PrimeWater

H2020-SPACE-2019
Research and Innovation Action

Delivering Advanced Predictive Tools from Medium to Seasonal Range for Water Dependent Industries Exploiting the Cross-Cutting Potential of EO and Hydro-Ecological Modelling

Workshop Report

End User Consultation Workshop: HABs Early warning - Moving from thresholds to impact based forecasting

The project has received funding from the European Union's Horizon 2020. Research and Innovation Programme under Grant Agreement No 870497.

The end user workshop was organised by the CSIRO AquaWatch project.

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1. Introduction

An online event was held on 1st October 2021 (AEST 11 AM – 2 PM) as part of the 7th Australian and New Zealand Cyanobacteria Workshop https://www.waterra.com.au/all-events/2021-09-29/7th-australian-and-new-zealand-cyanobacteria-workshop/. This was an optional 3rd day in the programme titled: *PrimeWater and CSIRO AquaWatch End User Consultation Workshop- HABs Early Warning - Moving from Thresholds to Impact based Forecasting & Management*.

As part of the workshop there was an interactive session to share information and obtain feedback on setting up the key components for developing a forecasting-based early warning system for HAB in water bodies in Australia.

1.1 Workshop Context

Many inland water bodies in Australia and around the globe often experience algal blooms that can impede with public health since many of them supply household needs for towns and landholders. In Australia, water from reservoirs is mainly used for stock needs, irrigation, recreation, flood mitigation and hydroelectricity, demonstrating the significant socioeconomic impact that water quality issues might incur.

PrimeWater is a Horizon 2020 (the EU Research and Innovation programme) funded project, that aims to maximize the potential of the Earth Observation (EO) technologies for the water sector by enhancing and expanding the information base for inland water quality attributes, integrating multi- and hyperspectral imagery from satellite, airborne and ground-based sensors, increasing the situational intelligence of water regulators, emergency planners, water related industry professionals and local communities.

The CSIRO AquaWatch Australia Mission supported by the SmartSat CRC aims to provide from 2026 routine, continental scale inland and coastal water quality information, including cyanobacteria detection for all major water bodies across the continent. In close collaboration with the SmartSat CRC and partners, the mission team is to begin the technical design process of key ground-based and space-based technologies that will form part of the AquaWatch system. Within the AquaWatch mission, an Inland water quality monitoring Pilot project will be trialled for a year using on-ground sensors network and EO for measuring real-time water quality data (chlorophyll, turbidity, algal cells, temperature) to feed to a web-based data portal. To generate early warning and forecasting for end users, this project will use real-time analytics to integrate sensors data, satellite data and predictive modelling.

Lake Hume is one of the case studies where joint research between CSIRO and the PrimeWater consortium is exploring multiplatform optical data for assessing water quality. Additionally, this joint initiative aims to assess the predictability of algal blooms – in terms of timing, extent, and intensity employing both process-based and data-driven, machine learning models. PrimeWater will further evaluate the limits of those modelling approaches in terms of their sources of uncertainty and forecast horizons.

1.2 Workshop overview

Both PrimeWater and AquaWatch mission aim at establishing a complete value chain linking science with the water sectors actual needs. Both projects are implementing a comprehensive consultation process with end users, scientists and water professionals, ensuring the co-development of added value, intelligent products and services for hydro-ecological hazards, early warning and predictive management. This workshop intends to initiate a discussion on possible ways of re-purposing short to medium term water quality forecasts into an early warning service for HAB outbreaks.

1.3 Workshop Objectives

- Inform local/regional Stakeholders on the current research findings of the PrimeWater and AquaWatch projects and demonstrate the early version of the operational forecasting service for inland freshwater systems implemented on local and international case study sites
- Share experiences from managing HAB related risks in Australian freshwaters
- Discuss how forecast-based early warning services for HAB can improve risk management operations
- Stimulate further work and foster engagement for the next phase of the projects

1.4 Workshop Participants

Representatives from local and regional stakeholders within and adjacent to the Murray-Darling Basin.

2. End user consultation

2.1 Structure of the End User consultation

The purpose of the consultation was to gain an understanding of end user views on the key components for developing a forecasting-based early warning system for harmful algal blooms. To make the session more engaging, an interactive tool called GroupMap was used (https://join.groupmap.com/6E7-D11-9FB).

