QUEENSLAND WATER MODELLING NETWORK

EXTERNAL ENGAGEMENT PROGRAM

Skills and Knowledge Audit – July 2019

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Summary

This report has been produced as part of the Queensland Water Modelling Network's (QWMN) External Engagement Program (EEP) and is intended to fulfil the review and reporting requirements of the EEP's Skills and Knowledge Audit project. The report represents the assessment and views of the authors and should not be interpreted as the views of the QWMN or the various stakeholders that contributed information and ideas to this report. This report is provided to guide conversations and identify potential solutions. Further analysis and integration with knowledge developed from wider EEP initiatives is required to identify and develop appropriate responses to the issues identified.

The overarching scope of the skills and knowledge audit was to characterise both current and future water modelling workforce skill and knowledge needs. Attitudes of different types of organisation (i.e., 1. Government; 2. Consulting; 3. Research/Higher Education) within the water modelling sector were captured. Within and between these types of organisations a distinction between "providers" and "clients" was also made when analysing results. The "provider" category included individuals and organisations that develop models and/or produce model-derived information. The "client" category refers to individuals and organisations that use model results to inform their activities.

Data collection and collation was achieved via four key mechanisms:

1) Interviews – Analysis of information from a set of targeted interviews with leaders in the water modelling profession that were completed between October 2018 and May 2019;

2) Workshop – Analysis of outcomes of a workshop on workforce development with a wide cross-section of water modelling professionals that was held in November 2018;

3) On-line survey – Synthesis of results of a survey completed predominantly by young professionals who attended a QWMN networking event held in February 2019; and

4) Review workshop – Feedback from a workshop involving the project steering committee and stakeholders on a preliminary draft version of this report.

Information developed through these activities was synthesised to provide a snap shot of the current approach to development of the Queensland water modelling workforce as well as identifying future development needs and emerging issues.

Results suggest that there are mixed views within the water modelling profession about the current state of workforce skills and knowledge development. Feedback from individuals in consulting organisations and model provider categories suggest that, while there are areas that could be improved, overall the water modelling workforce in Queensland is stable and that there are no urgent issues in the areas of training and skills development that are limiting the performance of these parts of the sector. A different view emerged from both the government and research/higher education organisations and within the model client category. Individuals and organisations in these groups reported significant challenges in recruiting professionals with experience in both the technical aspects of model application and broader knowledge of the policy and regulatory environments in which model-based information is used. It was observed that these groups often engage with more complex multi-disciplinary modelling activities which often require a capacity that can only be developed over many years. This combination of skills, knowledge and experience across different sectors and policy / regulatory environments is considered valuable and rare in the current workforce.

Results revealed that new professionals to government and consulting organisations are primarily sourced from local undergraduate university programs in mathematics, physics, physical sciences, engineering, planning and architecture. No single undergraduate training program was identified as advantageous over another. The national university system appears to be providing graduates with the necessary skills to enter the workforce but there are significant opportunities to enhance the quality of Australian-trained graduates. Specifically the majority (65%) of organisations interviewed reported a decline in the overall skills and knowledge of new graduates with declines in mathematics (60% of organisations) and physical process understanding (75% of organisations) specifically noted. A trend towards decreasing knowledge of the basic processes of model development, calibration, scenario simulation and evaluation of outputs was reported. There were also reported challenges for the recruitment of suitably qualified Australian candidates to enter research and higher education roles as either doctoral students or post-doctoral researchers – there were too few suitable qualified domestic candidates and so typically international applicants have to be sought.

Interviews revealed that the dominant mechanism for providing ongoing training and skills development within these organisations was via internal communities of practice (CoP) that exist both formally and informally within organisations and between organisations within the same sector. These CoP are characterised by a readily identifiable practice leader or champion, an internal “best practice” document and the extensive use of mentors. Many CoPs also make extensive use of on-line systems for sharing information and solving problems. Incorporation of these approaches and systems into future training initiatives is seen as desirable. The use of short courses offered by external training providers (e.g., software developers) as a mechanism for training the modelling workforce was reported to be in decline.

