QUEENSLAND WATER MODELLING NETWORK

EXTERNAL ENGAGEMENT PROGRAM

Strategic Investment Priorities Report – June 2020

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Purpose, Scope and Approach

The aim of this report, the Strategic Investment Priorities Report (SIPR) is to identify, assess and prioritise a set of strategic investment opportunities for the Queensland Water Modelling Network (QWMN) Secretariat (representing the State Government) to consider in planning the work of the QWMN with regards capability and capacity building for water modelling and use across Queensland.

The scope of the report and the work behind it:

- Focusses on the capability and capacity building activities of the QWMN
- Focusses on the next 4 years of operation for the QWMN
- Identifies and assesses opportunities for investment by the QWMN based on existing written evidence alone – no primary research was undertaken although it should be noted that the written evidence includes outputs from a workshop with over 60 representatives of the sector that occurred during the QWMN Forum 2020 (Filet, 2020)
- Prioritises investment opportunities based on a qualitative assessment rather than on a quantitative approach such as ROI

The work behind the SIPR involved reviewing the following pieces of written evidence:

a) Science Capability Audit – Water (Office of the Queensland Chief Scientist, 2014)
b) Research Development and Innovation strategy 2018-2020 (QWMN, 2018)
c) QWMN Forum 2018 Workshop "Supporting Modelling Workforce Capability" Output (McIntosh and Gibbes 2018)
d) Skills and Knowledge Audit (Gibbes and McIntosh, 2019) and Response (McIntosh, 2020) Reports
e) The current QWMN "Research Development and Innovation" projects (QWMN 2020)
f) The water modelling pipeline concept (Filet, 2020)
g) Pulse Check of the Queensland Modelling and Use Sector: Highlights from the QWMN Forum 2020 (Filet, 2020)

In addition, verbal evidence from discussions with the QWMN Community of Practice Manager about feedback from CoP events to date was taken into consideration.

Following the review of written and verbal evidence, investment opportunities were identified for the workforce/training pipeline and all components of the water modelling pipeline that met the following criteria:

- Achieve the QWMN purpose "to improve Queensland's capacity to model its surface water and ground water resources and their quality" and/or QWMN goals:
    1. Build a state-wide network with national influence to deliver transformative change
    2. Foster integrated and scalable modelling to address water risks and opportunities
    3. Champion a community of practice to leverage expertise
    4. Encourage strategic co-investment and co-production in water modelling RD&I
    5. Increase application of water modelling to inform decision making
- Directly meet multiple identified needs,
- Cost effective, and
- Achievable in the short term (within the next 4 years).

The identified opportunities were then prioritised based upon their comparative value and their likely cost (qualitatively assessed) in order to provide a cost effectiveness insight into each one (Appendix 1).

The following sections provides a brief review of key findings from the range of evidence considered across the two core areas of activity for the QWMN – Workforce capability and capacity development, and; RD&I. Each

section first of all highlights needs then proposes a set of opportunities before finally identifying those opportunities for investment that are recommended for QWMN consideration.

Workforce Capability and Capacity Development

The QWMN Skills and Knowledge Audit (Gibbes and McIntosh 2019) and follow up Response Report (QWMN Skills and Knowledge Audit Working Group 2020) characterised the range of skills and knowledge, capability and more broadly workforce recruitment, development, maintenance and replacement issues faced by the water modelling and use sector in Queensland. The modelling workforce is made up of state government, local government, consulting and academia. Combining these findings with those presented in McIntosh and Gibbes (2018) yielded the following insights.

Needs – education and training

The overall purpose of the QWMN is to improve the state's capacity to model its surface water and groundwater resources and their quality. The QWMN does so through research, development and innovation projects as well as through building the capabilities and capacity of Queensland's water modelling and use sector.

An important mechanism for achieving increases in capability and capacity is through supporting the education and training of future employees for the water modelling and use sector. A need to increase the extent and depth to which basic processes of model development, calibration and scenario simulation are included within undergraduate degrees has been identified (Gibbes and McIntosh 2019). Addressing the need is one way in which the future water modelling workforce for Queensland can be built.