The structure was as follows:

1) Mapping of stakeholders
2) Inputs on parameters/indicators that can be used as proxies to describe cyanobacteria outbreaks;
3) Thresholds of top parameters;
4) Impact indicators across sectors to describe impact of these outbreaks

The information provided is to be used to develop early warning services, using re-purposed short and medium term water quality forecasting information. The aim is for the information to also be shared with participants following the workshop. There is opportunity for continued engagement beyond the workshop through PrimeWater and AquaWatch

2.2 Stakeholder mapping

The interactive map asked participants to place the organization in the quarter of the disaster risk management matrix where it best fit in terms of core business:

- Risk knowledge and analysis → focus on understanding risks in an area
- Monitoring and warning services → providing information to relevant authorities on water related events
- Response capability → this would be response on the ground, possible coordinating response in the event of a disaster
- Dissemination and communication → when there is a disaster, coordinating communication between stakeholders and to the public

The results of the mapping exercises are in

Figure 1. It was noted that most organisations have multiple responsibilities, and the majority of organisations focus on monitoring and warning services.

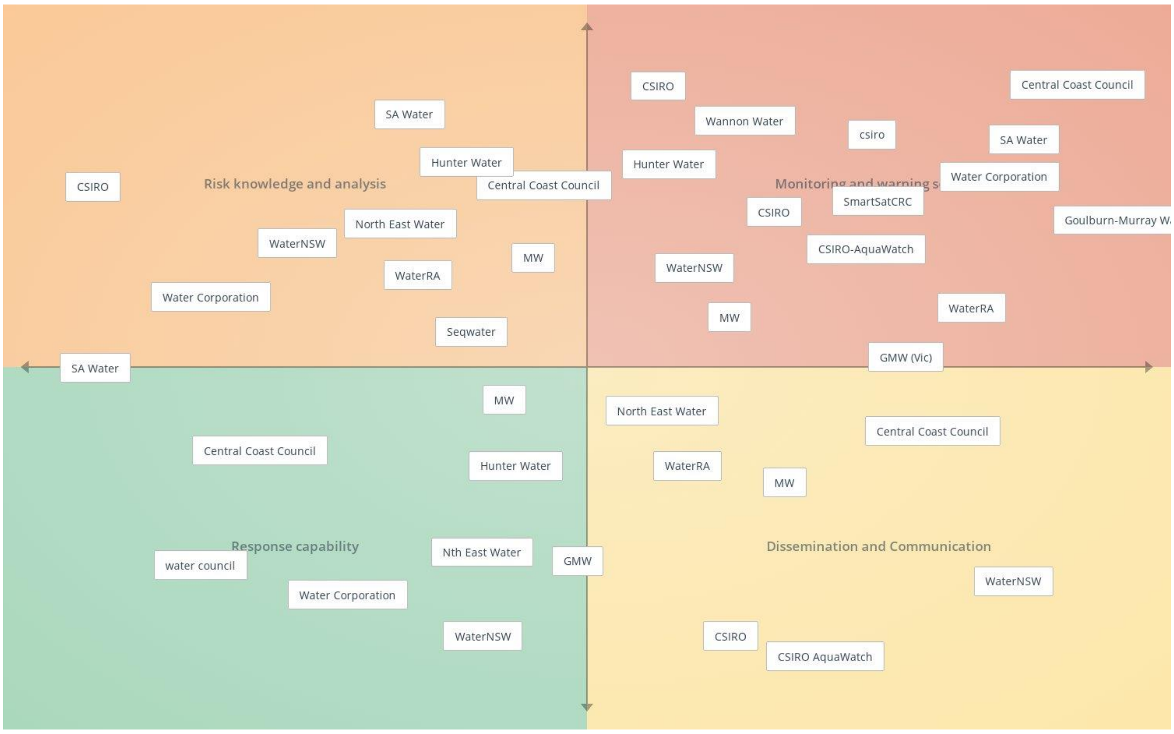

Figure 1. Stakeholder mapping of end-users in Australia workshop

The following questions from the mapping exercise were to determine the types of water bodies participants deal with in their hydroecological operations. There were then questions to determine the 1) level of engagement in early warning, and 2) how important early warning is for an organisation (Figure 2).

