WP1 – Co-Development

Report describing the beta versions of tool prototypes at each case study.

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Authors: A. S. French, E. de Eyto

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1. Introduction

The WATExR project aims to deliver a series of environmental and ecological seasonal forecasting tools to the water sector within a user-friendly software environment (e.g., QGIS). The tools will employ a variety of under-the-hood lake, catchment and fish phenology models to provide stakeholders (e.g., reservoir managers/educators/fish stock assessors) with predictions of aquatic phenomena at a seasonal time-scale. Using the tools, stakeholders will have access to probabilistic aquatic forecasts driven by state-of-the-art seasonal climate projections (see *Deliverable 2.2*). The tools will update monthly and provide an indication of the expected average environmental conditions during the impending 3 to 9 months relative to the average conditions experienced during the most recent climate period. In so doing, the water sector will join the growing list of environmental sectors for which seasonal climate forecasts are showing strong potential to inform management; e.g., mitigating fire risk in Mediterranean shrubland (Bedia et al., 2018), and reducing southern blue-fin tuna (*Thunnus maccoyii*) by-catch in the Southern Ocean (Hobday et al., 2011).

The translation of seasonal environmental forecasts into practical software/web tools for industry stakeholders benefits from effective communication between tool developers and end-users during the tool development and dissemination stages. For example, the marine sector has benefited from integration of seasonal sea temperature forecasts with statistical models and empirical data collected in collaboration with fisheries to produce online phenological and spatial marine forecasts; e.g., for southern blue-fin tuna (Eveson et al., 2018) and Maine lobster (*Homarus americanus*) (Mills, 2016). Developers of these forecast systems emphasise the importance of stakeholder engagement in the development process:

"Our experience suggests that development of a successful and enduring forecast system has three stages: assessment of needs, forecast development and implementation…" (Hobday et al., 2016)

*"… **Engagement with industry and/or management, as part of the first stage, is critical to define the problems that seasonal forecasting can address, to determine the critical timescales, and to source the data needed for model verification**... This stage can also be used to explain how to interpret uncertainty, probabilistic forecasts and lead-times, and to discuss realistic expectations about forecast skill."* (Hobday et al., 2016)

*"**Stakeholder participation is crucial at all phases of developing forecast products, and should be involved all the way from the scoping of the project through its development to its evaluation and into operational delivery**… engaged and informed stakeholders will ultimately inspire the development of new forecast products that the scientific community cannot foresee and ensure their success. Efforts to increase and support stakeholder engagement are therefore expected to yield large dividends."* (Payne et al., 2017)

With "co-development" in mind, WATExR scheduled a series of interactions between water sector stakeholders and environmental model users/tool developers. The aim of the interactions were two-fold: on the one hand, developers were to define the potential applications and limitations of seasonal forecasting to the water sector, while on the other hand, end-users were to outline their expectations for a management tool with worthwhile functionality.

This report describes the co-development process between stakeholders and tool developers during the first year of WATExR and its culmination in the form of prototype QGIS tool designs and workflows. The report summarises progress and outlines recommendations for the next stage of WATExR in relation to encountered limitations and potential obstacles to co-development of interactive tools.

2. Prototype tool design co-development exercise (*Interaction 1.2*)

During the WATExR second annual meeting, tool developers and stakeholders (end-users) were asked to illustrate their "vision" for a forecast tool as part of *Interaction 1.2* (Month 12). Here, the developers informed their design from their understanding of seasonal forecast communication (*Deliverable 2.2*), outcomes of an earlier *Interaction 1.1* (Month 1), and any subsequent communications with stakeholders. Stakeholders' visions were intended to illustrate desired features/functionality (particularly any shared functionality among the case studies), and provide an indication of the complexity of forecast information required by the end-user.

The co-development exercise involved two parallel sessions, whereby stakeholders and tool developers spent one hour separately drawing their "vision", before collating their ideas together into an agreed prototype design. The following subsections illustrate the range of stakeholder and developer (**Table 1**) visions and agreed prototype designs where available (**Figs 1-8**).

Table 1. WATExR case study stakeholders, tool developers and purpose of proposed tools.

Catchment/ lake/reservoir	**Country**	**Stakeholder**	**Tool Developer**	**Models to implement within tool**	**Purpose of tool and audience**
Mt Bold reservoir	Australia	South Australian Water	Marine Institute (MI)/ Dundalk Institute of technology (DkIT)	GOTM/ FABM	Predicting water quality/quantity for reservoir managers.
Burrishoole catchment	Ireland	Marine Institute	Marine Institute (MI)/ Dundalk Institute of technology (DkIT)	GOTM/ Statistical model	Predicting fish migration timing to aid fish stock assessments/monitoring.
Sau reservoir	Spain	Catalan Water Agency	Catalan Institute of Water Research (ICRA)	GOTM/ FABM	Predicting water quality/quantity for reservoir managers in line with Water Framework Directive.
Lake Filsø/Lake Arreskov catchments	Denmark	Ministry of Environment and Food	Aarhus University (AU)	SWAT/ GOTM/ FABM	Predicting water quality, ecological impacts and explaining extreme ecological/aquatic phenomena to the public.
Vansjø-Hobøl catchment and Lake Mälaren	Norway	Morsa river basin management authority	Norwegian Institute for Water research (NIVA)	GOTM/ FABM/ GLM	Predicting water quality parameters and Water Framework Directive status for water supply.
Wupper reservoir	Germany	Wupperverband	Wupperverand/ Helmholtz Centre for Environmental Research	GLM/ GOTM/ FABM	Predicting water quality parameters and Water Framework Directive status for water based recreation.
Lake Erken	Sweden	Stockholm Vatten	University of Uppsala	GOTM	Support education by providing simplified output of lake models from meteorology (historic; projected seasonal/climate).