A wide range of emerging issues were identified. A need to better develop the programming, data analysis and visualisation/communication capacity of the workforce – particularly for working with "big data" has been highlighted as essential across all organisations as well as the provider-client spectrum. A need to improve the sector's approach to succession planning and knowledge transfer in the modelling workforce was also identified – particularly in government and research/higher education organisations. A range of options to address these issues were identified including innovative cross-organisation internships for early- and mid-career professionals as well as development of new collaborative training opportunities delivered by consortiums of the consulting industry, government and higher education providers. Different initiatives could be tailored for both model providers and model client groups within the sector with a specific need to focus on the government-client group. These ideas merit further exploration.

More broadly, while the Queensland water modelling community is well positioned to take advantage of technological innovations to improve its overall capacity, there is a widespread call for additional investment in the science that underpins the models that are applied right across the industry. This is needed to ensure there is continual improvement in modelling capacity and outputs. Specifically, improved knowledge of the processes that drive water and water quality in natural systems is needed so that models can be advanced and trust in model-derived information is maintained and enhanced in the broader community. There is also a sector-wide recognition that there are still substantial challenges in access data for modelling projects. In many instances the time delays associated with accessing data make the data effectively useless (i.e., in many instances relevant data is not able to be provided in time to be considered by a given project or decision making process). All organisation types within the water modelling community have expressed an urgent need to develop effective on-line data repositories that are easily accessible by all potential users in the water modelling profession. How to best respond to these issues warrants further consideration and investigation.

It should also be noted that the information developed through this project needs to be interpreted with the limitations of the data collection approach in mind. Specifically the findings of this report will contain some bias inherent in the interview methodology. The results are also developed from the views of relatively senior professionals in the field and this may influence the perceptions of factors such as what is achievable/expected from undergraduate training programs, the capacity of young professionals and the importance of succession of knowledge. There is also an under-representation of the views of the model client category in the information developed. Further research could address some of these issues.

Keywords: *Water modelling, skills, knowledge, training, workforce, government, consulting, research, higher education.*

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1. Introduction

An audit of current and future skills and knowledge that provide the foundation for Queensland's water modelling and use sector was completed with the aim of identifying key issues and trends that might influence workforce development. The results of the audit provide a snapshot of the current state of the approaches used to recruit and train the water modelling workforce as well as identifying emerging issues and/or skill and knowledge gaps.

This draft report has been produced as part of the Queensland Water Modelling Network's (QWMN) External Engagement Program (EEP) and in particular is intended to fulfil the review and reporting requirements of the EEP's Skills and Knowledge Audit project. Specifically this draft version of the project report summarises the results of a series of interviews with key stakeholders in the Queensland water modelling and use sector as well as the analysis of results from an industry workshop and on-line survey. Current approaches to workforce recruitment and training are explored as well as approaches that could be used to address current or likely future skill and knowledge gaps to ensure sustained workforce capability.

It is important to note that the draft report represents the assessment and views of the authors and should not be interpreted as the views of the QWMN or the various stakeholders that contributed information and ideas to this report. This draft report is provided to guide conversations and identify potential solutions. Further analysis and integration with knowledge developed from wider EEP initiatives is required to identify and develop appropriate responses to the issues identified.

1.1 Background

A key task of the Education Research and Training (ERT) component of the Queensland Water Modelling Network's (QWMN) External Engagement Program is to undertake a water modelling skills and knowledge audit to characterise both current and future water modelling workforce needs along with the full range of current formal education and training opportunities of relevance to those needs within Queensland. Furthermore this project sought to examine anecdotal reports of a growing skills shortage across employers in the water modelling and use sector. Refer to appendix A for the terms of reference for this review.