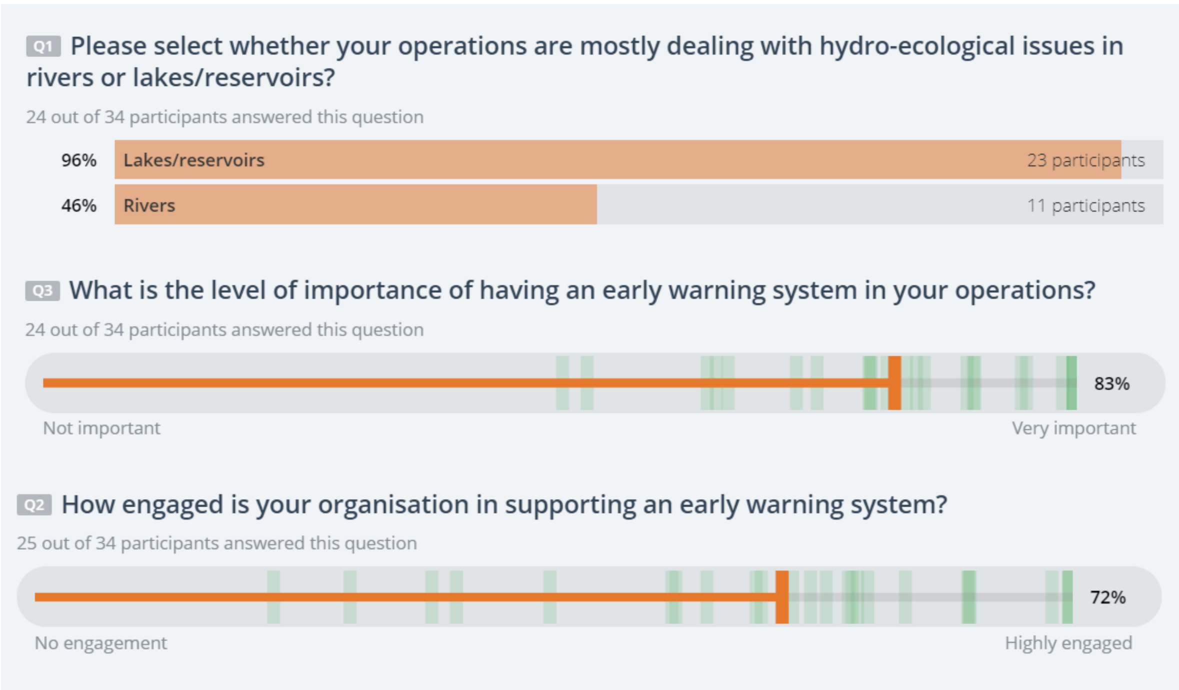

Figure 2. Mapping operations and early warning system engagement of workshop participants

Most of the participants (96%) were in organisations that were dealing with hydro-ecological issues in lakes/reservoirs. Nearly half the participants (46%) also addressed rivers. Overall, 12 respondents are working on both rivers and lakes/reservoirs, 10 just on lakes/reservoirs and 1 on just rivers (Figure 3).

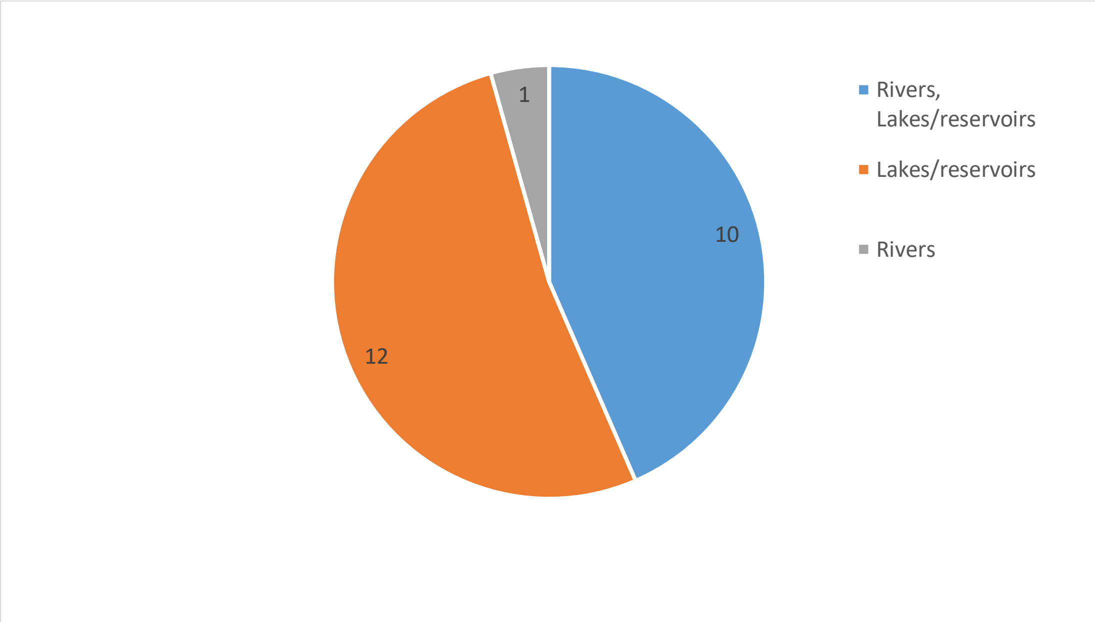

Figure 3. Distribution of water bodies where workshop participants operate (n=23)

Not all organisations engage in supporting early warning, but al organisations considered early warning to be important (all results were above 0.5 on a scale of 0 to 1).