2.1 Case study: Mt Bold reservoir, Australia

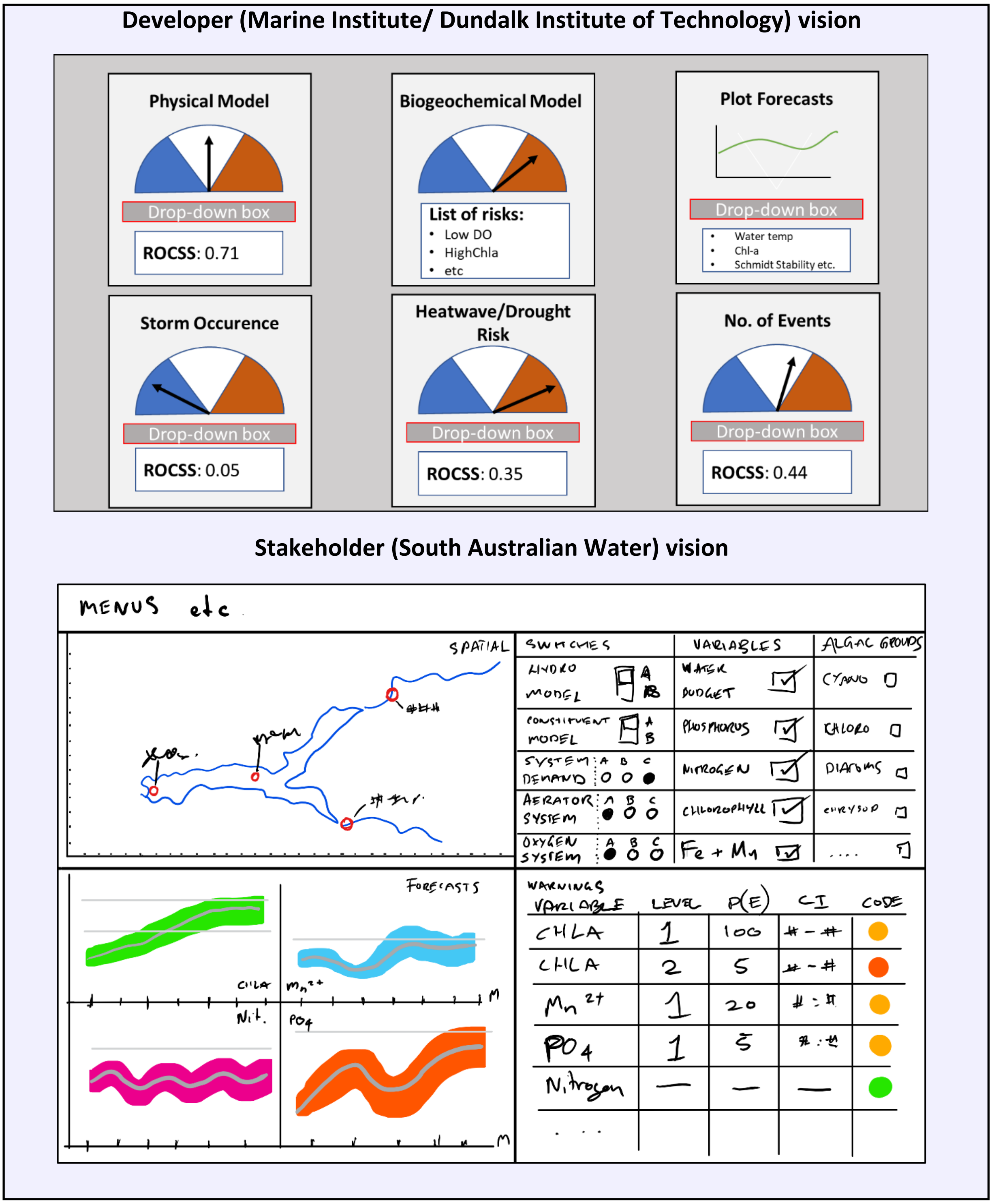


Fig 1. Tool prototype designs – Mt Bold reservoir.