Water modelling refers to a broad range of activities that requires specialist knowledge in meteorology, hydrology, soil science, mathematics, numerical methods, water quality science, ecology, data management, planning, policy development, regulation and communication. In the past 15 years there have been an increasing number of reports of a skills shortage in the global science and engineering sectors that provide background training in these various specialist fields, with some investigations specifically mentioning a shortage in the hydrological modelling and environmental modelling fields (UKEA, 2005; Matchtech, 2016; UK Gov, 2019; NERC, 2012). Past work (Harris et al., 2005) on attitudes and issues faced by some areas of the Australian water modelling industry (or the "predictive science" profession more broadly) have confirmed many of the issues raised in overseas examples however local research is rare. Much of the quantitative information on these skills shortages is specific to European and North American situations and there is little information on the Australian context. While similar information has been collated for the Queensland urban water sector (IPWEAQ, 2016), there have been no specific research into the water modelling and use sector. This report represents the first attempt to collate such information specific to the water modelling workforce.

2. Approach and methods

The overarching scope of the skills and knowledge audit was to characterise both current and future water modelling workforce skill and knowledge needs along with the full range of current formal education and training provision by Universities and other relevant organisations within Queensland. The audit also attempted to identify informal training activities including in-house courses and online communities that are currently used within the sector. The audit specifically focused on the Queensland water modelling and use sector with some input from national leaders in the Australian water modelling sector. This was achieved via three key project phases:

Phase 1 Initial Data Collection – A series of structured short interviews with selected modelling practitioners from the different broad sectors of the water modelling and use sector: 1) Government including Commonwealth, State and Local Government agencies; 2) Consulting organisations including both large and small to medium organisations; 3) Research and higher education organisations; and 4) Other organisations such as not for profit groups. Within and between these sectors a distinction between “providers” and “clients” was also made. The “provider” category included individuals and organisations that develop models and/or produce model-derived information. The “client” category refers to individuals and organisations that use model results to inform their activities and often require detailed understanding of modelling as well as policy and regulatory frameworks. Interviews lasted between 30 and 90 minutes depending on the enthusiasm of the interviewee and were completed between October 2018 and May 2019. This was the primary mechanism for collating data on current water modelling workforce skill and knowledge needs. This phase of the audit specifically avoided using workshops. Key points and subject areas discussed in these interviews are summarised in appendix B. A descriptive and interpretive method (cf. a structured and formal approach to content analysis) that sought to identify typologies and to group responses and issues, was used to analyse notes made during the interviews (i.e., a conversation analysis methodology was used) (Creswell, 2018). Through this process a set of thematic codes was developed and these form the basis of the groups of ideas and issues that were identified as of most significant in the interview responses. Information derived through this phase was not attributed to the individuals interviewed.

Phase 2 Stakeholder Workshop/Forum – The initial findings from the data collection phase were evaluated via a workshop scheduled as part of the QWMN 2018 Forum held in November 2018. This workshop mapped out selected career pathways of individuals in the water modelling and use sector as a means of identifying key workforce challenges in terms of recruitment and retention, skills, knowledge and capability. Outputs from this workshop were analysed to provide additional contextual information on trends in background training, career pathways and motivation for careers in water modelling.

Phase 3 Survey of Young Professionals – Results from an on-line survey of attendees of a QWMN networking event (Community of Practice – Career Ambitions and Water Modelling, February 2019) were also analysed to identify perceived benefits and challenges related to a career in the water modelling profession. The questionnaire also collected information on intentions to enter or remain in the water modelling field along with information on whether future engagement would be in provision of modelling services or use of results from modelling projects (i.e., a provider vs decision maker role). Refer to appendix C for a summary of the questions used in this analysis. A thematic coding approach (Creswell, 2018) was applied to identify ideas and issues that were of most significant in the survey responses.

Phase 4 Review and Reporting – Preliminary project results were presented to a small set of stakeholders and the project steering committee in a workshop-style forum May 2019. Feedback from this stakeholder group has been incorporated into this report. To complete this phase of the project this report will be circulated among the interviewees and selected key stakeholders to collect additional feedback and comment before completing the final project report. As part of the reporting process issues were highlighted when ≥ 25% of respondents identified the issue and as such not all issues raised have been reported. Where possible the report includes information on the proportion (expressed as a %) of responses that supported a given statement.