Needs - supporting a variety of career pathways

Building water modelling and use skills and knowledge is one way to support the development of the future water modelling workforce in Queensland. Understanding how to support initial recruitment into that workforce and then progression from there along different career pathways is another way.

There are multiple possible pathways into a modelling career (McIntosh and Gibbes 2018). Graduates from Bachelor degrees (e.g. Science or Engineering) may go straight into their first modelling role or further education (i.e. Masters or PhD) may be completed before entering the modelling workforce (McIntosh and Gibbes 2018). Therefore, there is a need for to create training opportunities for the water modelling and use sector in the context of both undergraduate and post-graduate degrees, and to expose professionals working in the sector to a greater diversity of organisations and functions in water modelling and use to develop their skills and knowledge without them needing to move jobs, possibly inter-state or beyond (McIntosh 2020 and see below).

Opportunities – employers

According to the output from the 2018 workshop on "Supporting Modelling Workforce Capability" (McIntosh and Gibbes 2018) two key actions that could be taken by employers to address career pathway challenges related to their being a lack of structured progression and development are:

- Providing staff with deliberate rotation between roles or jobs or types of work over years in order to build knowledge over an extended period of time. Considering structuring those rotations deliberately to provide knowledge and skills in desired areas of water modelling and use.
- Look to harness existing personal interests in the environment (broadly) amongst water professionals as a motivation for developing water modelling skills in such people, and to develop water and environment interests in those who have existing numerical and modelling skills.

Opportunities – within Universities

To address gaps in suitably qualified graduates, the QWMN "mentoring program" has been developed to target upper undergraduate students and to play a role in workforce growth by acting to improve their:

a) Critical water modelling skills and knowledge development,
b) Interest in water modelling as a career
c) Exposure to and connection with employer organisations

Ultimately this aims to produce more and more capable graduates interested in water modelling jobs.

The mentoring program should be complemented by university driven initiatives to embed modelling skills in relevant undergraduate university courses (such as environmental science and/or engineering). Relevant knowledge that could be better incorporated into undergraduate university courses includes: mathematical knowledge, physical process understanding and knowledge of the basic processes of model development, calibration, scenario simulation and evaluation of outputs. Practical modelling skills including the use of software platforms and tools could be incorporated into undergraduate degrees through the inclusion of modelling projects for students.

There may also be opportunities to utilise Data Science courses as a pathway for the development of key modelling skills (including coding, data analytics and data wrangling). Postgraduate level data science courses currently on offer include: USQ's Master of Science (Applied Data Science), UQ's Master of Data Science and QUT's Master of Data Analytics.

Training and education should not just be focused on undergraduates however. Offering advanced training opportunities for more experienced modellers could be useful for continuing professional development. Some examples of more advanced training opportunities might include uncertainty quantification and sensitivity analysis, and model stress testing. Such opportunities could be provided in the context of whole University courses taken singly, or smaller assessed or non-award micro-credentials.

However, the Skills and Knowledge Audit (Gibbes and McIntosh 2019) showed that a move away from formal courses and programs, and towards other forms of learning focussed on internet learning, peer to peer support and internal coaching and mentoring is happening. This creates a set of challenges and opportunities about how these more work-based forms of learning might be best supported systematically and at a high degree of quality.

There is a need to map out how the skills and knowledge demands of the sector are likely to evolve over the next 5-10 years and beyond to characterise the number of new graduates required vs the number of existing staff to be upskilled in particular areas. This will inform strategic workforce planning and development for the sector and inform Universities and other providers

Opportunities – University-Industry links

Closer links between universities and the private sector could have multiple benefits for development of professionals across the Queensland water modelling and use workforce. The QWMN has an important role to play in fostering these links. The activities that have been running through the QWMN so far, including the commencement of the first round of Innovation Associates and the establishment of a Community of Practice have helped to develop water modelling and use focussed linkages.