2.2 Case study: Burrishoole catchment, Ireland

Stakeholder (Marine Institute) visions

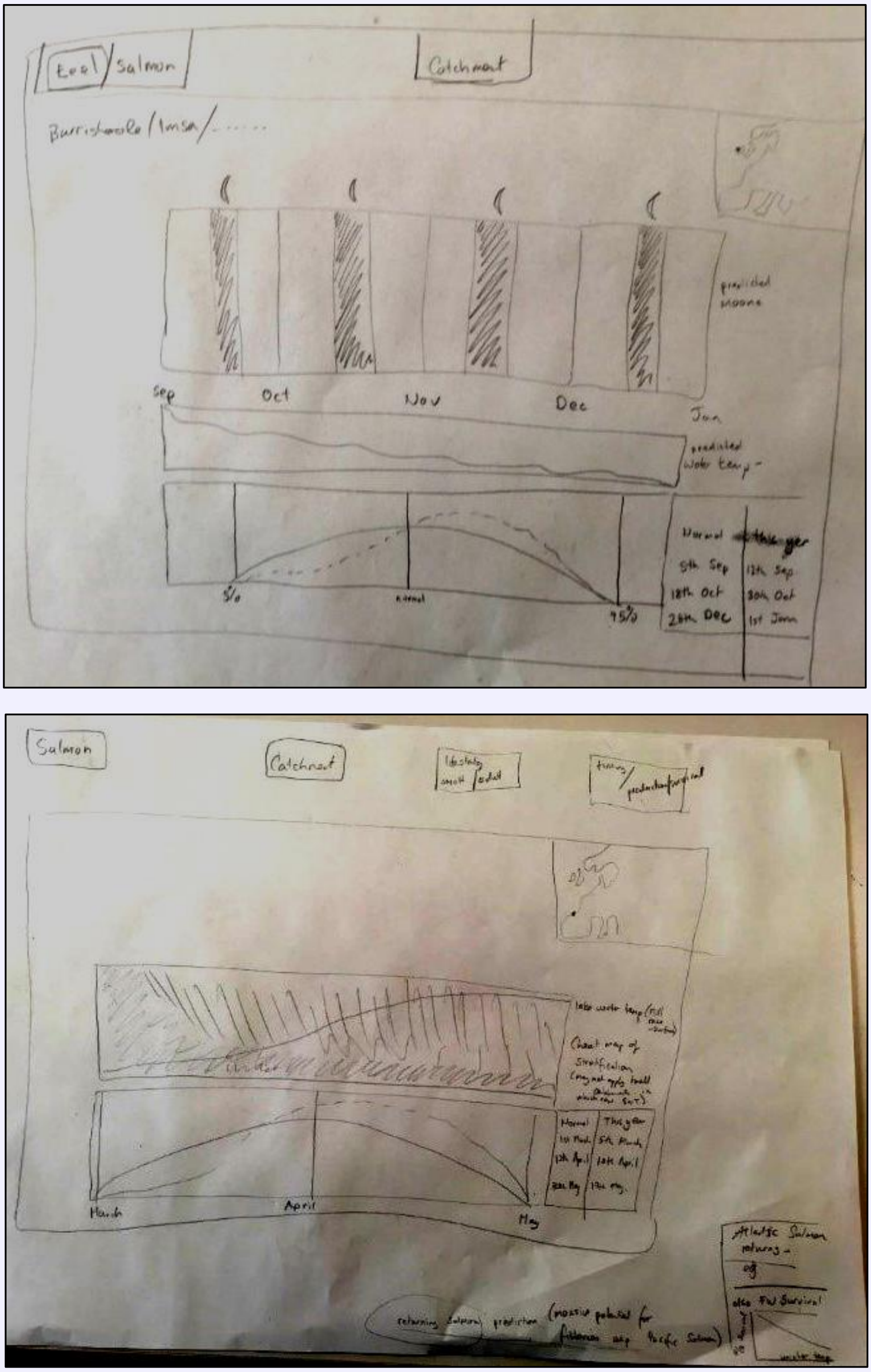
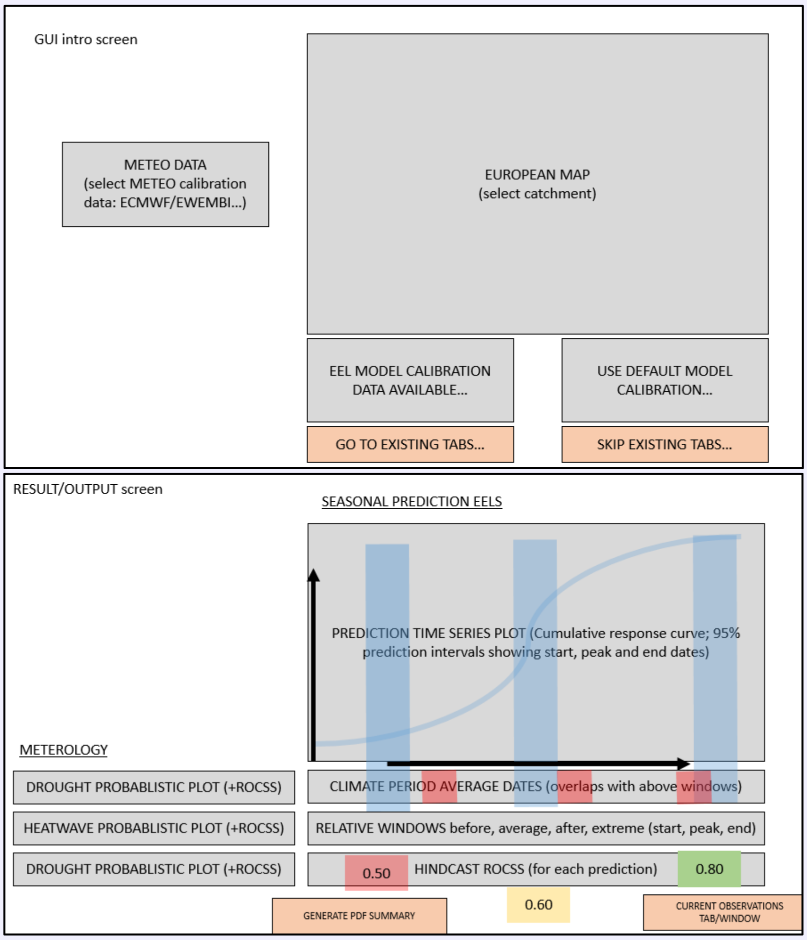


Fig 2. Tool prototype designs – Burrishoole catchment.