2.3 Prioritizing indicators and parameters for early warning

2.3.1 Context

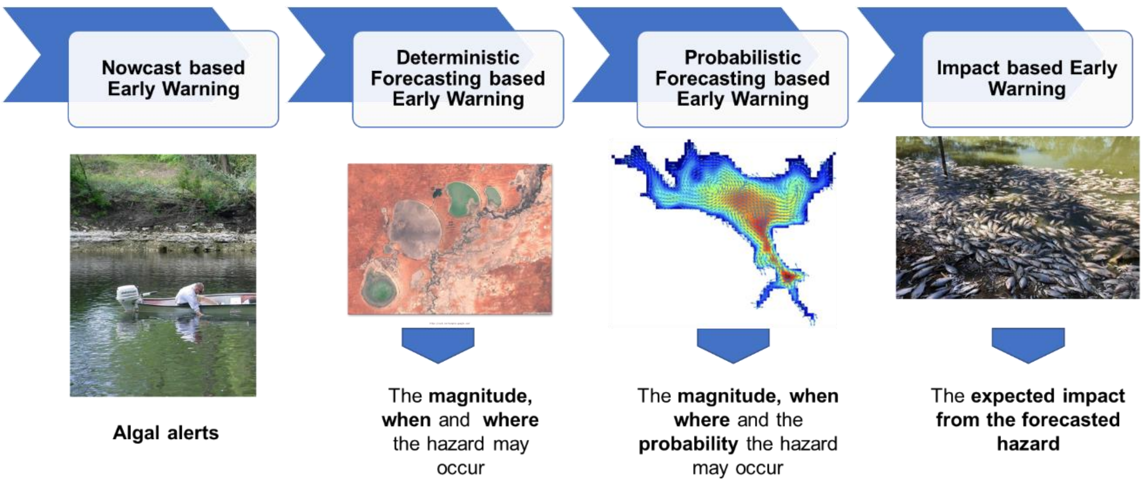

Figure 4. Forecasting approaches to support early warning

There are different forecasting approaches that can be used for early warning of water quality issues (Figure 4). The most common are **Nowcast based Early warning.** This uses grab samples and lab analysis, and monthly sampling campaigns. The results are algal alerts as they are happening so reactive measures can be taken,

What is being explored is the use of 1) **Deterministic Forecasting based Early Warning**, which uses modelled measures of physical, chemical, and biological contaminants; and provides forecasts up to 10 days in advance. This provides information on the magnitude, when and where a hazard may occur. And **2) Probabilistic Forecasting based Early Warning**, which uses an ensemble of modelled measures of physical, chemical, and biological contaminants; and provides forecasts up to 10 days in advance. This provides the same information as deterministic forecasting but also includes the probability of a hazard occurring in time and space. In deterministic models, the output of the model is fully determined by the parameter values and the initial values, whereas probabilistic (or stochastic) models incorporate randomness in their approach. Deterministic risk considers the impact of a single risk scenario, whereas probabilistic risk considers all possible scenarios, their likelihood and associated impacts.

The final type of early warning being explored is **Impact based Early Warning**, which uses problem specific Impact Indicators; providing forecasts up to 10 days in advance on the expected impact of the forecasted water quality hazards (such as population affected, or loss in fish productivity).

2.3.2 Results of prioritization of parameters and indicators

An initial list of parameters and indices that could be used as proxy indicators to describe cyanobacteria outbreak areas were provided to participants (Table 1 and Table 2).

