTI-RESERVOIR WATER BLENDING AS A SERVICE

Preventing the evolution of an algae bloom by combining different sources of water

Solution

Every day assess dynamically the effectiveness of various water transfer scenarios in terms of volume, timing and duration 10 days in advance through scenario-based forecasting tool for WQ characteristics and schedule proactively of water transfers between reservoirs to:

“improve WQ in downstream reservoir without impeding WQ in the upstream reservoir”

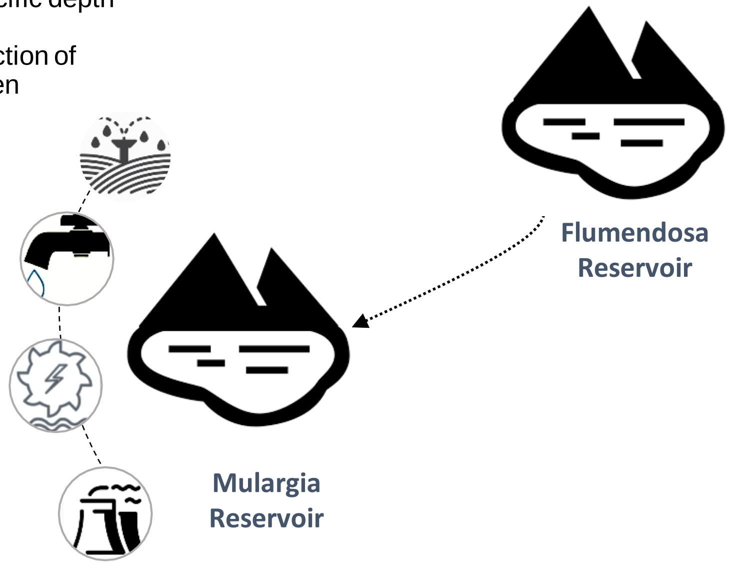


Dynamic Multi-reservoir Water Blending as a Service

Preventing the evolution of an algae bloom by combining different sources of water

Definition of system components

- Starting and ending elevations of the F-M tunnel, fixed (at specific elevation from bottom), or floating (at specific depth from surface)
- Estimating Maximum Flow of F-M tunnel as a function of hydraulic head (Water elevation difference between Flumendosa and Mulargia)



Definition of parameters to evaluate

Hydraulic Parameters, eg Water elevation
Water quality parameters, eg Chlorophyll, Nutrients
Statistics for each parameter

Definition of areas of Interest

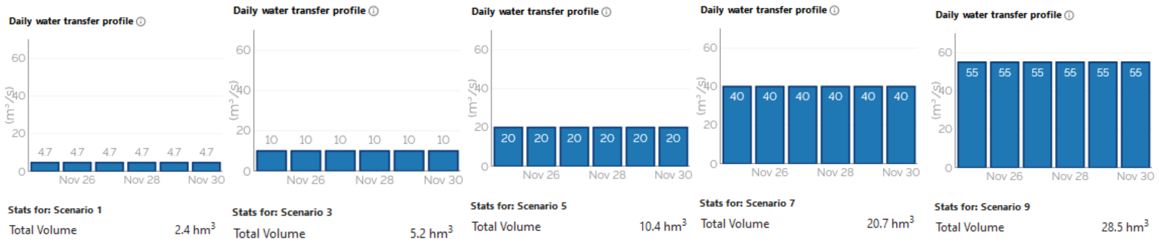
Multiple types of Areas of Interest can be defined e.g.:

- A single cell
- An area defined by a point and a radius
- An entire layer

And Multiple depth definitions e.g.:

- At specific distance from reservoir bottom? (e.g., at +245m)
- At specific depth from surface? (e.g., at 2m depth from surface)
- Between two depths? (e.g., from 0m to 8m depth)
- At the entire water column

Definition of scenarios to be tested

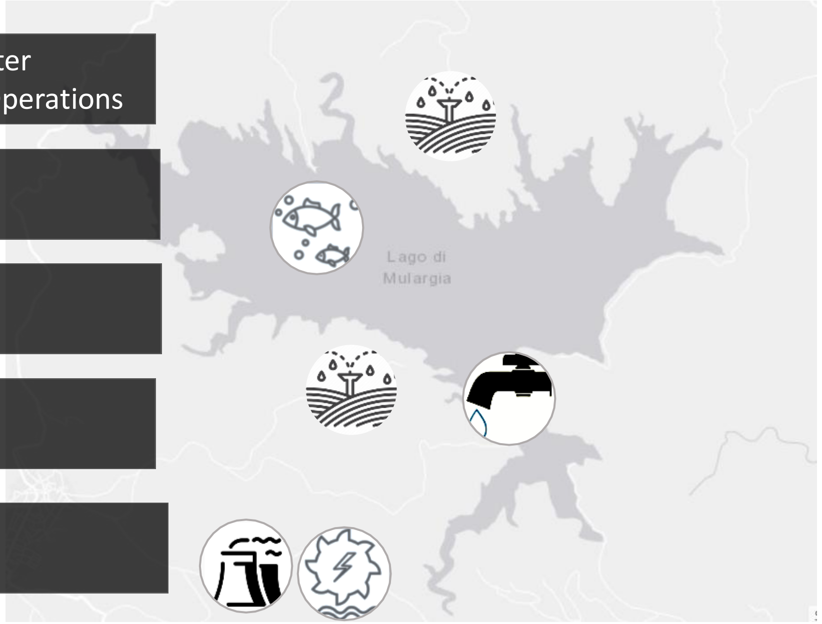


THE VALUE OF WATER QUALITY FORECASTS FOR DYNAMIC WATER BLENDING

Boundaries of Analysis

Downstream Water Users

- Potable Water Treatment Operations
- Industry
- Irrigation
- Hydropower
- Ecosystems



Can an Early Warning Forecasting System for Phytoplankton Bloom Alerts trigger any actions that could generate in the **short-term** Economic Benefits or Avoid losses ?