Opportunities for building sector capabilities and capacity through university-industry partnerships, where 'industry' means both private sector and government (State and local) include:

1) Supervision/mentoring of undergraduate students by experienced (industry) modellers

2) Supervision/mentoring of post-graduate level modelling research projects by experienced (industry) modellers
3) University-industry research partnerships focussed on sector wide issues, for example, climate change modelling or groundwater-surface water interactions.

Whilst there are certainly opportunities for both employers and universities, the QWMN could play an important role in helping to facilitate closer interactions. In order to achieve closer interactions whilst meeting training and development needs for the water modelling and use workforce, the following opportunities for investment are recommended.

Recommended Opportunities – QWMN

- Continue to support Young Water Modelling Professional / student focussed networking events to expose both groups to career opportunities in the water modelling sector (including potential employers)
- Catalyse the creation of QWMN led advanced level training and workshops using innovative, potentially work-based delivery mechanisms
- Examine ways in which industry can be supported to offer job rotations for staff professional development
- Continue to support university research projects focussed on industry driven problems through future cohorts of Innovation Associates
- Continue to facilitate collaborative (university-industry) water modelling and use research project development more generally

Strengthening Water Modelling Pipelines in Queensland

Water modelling as an activity is a complex mix of activities carried out by a diverse range of professionals occupying diverse roles across different kinds of organisations. The Skills and Knowledge Audit (Gibbes and McIntosh 2019) characterised the kinds of roles involved whilst the Pulse Check (Filet 2020) taken at the QWMN Forum 2020 framed the work of the water modelling and use sector in terms of a pipeline model (see Figure 1 – adapted from an original idea proposed by Tony Weber).

The idea of the pipeline emphasises the value chain and knowledge flow of activities from scientific research (required to provide a solid knowledge underpinning to models) through monitoring and data (required for model calibration and validation) to the development and use of water modelling and information support tools (technologies that encapsulate scientific knowledge and monitored data to answer specific questions or serve particular purposes) and the ultimate use of the outputs of such tools by decision makers in various settings. In the pipeline model these activity steps or stages can be poorly or well aligned, professionals operating in one stage can be doing so in collaboration and awareness of professionals working up-pipe and down-pipe from them or in relative ignorance, and different stages can be resourced to different extents meaning that some stages can function well whilst others do not. Functioning here refers to the extent to which a stage produces outputs that are aligned with the needs or outputs from other stages, as well as referring to aspects of performance including productivity (relative to other stages and in more absolute terms). Potential variations in the function of different stages means that pipelines as a representation of the whole modelling process have a range of ways in which they can function well or poorly with consequences for the robustness and usefulness of the information and knowledge ultimately delivered to and incorporated within decision-making.