3. Results

The interview phase of the project was able to capture a rich array of information from 22 individuals from different employer organisations within the water modelling and use sector. Two of these individuals were able to provide the views from more than one employer organisation due to recent changes in roles that resulted in a shift to another organisation within the water modelling workforce which allowed the views from 24 organisations to be assessed. This was complemented by information collated through informal discussions with an additional 5 professionals (2 large consulting and 3 research and higher education) in the water modelling field who were not able to complete a more structured interview due to scheduling constraints. Figure 3.1 provides a summary of the distribution of sectors represented in the interview process (informal discussions not included). These results suggest the interviews achieved a relatively even coverage across the government (9 organisations), consulting (8 organisations) and research and higher education (6 organisations) sectors with the "other" category (1 organisation) representing a not-for-profit collaboration between all three of these sectors.

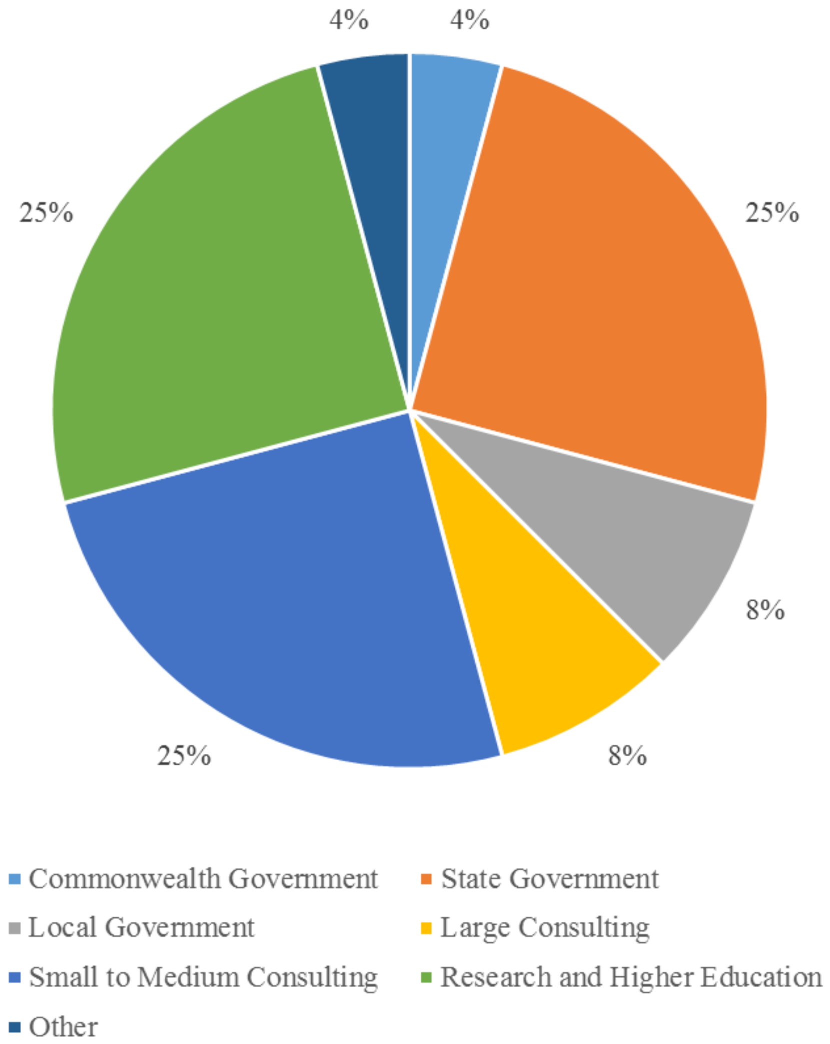

Figure 3.1 – Distribution of different types of employer organisations represented in the interview process.