Developer - Stakeholder (Marine Institute) combined vision



QGIS prototype plugin for Burrishoole fishery case study

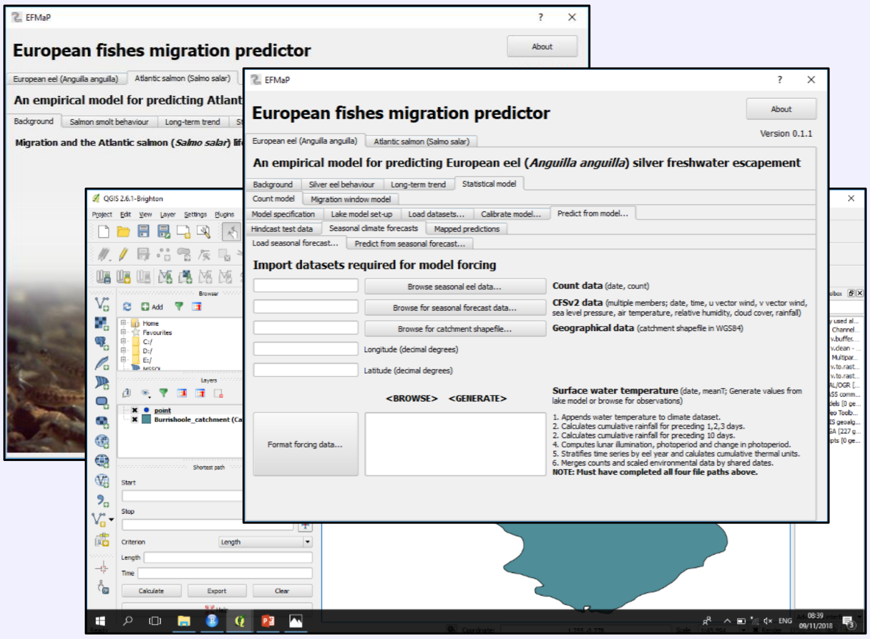
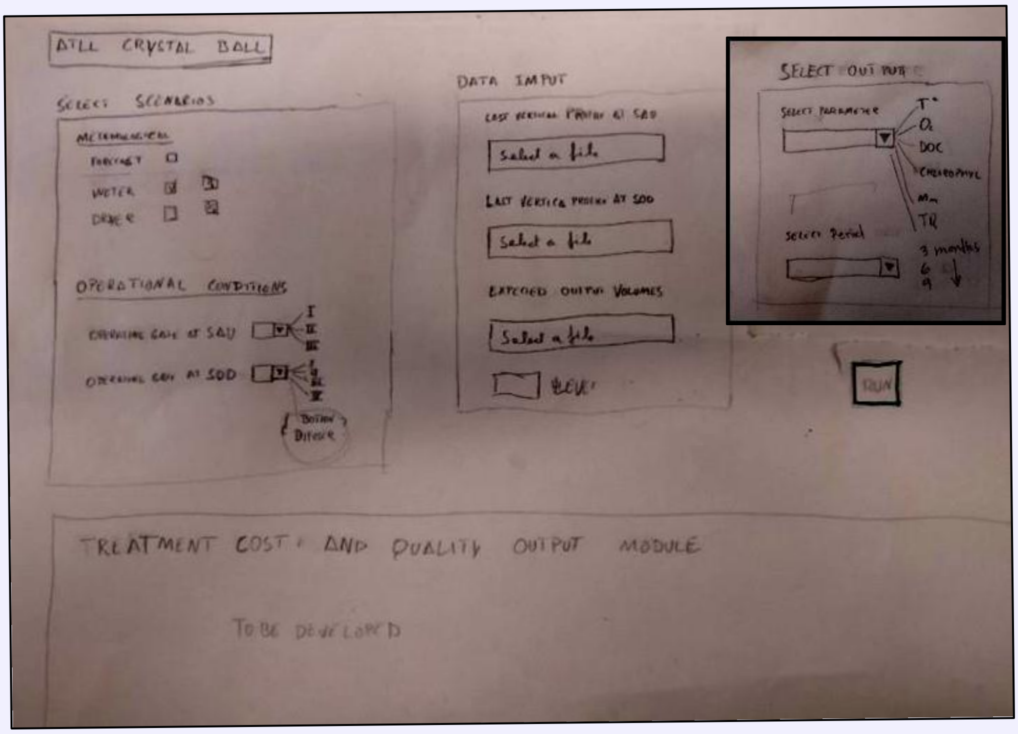


Fig 3. Tool prototype and screenshot of preliminary product – Burrishoole catchment.

2.3 Case study: Sau reservoir, Spain

Developer (Catalan Institute for Water Research; ICRA) vision



Stakeholder (Catalan Water Agency) - Developer combined vision

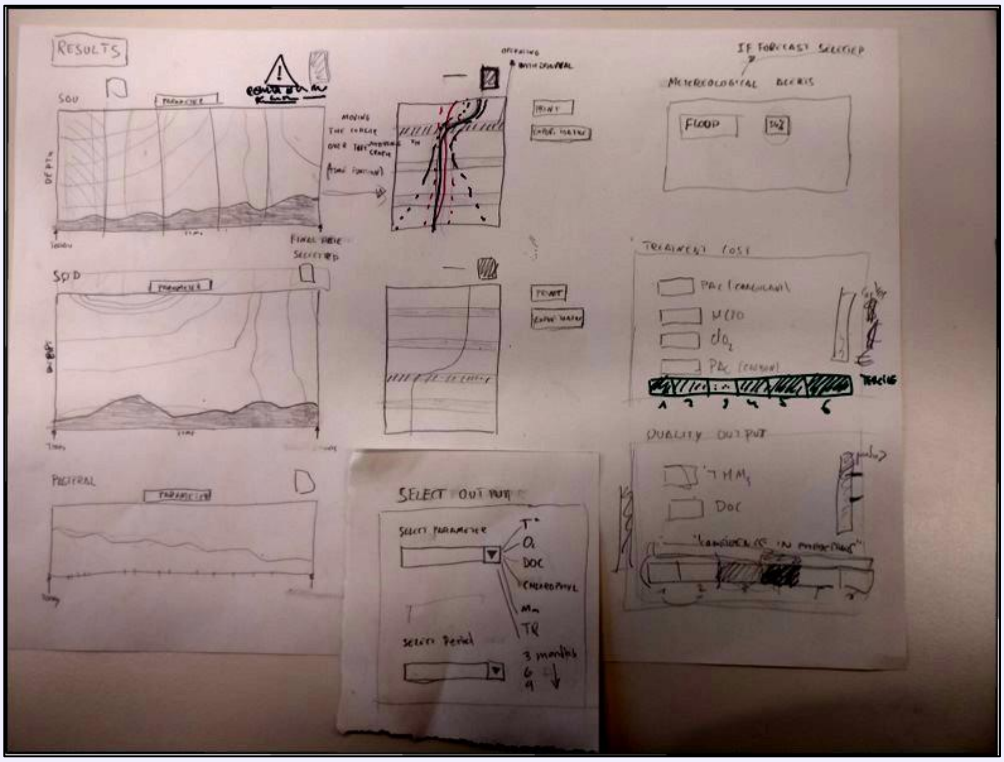


Fig 4. Tool prototype designs – Sau Reservoir.