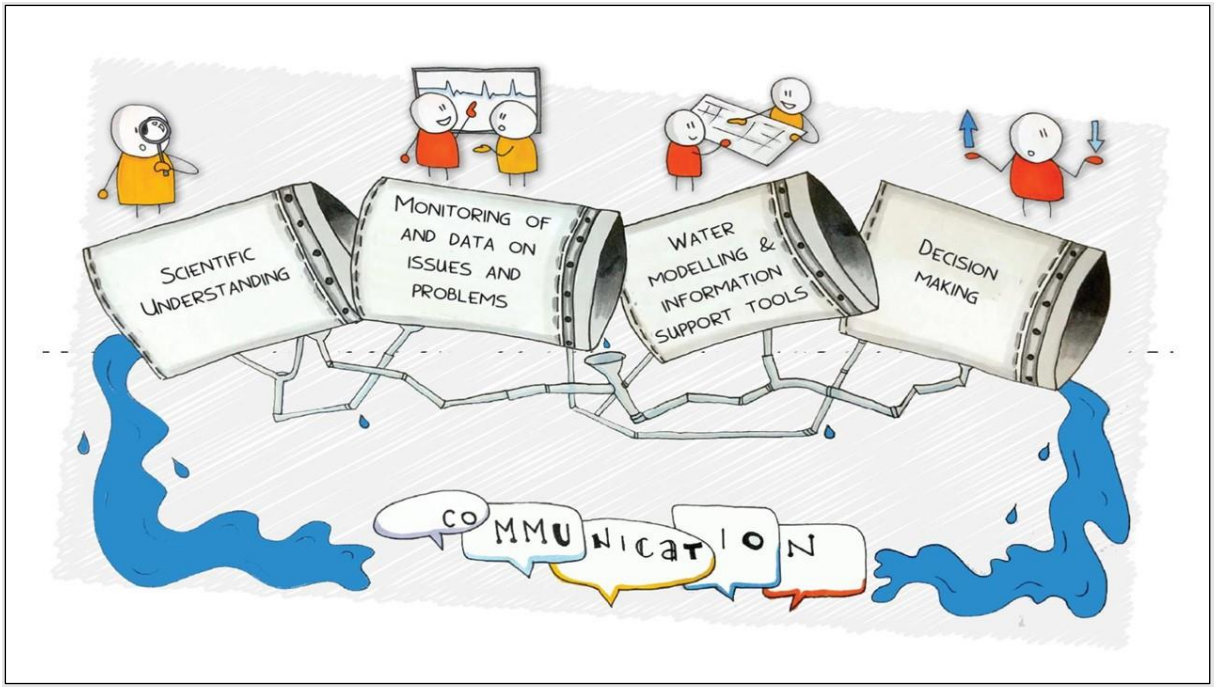

FIGURE 1 WATER MODELLING PIPELINE CONCEPT

It is important to note here that different decision-making areas (e.g. water resource allocation, surface water quality management, water supply and wastewater management, land use planning) are effectively served by different water modelling pipelines – different flows of knowledge from science through monitoring to tools and onwards. Sometimes different pipelines may be connected because for example the science is shared, monitoring systems or data pools are common, or modelling and information support tool technology might be common but this is not necessarily the case – different pipelines may utilise different science bases etc.

Taking a pipeline perspective means looking across and within pipelines at resourcing, at workforce development and health, at co-ordination and communication up and down pipeline stages for different decision making purposes and at the extent to which pipeline stages are sufficiently aligned to serve their ultimate purpose – improved decision making around water. Taking a pipeline perspective on reviewing evidence regarding the function of theQueensland water modelling and use sector, with a focus on suggestions from sixty plus participants QWMN Forum 2020 participants who shared their ideas and views on where the QWMN can focus in the next 10 years (Filet, 2020) yielded the following insights.

Scientific understanding

There was a recognition of the need for investment in modelling to be coupled with investment into development of the science capabilities that underpins water models in Queensland.

Science here refers to the domain knowledge of water or water-relevant real world processes that provide the mathematical or computational basis for models e.g. knowledge of rainfall-runoff and hydrological processes, or of sediment erosion and transport. This is different from the science of decision-making which, whilst a legitimate science, is concerned with the best way of making particular kinds of decisions given what domain knowledge says will happen under different conditions, about how to discriminate between different options for action or how to incorporate desirable characteristics into decision-making such as minimising cost or ensuring adaptivity.

Specific suggestions from QWMN Forum participants about investing in science included (Filet, 2020):

- A request for advocacy for "advancements in science underpinning the models"
- A request to expand the "research input from just model researchers to researchers who study the key processes"

The potential scope for supporting the scientific understanding that underpins our models is vast. Therefore a fairly simple mapping exercise is recommended initially to review the QWMN goals, identify current gaps related to the science underpinning our models and then identify groups who may be able to contribute. This mapping exercise could be guided by established RD&I priorities to focus the scope of the review component.