These groups of interviewees could also be categorised in terms of their involvement in the water modelling process and were designated as either: 1) Providers of models and modelling results; 2) Clients of models who use model results to inform their activities or 3) Both providers and clients depending on the specific details of a project. The distribution of interviewees among these categories is summarised in figure 3.2 and indicates that the interviews were slightly dominated by providers of model services with an under representation of the client-only group. Specifically there was a notable lack of organisations such as regional resource management bodies who are user of model data and results.

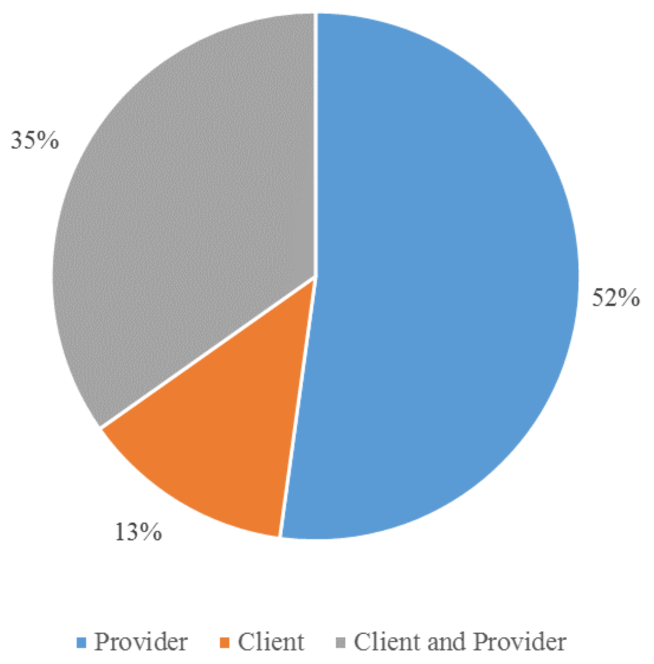

Figure 3.2 – Distribution between modelling service providers and clients who use modelling information and results as part of their activities.

The interview and workshop processes (project phases 1 and 2) also identified and categorised the various different roles that individuals can have in the water modelling process. Most organisations reported that their modelling teams consisted of the groups of professionals that were able to fulfil the following roles:

- ***Communicators*** – Specialists in the communication of scientific information that are used to synthesise the outcomes of modelling projects usually to inform decision makers. Professionals in this role usually have a background in bio-physical science and/or data science as well as some of the skills and knowledge of the data wrangler category (see below). This group was not well represented in the phase 1 interviews or phase 2 workshop.

- ***Computational specialists*** – Specialists in developing and managing computational architecture that allows models to run efficiently. This includes providing computational services such as high performance computing systems and support and advice to model developers to enhance the computational efficiency of model codes Individuals generally have a background in information technology, computer science or engineering. These individuals were not represented in the interview process or stakeholder workshop, however, most organisations that were engaged by this project have dedicated computational specialists.

- ***Data analysts*** – A group of professionals who are engaged in collating and analysing data from both environmental monitoring systems and model outputs. The data analysis can be for a range of purposes including: improving understanding or gaining insights into different environmental systems, future model development, development of model input data and examining the performance of models. This role is similar to data wranglers but often requires more background knowledge of the physical processes that operate in environmental systems. This group was well-represented in the interview process as the model driver role (see description below) also includes significant aspects of the data analyst role (i.e., most model drivers are also good data analysts but data analysts do not need to be model drivers).

- ***Data wranglers*** – A broad group of professionals that use a combination of data science, coding and geographical information systems (GIS) expertise to manipulate data for use in the modelling process. This can include sourcing and processing data for use as inputs to models as well as post-processing model results to aid in interpretation and communication of these outputs. Professionals in this group do not necessarily have a background or expertise in hydrology or water science. This group was represented in the interview and workshop process with approximately 30% of individuals working in this role from time-to-time. All organisations that were engaged by this project have dedicated data wranglers and reported that there was a growing demand for professionals with these capabilities.