2.4 Case study: Lake Filsø/Lake Arreskov, Denmark

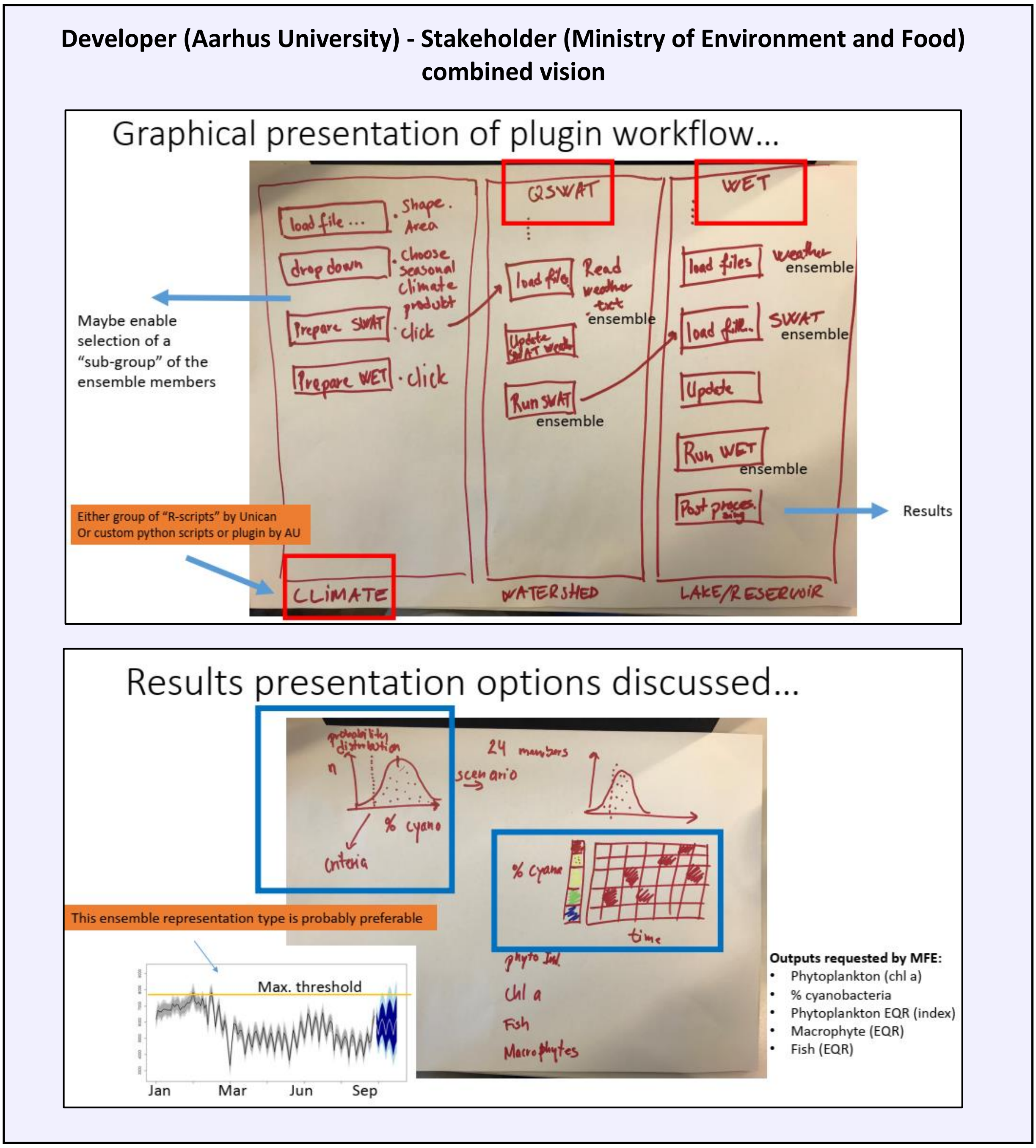
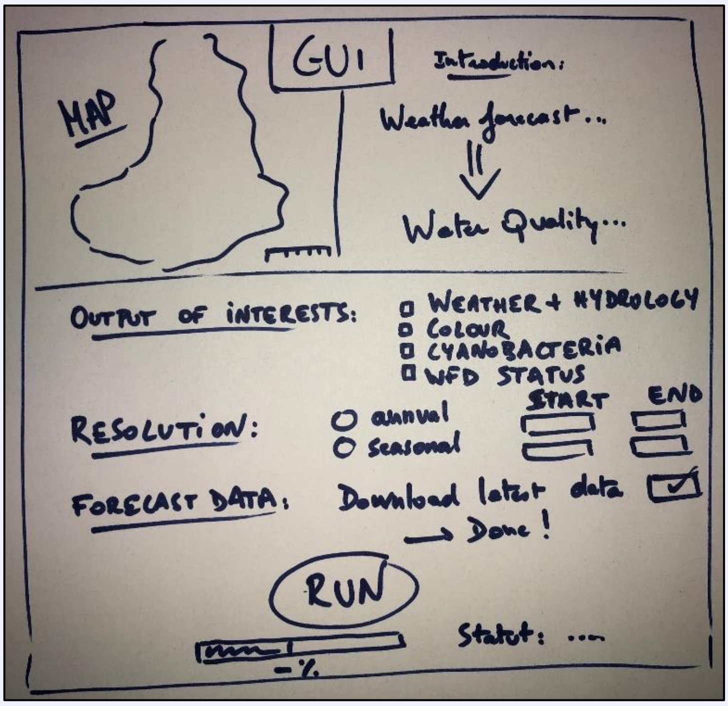


Fig 5. Tool prototype designs – Lake Filsø/Lake Arreskov.