Table 1. List of parameters that could be used as proxy indicators to describe cyanobacteria outbreak areas

	Parameter
Rivers	Outflow from sub-catchments
	Nitrogen, Phosphorus and Sediment loads from sub-catchments
	Temperature of water from sub-catchments
Lakes/ Reservoir	Chlorophyll (green algae, cyanobacteria, diatoms) inside the reservoir
	Cell counts/ bio volume concentration
	Nitrogen (NO3, NH4), Phosphorus (PO4) inside reservoir
	Water temperatures inside reservoir
	Dissolved oxygen inside reservoir

Table 2. List of indicators that could be used as proxy indicators to describe cyanobacteria outbreak areas

	Indicator
Rivers & Lakes/Reservoirs	Intensification of cyanobacteria bloom Description: The indicator can be calculated from localized changes in chlorophyll levels, providing an indication of Increase/decrease or the Rate of increase/decrease of the cyanobacteria 10 days in advance.
	Evenness of cyanobacteria community Description: The indicator can be calculated based on forecasted values of the different members of cyanobacteria community, based on Pielou' s evenness index. The evenness index (J') might serve as an estimate of the diversity of the algal community describing the change in the dynamics of the cyanobacteria community 10 days in advance.
Lakes/ Reservoir	Reservoir stratification tendency Description: The evolution of various limnologic indicators such as Depth of the thermocline, Lake number, Wedderburn number, Schmidt stability can be calculated based on the forecasted water mixing patterns 10 days in advance.

The participants had the possibility of adding any additional parameters or indices that were relevant to their context. Additions included:

- Surface area to depth ratio
- Phycocyanin
- Phycoerythrin
- Chlorophyll- a +transparency
- Surface scums
- Meteorological conditions (wind, temperature, sunshine)
- Reservoir depth
- Light penetration
- All the parameters listed but for wastewater lagoons
- Lake and reservoir levels
- Antecedent conditions (e.g. rainfall, drought, soil moisture)
- Dissolved organic Carbon
- Turbidity
- Total Suspended sediment concentration
- Euphotic to mixing depth
- Off -stream reservoirs

The next step was to prioritize these parameters and indicators in descending order as proxies for cyanobacteria outbreaks (Table 3). It should be noted that participants did not need to rank all parameters so those chosen by the majority of participants had a higher overall ranking. Repeated parameters/indicators were removed.

Table 3. Consolidated ranking of parameters/indicators to use as proxy indicators to describe cyanobacteria outbreak areas

Rank	Title
1	Chlorophyll (green algae, cyanobacteria, diatoms) inside the reservoir (Lakes/ Reservoirs)
2	Phycocyanin
3	Surface area to depth ratio
4	Cell counts/ bio volume concentration (Lakes/ Reservoirs)
5	Phycoerythrin
6	Chlorophyll- a +transparency
7	Surface scums
8	Meteorological conditions (wind, temperature, sunshine)
9	Turbidity
10	Reservoir depth
11	Light penetration
12	Nitrogen, Phosphorus and Sediment loads from sub-catchments (Rivers)
13	All the parameters listed but for wastewater lagoons
14	Intensification of cyanobacteria bloom (Rivers & Lakes/ Reservoirs)
15	Lake and reservoir levels
16	Antecedent conditions (e.g. rainfall, drought, soil moisture)
17	Outflow from sub-catchments (Rivers)
18	Reservoir stratification tendency (Rivers & Lakes/ Reservoirs)
19	Dissolved organic Carbon
20	Nitrogen (NO3, NH4), Phosphorus (PO4) inside reservoir (Lakes/ Reservoirs)
21	Dissolved oxygen inside reservoir (Lakes/ Reservoirs)
22	Temperature of water from sub-catchments (Rivers)
23	Water temperatures inside reservoir (Lakes/ Reservoirs)
24	Total Suspended sediment concentration
25	Evenness of cyanobacteria community (Rivers & Lakes/ Reservoirs)
26	Euphotic to mixing depth
27	Off -stream reservoirs

2.4 Thresholds for parameters/indicators

Participants were asked to provide threshold information on the top 2 parameters/indicators selected based on specific best practices or industry standards. Table 4 provides a summary of the thresholds for the top parameters/indicators selected. In some cases, such as for meteorological conditions (wind, temperature, sunshine), and reservoir stratification tendency, this type of information would not be applicable.