- ***Decision makers*** – A group of professionals, mainly from government organisations, that use the results/outputs from models to inform environmental management decisions or policy development. This group possesses a good knowledge of the regulatory frameworks that are relevant to a range of water related activities. Traditionally professionals in this group have also had past experience as model drivers (sometimes in fields outside of the water modelling field) and/or a sound knowledge of the generic modelling process. Outcomes of this project suggest that individuals in this role do not have any direct experience in any of the other modelling roles and are increasingly relying on model communicators and/or problem formulators to interpret model-derived information and place it in context of decision making frameworks.

- ***Model developers*** – Individuals and groups that are typically involved in the development of models and/or updating of model source code. They require high-level computer programming skills and a good understanding of modern computational techniques as well as the capacity to understand bio-physical processes and develop mathematical approaches to describing these processes. This group was lightly represented in the interview process and stakeholder workshop with specialists limited to only a few organisations (6 organisations) across all the sector.

- ***Model drivers*** – Professionals mainly comprised of individuals with engineering backgrounds (civil, chemical and environmental) that apply existing models to answer specific questions. Individuals in the group often have skills and knowledge from all of the other categories in this list. This group was well-represented in the interviews from phase 1 and the phase 2 workshop and tends to be the group that most people associate with 'modelling".

- ***Problem formulators*** **–** Specialists from both the provider and client categories that are able to identify problems that can use information from models to identify potential solutions. They are often involved in the development of a scope of works or commissioning modelling projects and require good technical understanding of the whole modelling process as well as the policy and regulatory frameworks that are relevant to a range of water related activities. Professionals in this group are also expert at communicating the outputs of model simulations to a range of different stakeholders. Individuals in these categories tend to be senior professionals that have broad experience across a range of different sectors and/or specialised modelling areas. This group was well-represented in the interviews from phase 1 with all interviewees having capacity in this area due to the seniority in the water modelling profession.

Sufficient information on which of the above roles that interviewees assumed was not able to be collected to provide analysis for each of these categories. This is an area that could be considered for further research if there is sufficient interest.

Through the interviews and workshop information from organisations that span the full range of water modelling activities was collated. This included organisations that specialised in modelling of one of more of the following areas:

- ***Catchment hydrology, water quality and pollutant load estimation*** – Surface water rainfall-runoff and flow routing for a range of application, mainly associated with water resources and/or ecosystem management;

- ***Coastal modelling/Met-ocean modelling*** – Coupled simulation of meteorological and oceanographic processes often with the aim of examining the influence of waves and ocean currents in various ecological systems, wave forces on structures and wave-induced sediment transport in the near coastal zone.

- ***Data analytics/data-driven modelling*** – Use of a combination of data science, statistical models and communication skills to interpret and communicate complex information from various monitoring and water modelling systems.

- ***Ecological modelling*** – Application of both statistical and mechanistic models to explore species and ecosystem responses to various environmental management scenarios.

- ***Flood modelling*** – Application of various combinations of rainfall-runoff and flow routing models to inform flood risk assessment.

- ***Geomorphic modelling*** – Simulating the interaction of surface water flows and geological materials to examine the influence of erosion and deposition on the geomorphological features of natural waterways.

- ***Groundwater flow and contaminant transport*** – Simulation of groundwater flow to inform water budgets in urban and agricultural areas along with associated investigation of contaminant transport and fate for various constituents including saltwater and chemicals depending on specific project needs.

- ***Hydraulic modelling*** – Simulation of urban water supply, sewer and stormwater networks to inform design and management.

- ***Integrated water cycle modelling*** – Combining various water supply, sewage management, rainfall-runoff and economic modelling approaches to inform total water cycle management investigations.

- ***Urban hydrology and water quality modelling*** – Application of various rainfall-runoff and flow routing models in combination with pollutant load generation and treatment models to provide information for environmental impact assessment processes and/or evaluation of water sensitive urban design solutions.

- ***Receiving water quality modelling*** – Coupled hydrodynamic and biogeochemical modelling to examine various water quality and ecosystem health responses to different environmental management scenarios in streams, rivers, estuaries, embayments and oceans as well as pond and lake systems.