2.5 Case study: Vansjø-Hobøl catchment, Norway

Developer (NIVA) - Stakeholder (Morsa river basin management authority) vision



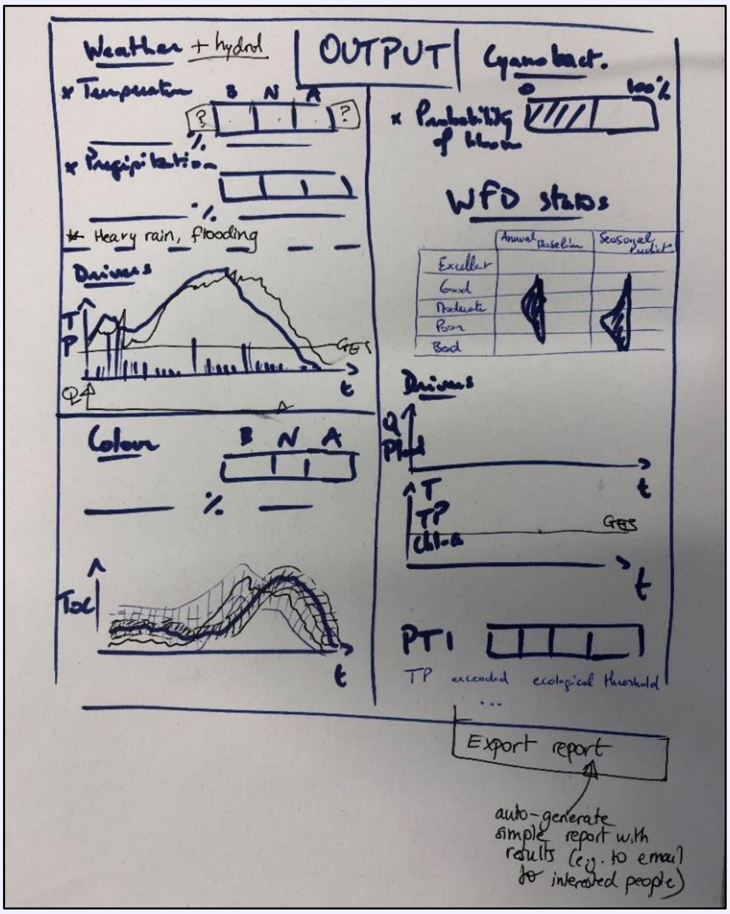


Fig 6. Tool prototype designs – Vansjø-Hobøl catchment.

2.6 Case study: Wupper reservoir, Germany

Developer (UFZ) - Stakeholder (Wupperverband) vision

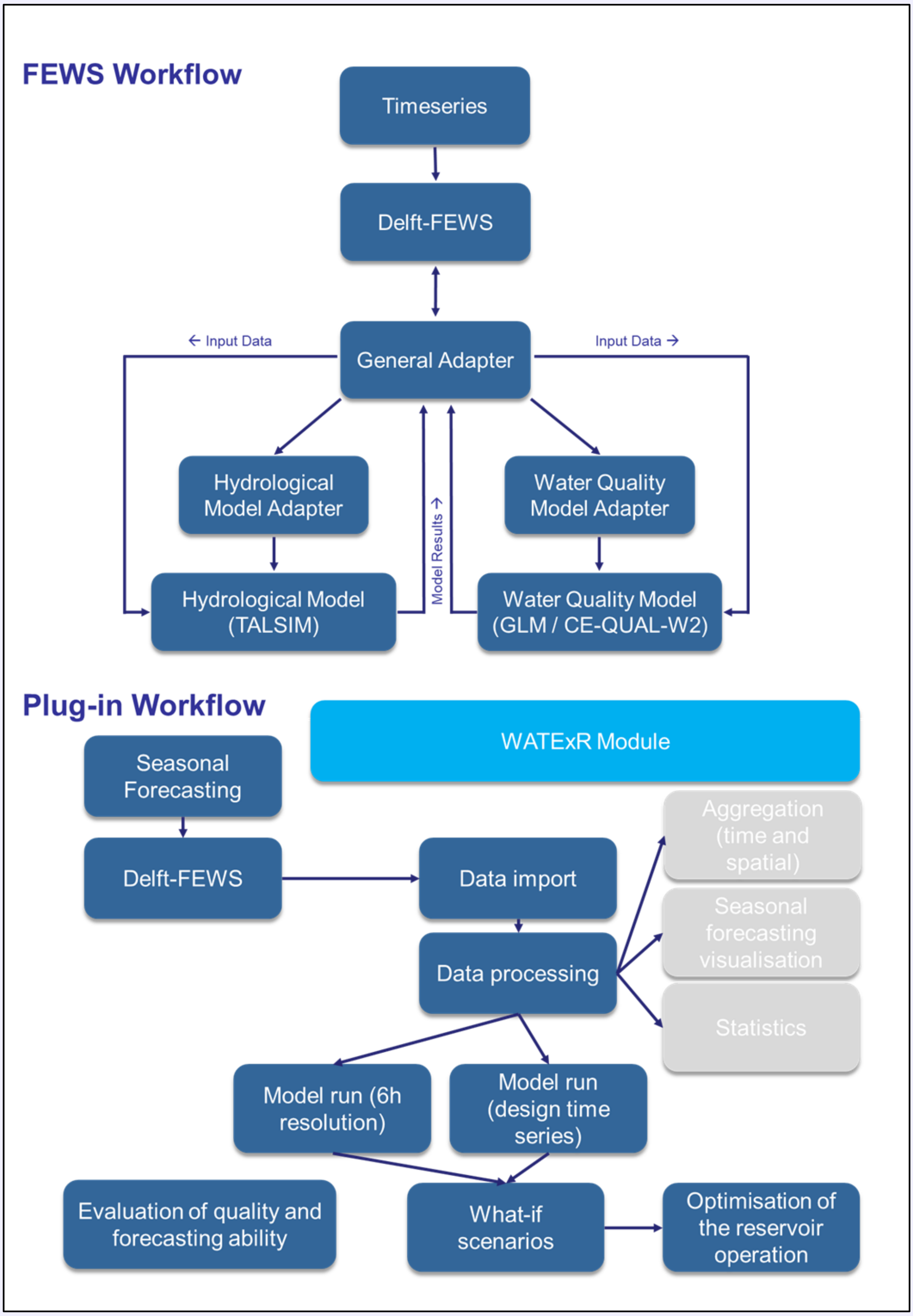


Fig 7. Tool prototype workflow – Wupper reservoir.