In examining the issue of building science capabilities and capacity to better underpin water models and modelling in Queensland there is a need to appreciate that scientists are best positioned to be able to assess the extent and quality of available knowledge within their domain, whilst decision-makers are best positioned to be able to assess what scope and quality of scientific knowledge is needed to inform decision-making processes sufficiently. The process then about whether, how and to what extent to invest in strengthening science capacity depends then on a dialogue between science and decision-makers. There is another useful dialogue to be had as well – one between decision-makers and decision-scientists about how to best frame and solve complex water related decision-making tasks.

Recommended Opportunities - QWMN

- Support a mapping and capacity assessment activity – to identify groups of scientists and researchers who may be able to contribute to improving the science underpinning our models, assess their overall capacity and determine whether and how that capacity might be strengthened

Monitoring and data on issues and problems

One of the biggest issues faced by modellers is in obtaining suitable datasets for model development, validation and calibration. Whilst it is recognised that the data needs often relate to the modelling objectives and the model complexity, specific data needs highlighted by QWMN Forum participants include (Filet, 2020):

- "Climate predictions", and
- "Spatial data (including remote sensing)".

Overall, there is a strong desire for improvements in data sharing, data commons and accessible data with standard metadata.

To address these needs, there are some fairly simple first steps that follow on directly from recent activities, including the QWMN Technical Forum 2020, and can be completed relatively quickly.

Recommended Opportunities - QWMN

- Instigate a process of identifying the most significant data needs and how best to plug them – data pooling / sharing, data gathering or use of alternative data sets, including remotely sensed data
- Identify strategies, partnerships and leverage opportunities to support improved data sharing
- Support targeted Community of Practice events to bring data providers and modellers together to establish

Water modelling and information support tools

Some of the key suggestions from QWMN Forum participants that related to water models and tools included (Filet, 2020):

1. "Stronger links between modelling and monitoring"

2. “Integration of models for surface water and groundwater”
3. “A continued focus on model development and improvement”
4. “Opportunities for collaborative model development”
5. A growing need for “capacity building for uncertainty quantification and sensitivity analysis, model & decision stress testing”.

Suggestions 1-4 above relate to RD&I and are consistent with the QWMN RD&I Strategy (QWMN 2018).

QWMN has been helping to support knowledge sharing through forums, workshops and working groups. These approaches are well suited for meeting the water modelling and information support tool related needs identified by the QWMN Forum 2020 attendees.

Recommended Opportunities - QWMN

- Facilitate of efforts to achieve collaborative model development
- Support knowledge sharing on advanced modelling topics including uncertainty quantification
- Initiate workshops and working groups for the development of modelling standards for specific modelling packages

Decision-making

The suggestions related to decision making included improvements in links with models and opportunities for capacity building (Filet, 2020):

- “Linking to environmental impacts models & planning framework”
- “Implementing decision frameworks for dealing with model outputs”
- “Applied research outcomes leading to policy change”
- “Capacity building for robust & adaptive decision making”

The modelling-decision making link is critical to delivering the QWMN goal 5, to “increase application of water modelling to inform decision making”. Investment in this area is a logical next step following on from investment in water modelling and information support tools. There is a strong need for support for both sides of the modelling-decision making link, therefore the following opportunities are recommended.

Recommended Opportunities - QWMN

- Facilitate policy and communication training for modellers to better design and communicate models and their outputs
- Support establishment of common language and communication approaches for increasing the uptake of modelling outputs in decision making
- Better incorporate the modelling-decision making link in the planning and activities of the QWMN as it is not currently well incorporated

Communication

The QWMN has an important role to play in helping to facilitate communication. Suggestions for improvements in this area included (Filet, 2020):

- Communication with stakeholders and end users (social science component) from the start of the modelling process ("opportunity to link modelling and communication expertise")
- "knowledge sharing" through the network on multiple topics including possible topics suggested by 2020 QWMN Forum such as"nutrient offsets" and "the effect of cover variation on runoff"

Several suggestions from the 2020 QWMN Forumspecifically related to broadening the network with an aim to increase involvement by early career water modellers (Filet, 2020):

- "increase the number of students involved in model development"
- "greater engagement of younger professionals"
- "provide a network for undergraduate thesis students working on modelling projects"

In response to these identified needs, opportunities for further development of the network are recommended. These recommended opportunities aim to build on the successes of the past 3 years in growing the network and capture a broader group of participants, including young professionals and those in regional areas.