- ***Agricultural systems modelling*** – Application of various soil moisture, land irrigation and agricultural water needs assessment models to support the design and management of agricultural and treated water disposal systems. Often referred to as paddock modelling.

- ***Water balance and water budget modelling*** – Application of various modelling approaches to estimate future demand and water supply for rural/agricultural water, urban water supply and management of water in the mining and mineral processing industries.

Again sufficient information on which of the different water modelling areas outlined above was not able to be collected to provide analysis for each of these categories. This is an area that could be considered for further research if there is sufficient interest.

Despite the wide range of different water quality modelling applications among those interviewed a consistent set of issues and themes emerged. The word-cloud shown in figure 3.3 illustrates some of the key themes that emerged from the interviews. These issues and themes are summarised in the following sections for each of the key areas addressed during the interviews.

Figure 3.3 – Word cloud developed from key categories identified in interview responses.

3.1 Past and present approaches to workforce recruitment

3.1.1 Recruitment process

Interview results revealed that most organisations rely on formal recruitment and selection processes to source new talent for their modelling groups. Increasingly this approach includes the use of international searches (now essential in research and higher education) through third-party recruitment service providers. A small portion of the organisation interviewed (mainly in the engineering consulting sector) also used an informal process of selection/recommendation from within existing professional and peer networks. Most organisations use a traditional application and interview (either face-to-face or online) process to select among short-listed recruits. Some organisations noted the challenges in assessing some of the desirable skills (e.g., problem solving – see discussion in next section) during an interview process. This apparent gap in the recruitment process might be something that could be addressed through an industry-wide training, development and assessment initiative.

3.1.2 Desirable background training and skills

All organisations identified foundation skills in mathematics (commonly engineering mathematics), statistics and the biological and physical sciences as essential requirements for people entering their organisation. While some organisations identified some specific undergraduate degree programs (e.g., civil engineering, environmental engineering) as preferred background training no organisations had set requirements in this area. Applicants with undergraduate degrees in the biological and physical sciences, ecology, planning, mathematics, statistics, engineering and environmental science are considered appropriate depending on the exact nature of a given role.

Some organisations reported that they valued and actively sought recruits with experience in specific modelling software packages however there was a more dominant trend towards recruiting graduates with broad combinations of backgrounds instead of experience with a specific package. Furthermore there is an emerging trend towards recruiting new staff with combinations of data science and communication backgrounds. The majority (65%) of organisations interviewed reported a decline in the overall skills and knowledge of new graduates with declines in mathematics (60% of organisations) and physical process understanding (75% of organisations) specifically noted. This trend was consistent across all types of employer organisation as well as the provider and client groups. A trend towards decreasing knowledge of the basic processes of model development, calibration, scenario simulation and evaluation of outputs was also reported.

Interestingly all organisations identified a more specific set of non-software specific and non-technical skills that are sought after in new recruits. These skills and abilities include (in order starting from most desirable):

a) ***Critical thinking and problem solving*** – The ability to critically evaluate information to produce evidence based solutions to complex problems. This includes the capacity to apply a methodological approach (including documentation of that approach) in a self-directed and self-monitored manner to evaluate or appraise their own work as well as that of others.

b) ***Teamwork*** – The capacity to efficiently and effectively work as part of a team to deliver modelling outcomes. This includes background knowledge of basic team dynamics, the role of team leaders and methods for team communication and conflict resolution. Most interviewees noted that a key part of the recruitment process was an assessment of an applicant’s ability to work well within the organisation’s existing teams.

c) ***Independence, resilience and persistence*** – The capacity to take ownership of problems or projects combined with the ability to self-learn / self-teach to find solutions to challenges or workflow blocks/stoppages.

d) ***Project management*** – Knowledge of fundamental project management frameworks and the ability to work within these frameworks, specifically project documentation, time management and budget management aspects. This also includes an understanding of how water modelling fits within contemporary regulatory frameworks and business environments (i.e., economics of for-profit organisations, client-service provider relationships).