2.7 Case study: Lake Erken, Sweden

Developer (University of Uppsala) - Stakeholder (Stockholm Vatten) vision

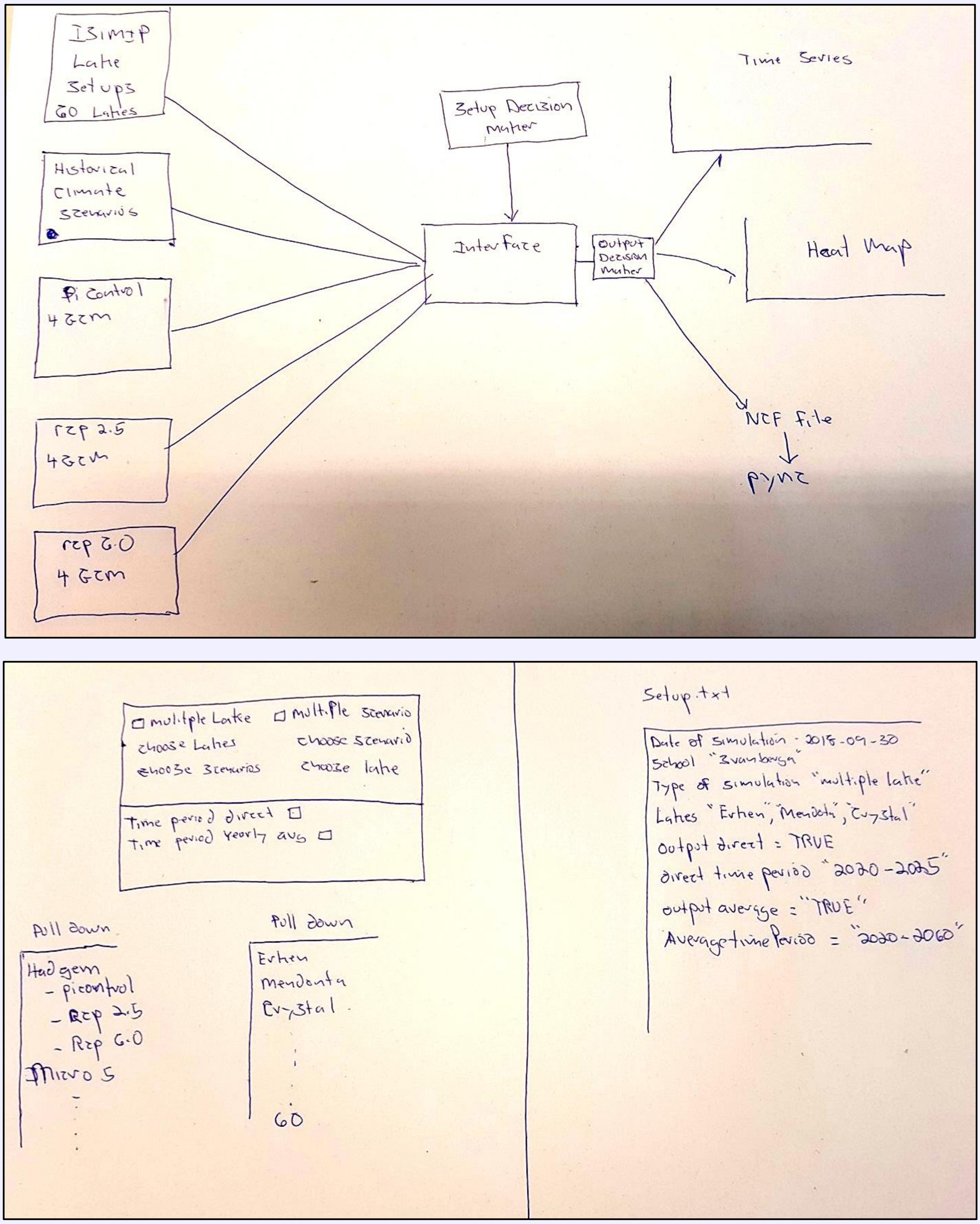


Fig 8. Tool prototype workflow – Lake Erken.

3. Results and Discussion

3.1 Stakeholders and developers share expectations for tool design

Most case studies (but not all; see 2.6 and 3.2) intend to use QGIS as the development platform for their tool. However, for the lake/catchment model based tools it is not yet clear whether an adaptation of the WET tool (e.g., by addition of extra menus), Soil and Water Assessment Tool (SWAT; Molina-Navarro et al., 2018) or construction of new tools is required. Nevertheless, the open-source nature of QGIS and WET should facilitate transfer of functionality/code between plug-ins.

The shared functionality among case study tool prototype designs suggests that a collaborative approach to development among case studies would be beneficial. For example, most case studies wish to implement a real-time system that can present forecasts for a range of shared lake thermal and biogeochemical parameters. Likewise, most prototypes designs included a measure of forecast trust/skill based on ROCSS (see *Deliverable 2.2*).

3.2 Stakeholder involvement in tool development varies among case studies

Prior to WATExR's second annual meeting in Magdeburg, Germany, an online questionnaire was sent to stakeholders at each of the six case studies. This questionnaire was designed to gauge stakeholders' involvement in the project during the first year, with a focus on their involvement in tool design (**Fig 9**). All stakeholders agreed that a generic tool design work-flow would be appropriate to answer their case study specific needs.

The questionnaire also asked for general comments and received the following from three stakeholders:

(1) "Our case study requires quite different analysis than the lake case studies, but I am confident that our co-developers will produce something usable for us"

(2) "The project should be more open to the tools we are using already for operational purposes."

(3) "As a 'distant' partner, there are some challenges for engagement! Some of my scores above should therefore not reflect poorly on the developers."

Comment (2) highlights potential conflict between developers and stakeholders and shows that QGIS based tools might not be the ultimate output for all case studies.