Recommended Opportunities – QWMN

- Supporting the initiation of a "Young Water Modelling Professionals" group within the QWMN
- Supporting the development of an online group/online discussion board help to increase communication between water modellers (particularly those who may struggle to attend face to face events)
- Facilitating an increased level of university and industry involvement in current QWMN activities (including the Hack event, CoPs, mentoring) to increase support for them
- Investing in developing a clearer social science-based understanding of communication, trust and water modelling and training to stem from this

Reflections on Research, Development and Innovation

Whilst the focus of this report has been on capability and capacity development in relation to the Queensland water modelling and use sector, a number of opportunities for improving QWMN RD&I more generally became apparent during the process of developing this report. These opportunities and what they might mean for QWMN are covered here in this section.

There are known knowledge gaps in some of our models (Filet, 2020), making it important to capture and appreciate these through the facilitation of modelling gaps identification. Some of these modelling gaps can only be adequately addressed by considering relating gaps in monitoring. The Office of the Queensland Chief Scientist (2014) recommended "investment in research related to emerging issues by combined monitoring, modelling and visualisation". This approach lead to the initiation of the QWMN, has underpinned at least two of the QWMN funded projects and is still very relevant for prioritising future QWMN Research, Development and Innovation projects.

Specific modelling areas that have been identified as high priority through the QWMN Research, Development and Innovation (RD&I) strategy 2018-2020 (QWMN, 2018) include climate change and variability modelling, groundwater-surface water interactions and model integration (e.g. land-use modelling and hydrological modelling). Since the RD&I strategy was developed, eight RD&I projects have been initiated with all eight aligned to the priorities outlined in the strategy (QWMN, 2020b). Yet the funded RD&I projects (QWMN, 2020a) have tended to focus on some of the identified RD&I priorities (QWMN, 2020b)so there are opportunities for further research in the other priority areas, particularly those not addressed within current QWMN projects, such as modelling groundwater-surface water interactions and modelling the impacts of urban infill.

The following suggestions, which support identified research priorities (QWMN, 2018) and support strategic co-investment (QWMN Goal 4) are put forward to highlight, in a limited way, recommendations for QWMN RD&I activities.

Principles for QWMN RD&I

- Continue to foster university-industry research partnerships focussed on sector wide issues, for example, climate change modelling or groundwater-surface water interactions.
- Continue to support collaborative, multi-partner projects for specific issues such as groundwater-surface water interaction modelling and urban infill modelling
- Consider providing funding for the collection of monitoring data where monitoring data gaps are holding back model development

CONCLUSION

The QWMN is recognised as playing a significant role in water modelling and use in Queensland and to be creating a pathway for national impact and beyond (Queensland Water Modelling Network 2020b) in both capability and capacity building, and RD&I. Going forward there are a range of ways in which the QWMN can, either through funding or by catalysing action, continue to build upon its success in relation to building the capabilities and capacity of the water modelling and use sector in Queensland:

- In terms of **workforce development,** the QWMN has opportunities to:
    - Assist Universities in strengthening their curricula to provide a better education in the basics of modelling, and also to shift their modes of delivery to better serve the growing demand for work-based learning from water modelling and use professionals
    - To help make the projections of workforce skill and knowledge (competency) demand clearer over the coming 5-10 years and beyond to provide confidence from providers (Universities and others) to invest in developing new programs and courses
    - To continue to support young water modelling professionals and students to network and gain exposure to more experienced professionals and employers from across the sector
    - To look at ways to catalyse industry and government to offer water modelling and use staff more and more diverse ways of continuing professional development including job rotations
- In terms of **strengthening the water modelling pipelines** that connect and deliver science knowledge to decision-making through models and data the QWMN has opportunities to:
    - Support the creation of a science capability and capacity map for different water-related decision-making areas that fall within the scope of QWMN to understand where capacity building investment might be best made.