Table 4. Thresholds for selected parameters based on specific best practices or industry standards of participants

Indicator 1	
Chlorophyll (green algae, cyanobacteria, diatoms) inside the reservoir (Lakes/ Reservoirs)	Metropolitan drinking water: chlorophyll-a concentrations up to 5 ug/L- acceptable > 5 ug/L triggers algal speciation Then follow ADWG guidelines/ supply agreements
	Treatment plant capability - it will depend on system
	Phycocyanin in relative units as cells/mL (RFU)
	Chl a conc 20 ug/L
Phycocyanin	Phycocyanin concentration using a method designed by Bozena Wojtasiewicz (CSIRO) say 6.5ug/L
	Treatment plant capability, and risk to recreators - it will depend on system
	Cell counts converted to biomass of the dominant toxic species as to current ANZ guideline
	0.1, 30 and 700 microgram/L
	Depends on water body trophic state – oligo-meso-eu-hyper trophic
	Phycocyanin: 0.2 - 0.4 RFU = acceptable, >0.4 = alert
Cell counts/ bio volume concentration (Lakes/ Reservoirs)	Biovolume >4 (toxic) or 10 (non-toxic) mm^3/L for recreation warnings [there are many other parameters that work in many combinations to produce a 'bloom' but it seems too complex to model and measure, at least in real time]
	Metro WTPS: < 500 cells/mL = acceptable, @ 500 cells/mL = alert, >500 cells/mL unacceptable
	Phycocyanin levels are currently only indicative without proper in-situ measurements. This is more of figuring out how cyanobacteria blooms are spatially distributed
Surface scums	Depends on water body trophic status - oligo-meso-eu-hyper trophic
Turbidity	Turbidity 5 NTU

2.5 Impact indicators

The concept of impact indicators was presented which considers how the impact of a HAB event across the various environmental, societal and economic sectors (or even within the

same sector) could be different.

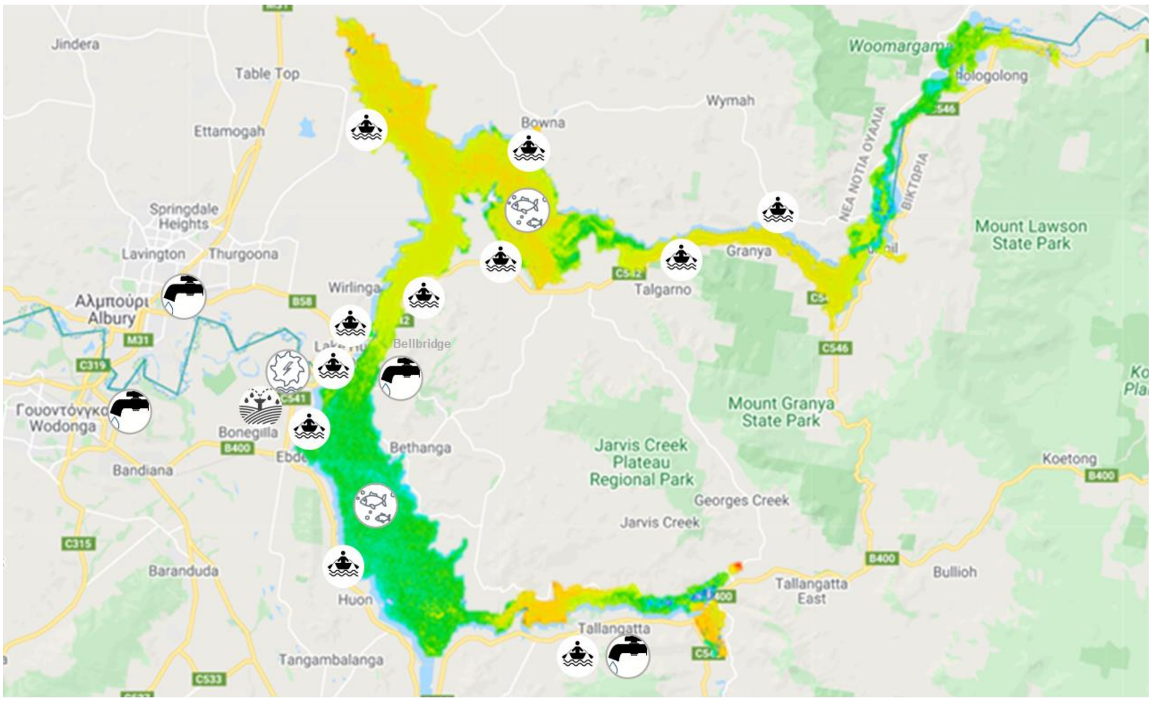

Figure 5 depicts the different sectors around Lake Hume as an example that could be impacted by a HAB outbreak. For example, a HAB outbreak in a water body will require a high level of response in the potable water sector due to the health risks, but this may be less of an issue for the hydropower sector. The impact can also depend on available treatment processes between potable water service providers. Participants were asked to consider the correlations between a HAB event and the impact. The approach would be to identify an appropriate HAB threshold beyond which impacts are acceptable, or the level of impact is unacceptable.