Ecological Services

- Scenic
- Boating
- Fishing
- Swimming
- Drinking
- Support economic activity

Activities

- **Recreation**
- Enjoy property
- Potable Water Treatment Operations
- Tourism Sector
- Aquaculture Sector
- Agricultural Sector
- Energy sector
- Other Water dependent industries

Impacts

Satisfaction

Health Impacts

Property value

Direct tangible cost that accrue directly to assets such as:

-Increased treatment, inspection and maintenance costs for drinking water facilities

-Damage to agriculture (Crop losses), aquaculture (fish kills or fish price reduction), Livestock losses

-Cost of mobilization of O&M Services (e.g WTPs operations), emergency response services , etc

Losses due to business interruption that accrue from the disruption of activities in areas directly affect by the disaster such as:

-Loss of revenue (water supply disruption, energy curtailment, prohibition from recreational uses)

-Losses due to the absence of public services (penalties from water supply disruption, energy curtailment)

Indirect costs that accrue from knock-on impacts of direct or business interruption losses such as:

-Loss of reputation

-Sales drop in businesses reliant on water

-Commodities price increases

-Increase in unemployment

-Opportunity costs of further development

Achieve cost reductions from chemicals and energy

Integrate raw water quality with an emulator of the WTP processes and enhance preparedness of the water utility operator against possible changes in the water quality influx

Theoretical Framework

We adopted the use of Water Quality Elasticities of Costs - **the percentage change in costs resulting from a 1% change in source water quality**, for linking source water quality parameters, such as turbidity, total organic carbon (TOC), nitrogen, and phosphorus to DWTP expenditures.

Then, based on the forecasted changes in the abstracted Water Quality, the **short-term potential impact to the WTP operation could be quantified** (compared to a long-time average incoming water quality).

In case that **pro-active measures** can be taken at the lake level for improving Water Quality, the above **costs can be avoided** and therefore can be regarded as direct benefit.

James I. Price and Matthew T. Heberling (2020), The Effects of Source Water Quality on Drinking Water Treatment Costs: A Review and Synthesis of Empirical Literature

Water Quality Elasticities

Literature indicates diverse set of results for the Elasticities in each study, due to the modeling approach, data structure, definition of treatment costs and water quality, and statistical method

Water Quality Elasticities of Costs for the **Bob McEwen Water Treatment Plant** that is abstracting water from **Lake Harsha**

WQ Parameter	Elasticity (Short-term))
Turbidity	0,02
Total Organic Carbon (TOC)	no significant short-term relationship between TOC and O&M costs.

Heberling, M. T., C. T. Nietch, H. W. Thurston, M. Elovitz, K. H. Birkenhauer, S. Panguluri, B. Ramakrishnan, E. Heiser, and T. Neyer (2015), Comparing drinking water treatment costs to source water protection costs using time series analysis, Water Resour. Res., 51, 8741– 8756, doi:10.1002/2014WR016422.

For the **Water Treatment Plants** that are abstracting water from **Mulargia Reservoir** developing cost and price function models for extracting case specific elasticity factors is beyond the scope of PrimeWater

For hypothesis testing PrimeWater adopts the mean value of short-term elasticities that have been derived in literature

WQ Parameter	Elasticity (Short-term/Mean value)
Turbidity	0,14
Total Organic Carbon (TOC)	0,39
Nitrogen/Nitrate	0,06

James I. Price and Matthew T. Heberling (2020), The Effects of Source Water Quality on Drinking Water Treatment Costs: A Review and Synthesis of Empirical Literature

The Value of Water Quality Forecasts for Dynamic Water Blending

The impact model for the Potable Water Treatment Operations

Reducing the impact of a Water Quality outbreak before it evolves

Improve water transfers among your interconnected reservoirs to mitigate in advance, upcoming water quality hazards and reduce impact to downstream uses

By applying blending in four 7-day spike events during a year and reducing average chl-a concentration from 24 μg/L то 17 μg/L, (which is equivalent to an **annual** average chl-a reduction of 6%) **treatment costs may be reduced by 2.33% on an annual basis**.

TOC (or Chl-a) Elasticity of Costs

- It is assumed that TOC reflects algae carbon content
- 1% decrease in TOC (or Chl-a) (against a reference value) leads to a 0.39 % decrease in operating costs.

Reference Value for Chl-a

- The background (annual average) value of Chl-a equals to ~9 μg/L according to the water quality model on the top layer of the abstraction point

Avoided Treatment costs for a single Chl-a spike event

- 30% avoided costs for a single event
- By lowering the average Chl-a concentration during a spike event by 7 μg/L (=78% against ref. value), costs are decreasing by 30% (=0.39*78%) for the specific event

Thank you for attending!

PrimeWater Team:

European Commission

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