- Support the development of data sharing in Queensland through CoP events that facilitate data owners and modellers interacting, and by conducting an audit of common data needs and sources to inform practical planning.
- Build capacity for improved modelling by supporting the development of collaborative modelling practice, by facilitating knowledge sharing and learning about advanced water modelling topics, and by catalysing the formation of working groups to develop modelling standards for different modelling packages.
- Improve the uptake of water modelling outputs into decision-making by creating training programs and packages for modellers in effective communication, by adopting a more explicit and stronger approach across all QWMN activities to better link decision-making practice to water modelling, and by supporting the development of communication standards and process guidance to promote the easier use and uptake of model outputs by decision-makers.
- Invest in developing a clearer social science basis to good model and modelling communication practice that focusses on engagement, collaboration and trust building, then going beyond building capacity to improving communication within and across pipelines through supporting dedicated young water modelling professional fora, supporting continued online CoP and other events and facilitating greater student and University participation in all QWMN activities.

Finally, the QWMN has an opportunity to strengthen its RD&I capacity by:

- Fostering and strengthening industry-University linkages for RD&I, and more generally supporting collaborative projects and working arrangements.
- Widening its remit by including monitoring where modelling is being held back by data paucity.

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APPENDIX – QWMN STRATEGIC PRIORITY RANKINGS

QWMN Opportunities	Impact (low-high)	Cost (low-high)
Short timeframe		
Instigate a process of identifying the most significant data needs and how best to plug them – data pooling / sharing, or data gathering or use of alternative data sets, including remotely sensed data	high	low
Support targeted Community of Practice events to bring data providers and modellers together to establish connections and catalyse data sharing	high	low
Facilitate of efforts to achieve collaborative model development	med	low
Supporting the development of an online group/online discussion board help to increase communication between water modellers (particularly those who may struggle to attend face to face events)	med	low
Support knowledge sharing on advanced modelling topics including uncertainty quantification	med	med
Catalysing the creation of QWMN led advanced level training and workshops using innovative delivery mechanisms	med	med
Medium timeframe		
Creating a mechanism to facilitate collaborative (university-industry) water modelling and use research project development more generally	high	low
Initiate workshops and working groups for the development of modelling standards for specific modelling packages	high	low
Better incorporating the modelling-decision making link in the planning and activities of the QWMN	high	low
Supporting establishment of common language and communication approaches for increasing the uptake of modelling outputs in decision making	high	med
Facilitating policy and communication training for modellers to better design and communicate models and their outputs	high	med
Support a mapping and capacity assessment activity– to identify groups of scientists and researchers who may be able to contribute to improving the science underpinning our models	med	low
Supporting the initiation of– a "Young Water Modelling Professionals" group within the QWMN	med	low
Facilitating an increased the level of university and industry involvement in current QWMN activities (including the Hack event, CoPs, mentoring) to increase support for them	med	low
Supporting Young Water Modelling Professional / student focussed networking events to expose both groups to career opportunities in the water modelling sector (including potential employers)	med	med

Long timeframe		
Foster university-industry research partnerships focussed on sector wide issues, for example, climate change modelling or groundwater-surface water interactions	**high**	**low**
Funding university research projects focussed on industry driven problems through future cohorts of Innovation Associates	**high**	**high**
Provide funding targeted at collaborative integrative modelling (for a specific issue e.g. groundwater-surface water interactions, landfill modelling) – with a requirement that proposals must have multiple research partners	**high**	**high**
Provide funding for the collection of monitoring data where monitoring data gaps are holding back model development	**high**	**high**
Investing in developing a clearer social science based understanding of communication, trust and water modelling and training to stem from this	**med**	**med**