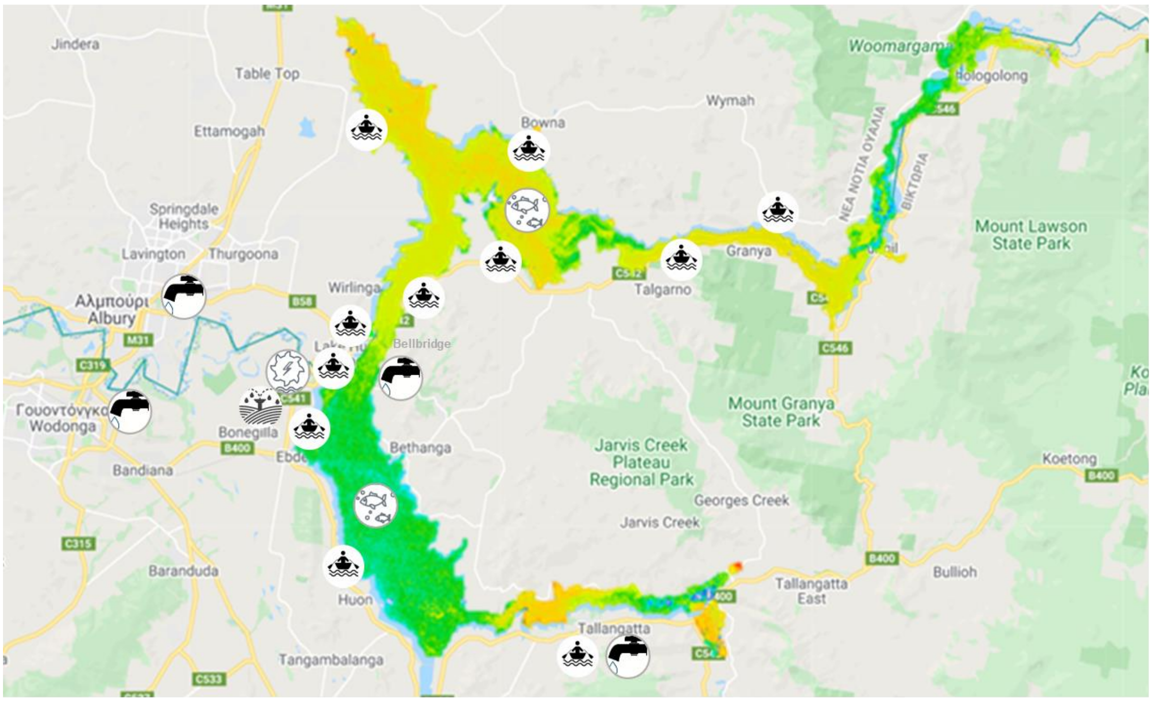

Figure 5. Map of Lake Hume with different water sector users depicted

Participants were asked to suggest any impact indicators across various socio-economic and environmental domains that could be used to quantify the impact of a cyanobacteria outbreak. A summary of the suggestions provided by sector is in Table 5. The highest number of suggestions were for potable water treatment operations and amenity and recreation sectors. Indicators for both included health issues as well as complaints as well as media reports. For the potable water sector disruption in operations and increased treatment costs were also prominent. For freshwater fishing/aquaculture operations and irrigation, impact indicators were related to loss of decreased production and loss of stock. For irrigation, bioaccumulation in the food chain was suggested which could also be applied to aquaculture. Impact indicators for the hydropower sector were limited to operations (loss of production, turbine clogging) and the potential for seeding algal blooms downstream. Other impact indicators beyond the sectors provided included aquatic ecosystem health declines, and loss in real estate values.

Table 5. Summary of impact indicators identified by sector

Sector	Impact indicators
Potable Water Treatment Operations	Adverse media reports
	Aesthetic issues / complaints; taste and odour complaints
	Clogging of filters
	Health issues
	Treatment process affected (no drinking water quality compromise): plant shutdowns and increased treatment costs, increased capital projects to improve capacity.
	WTP shutdown
	Inability to meet water demand due to WTP shutdown or being downrated
	Increased chemical costs i.e. Carbon
	Potable water production capacity
	storage isolation
	Issuing of 'do not drink' notices to community
	pH challenge
Amenity and Recreation	Adverse media reports
	Aesthetic value
	Closure of reservoir to water contact activities
	Days a recreation warning in force
	Dog deaths
	Fish deaths
	Health concerns (reports of illness or death)
	Impacted reputation
	Loss of tourism
	public, media and ministerial pressure
Freshwater Fishing or Aquaculture Operations	Dissolved Oxygen
	(Mass) fish kills
	Forced early harvesting
	Increased costs for cleaning and re-stocking
	Lost tourism
	Toxins in fish, mussels, Oysters
Irrigation	Biomagnification of toxins in the food chain
	Decreased milk production
	Filter blockages
	Fresh vegetables contamination
	Un-usable crop due to bioaccumulation of cyanotoxins