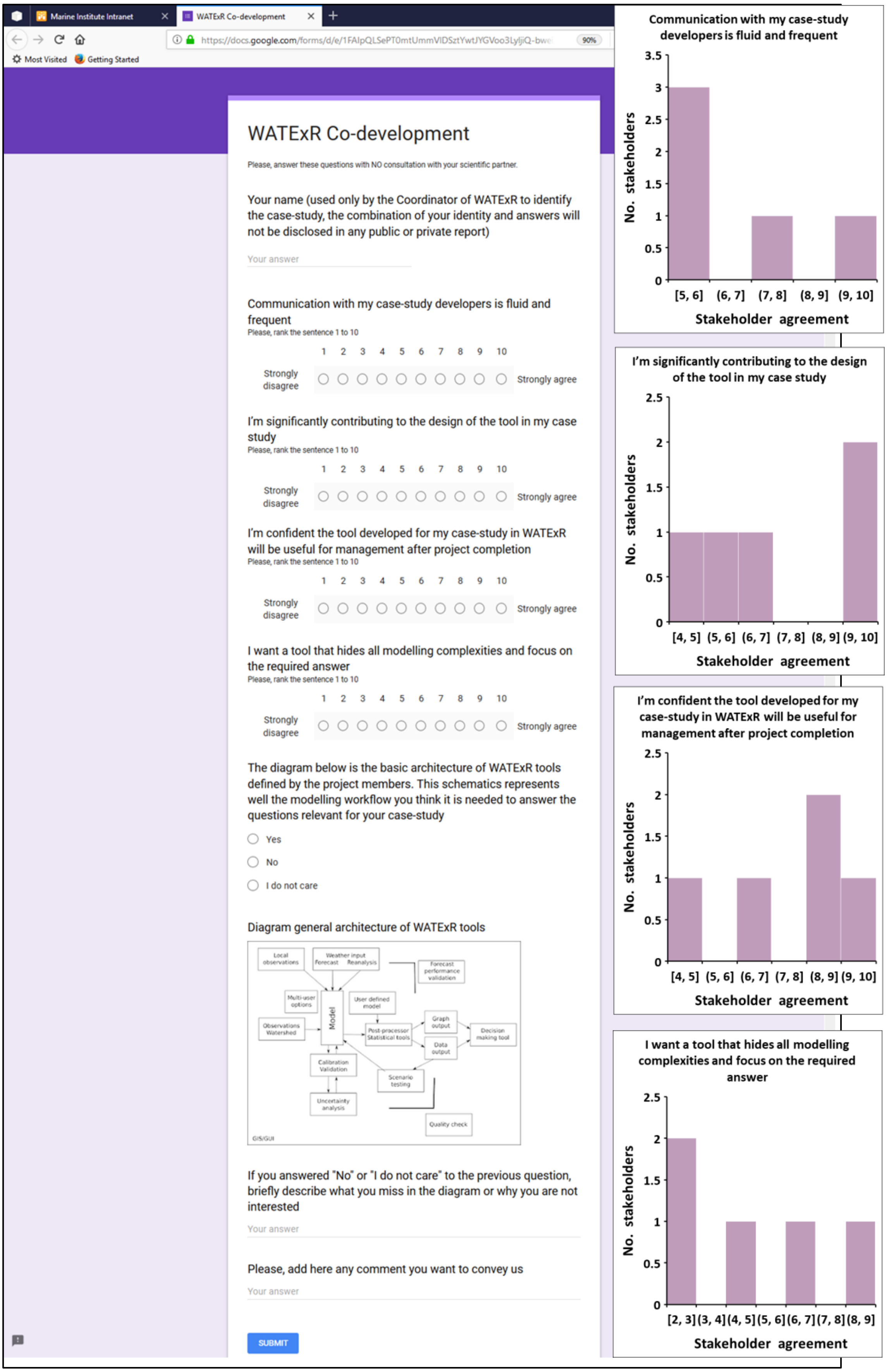


Fig 9. Online questionnaire sent to stakeholders (left). Summarised answers (right).

3.3 Understanding communication of probabilistic forecasts varies among case studies

Almost all plugin designs included a time series plot or predictions that included absolute values and prediction/confidence intervals. This approach is generally not applicable to probabilistic (ensemble derived) forecasts and was noted and accepted by all case studies following presentation of prototype designs during *Interaction 2.1*.

3.4 Recommendations for the next phase of tool development

3.3.1 Communication of predictions should be standardised

Seasonal forecasts should be communicated in relative terms (e.g., expected summer temperatures relative to the climate period), and with tercile plots where appropriate. Forecasts may also be expressed in quintiles to quantify extremes, though statistical power for calculation of the trust metric (ROCSS) will inherently decrease owing to there being fewer historic extreme events (as opposed to simply below/above average events) in the hindcast analyses. Where time series are of interest, developers should quantify the average date of (for example) onset of stratification for a selected climate period, and subsequently present seasonal expectations relative to this date (i.e., before, no different to usual, or after). Given that time series are a desired output of the plugins for most stakeholders (and were included in many of the prototype designs), it might be useful to re-emphasise the communication of seasonal forecasts to all project participants (following the guidance of *Deliverable 2.2*).

3.3.2 Communication of uncertainties should be clear

It is essential to communicate trust in seasonal forecasts clearly. This could be visually, by presenting predictions with different colours (e.g., forecasts presented in green are trustworthy and forecasts in red are not), but in general it would be useful to not present untrustworthy forecasts at all (i.e., by presenting only forecasts for which forecasts have historically agreed with observations significantly more frequently than would be expected by chance). Visual indicators of trust (or forecast “skill”) for seasonal climate forecasts are discussed by Frías et al., (2018).

3.3.3 The practicalities of tool development should not be underestimated

Depending on case study requirements, QGIS plugin development could involve a major time commitment (e.g., Python and R programming). While some implementations of lake and catchment models are already available (e.g., WET and QSWAT) and might provide a useful starting point for prototypes with shared functionality, integrating seasonal meteorological data with both mechanistic and statistical environmental/ecological models in a QGIS plugin is a novel challenge. Instructional videos for building plugins have been developed by the Danish project partner (https://vimeo.com/237723253), but compromises, such as adopting a single model (e.g., GOTM only in the Sweden case study) may be necessary.

3.3.4 Lessons may be learned from recent seasonal ecological forecasting

The public (and industry) perception of any seasonal forecast systems is fragile and relies on continued communication between developers and end-users even after the development stage. For example, the Maine lobster (*Homarus americanus*) fishing industry and its regulators reacted to a price collapse in 2012, which they attributed to an extremely early lobster harvest for which the supply chain was not ready, by asking researchers to develop a seasonal forecast system (Mills, 2016; Mills et al., 2017). The forecast was discontinued after only two fishing seasons after complaints from the industry that the forecast added “unhelpful additional complexity” (Bever, 2017). The lesson that WATExR might learn from this is to ensure that uncertainty is communicated within the plugin with very strong warnings and that these warnings are thoroughly explained to stakeholders.

4. Conclusion

The tool prototype designs illustrated in this report form a reference point for all case studies. There remains some necessary flexibility during the early development phase, particularly while issues surrounding the presentation of seasonal forecasts remain. Progress in tool development has been steady, but is expected to accelerate during the next 11 months. By project month 20 (*Deliverable 3.2*), functional prototype tools should be in place in a form that may be downloaded by/presented to stakeholders for testing.

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