Sector	Impact indicators
	Health impact of operators/users of irrigation area
	Impact to surrounding land/waterways from irrigation area runoff
	Loss of recycled water irrigation
	Stock deaths
	Stock withholding periods
Hydropower Production	Loss in production
	Seeding of blooms downstream
	Turbine clogging
Other sectors	Aquatic ecosystem health decline
	Climate change e.g. Carbon and CO2 influence on HABs
	Fish deaths
	Human health impacts
	Impacts to RAMSAR sites
	Loss in real estate values

3. Continued engagement

3.1 Opportunities

Join the PrimeWater Multi User Panel Week - https://www.primewater.eu/2021/10/15/register-now-for-the-primewater-multi-user-panel-stakeholders-week-15-19-nov-2021/

There will be five different discussions on how to repurpose satellite-derived water quality data and forecasts into water industry intelligent services. Stakeholders from each sector are invited to 2.5-hour sessions. Each day, we will focus on a different sector. More information and the links to register are below.

- Day 1 – Water Resources Management
    - 15 November 2021, 13:00 GMT
    - Register **HERE**
- Day 2 – Disaster risks Management
    - 16 November 2021, 13:00 GMT
    - Register **HERE**
- Day 3 – Potable water
    - 17 November 2021, 8:00 am GMT
    - Register **HERE**
- Day 4 – Energy Sector (with focus on thermal plants)
    - 18 November 2021, 8:00 am GMT
    - Register **HERE**
- Day 5 – Amenity, Recreation and aquaculture
    - 19 November 2021, 13:00 GMT
    - Register **HERE**

For more information, please contact: samuela.guida@iwahq.org

Take part in an Online Survey - User preferences for Earth Observation services

This survey contributes to the research activities of the PrimeWater project and it is targeted to anyone interested in water monitoring and forecasting services. The results of the survey will contribute to our understanding of how social and institutional attributes determine the adoption of EO-based services in decision-making processes. More details about the objectives and the outcomes of PrimeWater project are available at https://www.primewater.eu.

Join the IWA Community of Practice on EO for Water Management - https://iwa-network.org/projects/earth-observation-for-water-management-community-of-practice/

The IWA Digital Water Programme (DWP) acts as a catalyst for innovation, knowledge and best practice. It provides a platform to share experiences, promotes leadership in transitioning to digital water solutions and consolidates lessons to guide utilities during their digital transformation.

To ensure wider engagement with IWA members on digital water, the DWP is encouraging the formation of regional and topical subgroups where members can share experiences, identify gaps, and come up with efficient solutions on a specific topic.

The Earth Observation for water management subgroup, launched in summer 2021 as Community of Practice (CoP), brings together experts from different sectors of the water industry interested in the use of Earth observation technologies for improved water quality and quantity management.

The CoP is also linked to the PrimeWater H2020 EU project, and the GEO AquaWatch initiative.

3.2 More information on PrimeWater and GEO AquaWatch

PrimeWater - **https://www.primewater.eu**

PrimeWater is a Horizon2020 funded research project that generates information on the effects of upstream changes on future water quality and quantity. Building on advanced Earth-Observation data products, integration with additional data sources and diagnostic modelling tools, public and private sector decisions for water resources management are provided with better and actionable information.

PrimeWater Operational Platform **https://www.primewater.eu/operational-platform/**

PrimeWater offers a complete suite of services that enable water industry professionals to identify and assess at an early-stage possible hydro-ecological risks in freshwater systems, trigger anticipatory actions and reduce exposure to water quality hazards through smart, adaptive lake management.

PrimeWater Virtual Lab - **https://www.primewater.eu/virtual-lab/**

The Virtual Lab grants access to the experiments performed in all scientific domains of the PrimeWater project: remote sensing, process-based modeling, and data-driven modeling.

Geo AquaWatch - https://www.geoaquawatch.org/

AquaWatch is an Initiative within the Group on Earth Observations (GEO) that aims to develop and build the global capacity and utility of Earth Observation-derived water quality data, products and information to support water resources management and decision making.

4. Acknowledgements

PrimeWater

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US Environmental Protection Agency

Melbourne Water

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