e) ***Communication and engagement*** – Includes basic oral and written communication ability with a specific focus on producing written technical reports and oral presentation of complex technical information to other members of a project team or stakeholders.

f) ***Coding and data analytics*** – The ability to source information and to use basic programming languages to input, analyse, visualise and output large amounts of data efficiently. The emerging preference in this area is for open-source languages such as Python and/or R in place of licenced products. While listed last among the current skills and abilities this is emerging as a key need for future workforce development (refer to section 4.3 for additional discussion).

g) ***Multi-disciplinary knowledge*** – A knowledge of the underlying mathematics, physical and biological sciences combined with experience in applying models as well as a good understanding of the policy and legislative frameworks in which decisions about water and environmental management are made. This combination of abilities is not expected of new graduates as it takes extended timeframes to develop the necessary experience. These abilities are highly sought after, particularly in the government sector.

Furthermore it was specifically noted that these skills aren't explicitly part of many contemporary undergraduate degrees. This is particularly the case in fields such as mathematics, science and engineering where problem solving, teamwork, project management and communication skills are something students are assumed to develop as part of their progression but are rarely formally assessed to confirm this progression. Again this apparent gap in existing training systems might be something that could be addressed through an industry-wide training, development and assessment initiative or embedded as part of future community of practice / mentoring initiatives.

3.1.3 Age profile of water modelling workforce

As expected interview results revealed a wide mixture of age profiles within the organisations consulted, however some broad trends emerged within different sectors of the workforce:

- Consulting organisations – Most organisations reported workforce age profiles to be evenly spread between new graduates (early 20s) to approximately mid-career (early 40s) with older, more experienced professionals often leaving the technical aspects of water modelling to take on broader management and client liaison roles within their organisations. Recruitment of new staff occurs across this age range but graduate recruitment is more prevalent.

- Government agencies – An age profile spanning the full range from new graduates (early 20s) to end of career (65 +) was reported for most modelling groups within government agencies, however there can be significant generational gaps. This is driven by the episodic nature of new recruitment, which is reported to be predominantly from the new graduate age range, but does not occur on a regular basis due to a sporadic funding environment which is driven largely by changing political and policy priorities.

- Research and higher education – This sector is characterised by a slightly older workforce with continuing positions held by individuals who were generally 35+. This reflects the additional training and experience (i.e., research higher degree training and some form of post-doctoral experience) required for professionals working in these roles as well as the highly competitive nature of this sector which makes it challenging for less experienced professionals to gain entry. Fixed term post-doctoral positions are generally held by modellers in their late 20s and early 30s while graduates are typically found in research higher degree cohorts and neither of these categories are considered to be part of the organisation's permanent workforce.

All organisation types noted that the recruitment process was rarely steady (particularly in government agencies) but instead tended to occur in waves associated with changing investment programs and priorities. When examining the age-structure across the provider-client spectrum it was evident that the client group is heavily reliant on mid- to end-career professionals. This group also reports challenges in recruiting new professionals due to a reported lack of skills and experience. It was reported that it was rare to find a professional who had both technical skills and experience in modelling as well as the necessary knowledge and experience of working within policy and regulatory frameworks (most professionals possess capacity in only one of these areas). It was also suggested by some respondents that there is a perceived lack of interest in these roles (i.e., a suggestion that many "modellers" prefer to work in a "model driver" role rather than the "decision maker" role only).

3.1.4 Other workforce recruitment and retention issues

Feedback suggested that in consulting organisations and to a lesser extent the government organisations there was a good market for new staff with suitable water modelling ability and that the majority of organisations interviewed (85%) indicated that they had not experienced a shortage of new graduates when recruiting. It was noted that since approximately 2012 it has been quite easy to recruit experienced people from the mining industry due to the downturn. This has meant that hiring of new graduates was reduced over an approximate 8 year period. Those organisations that did report challenges with graduate recruiting were in the government sector and were dominated by the client or end-user of modelling information category. Interestingly a majority of organisations interviewed (55%) did report a shortage of personnel with a combination of modelling experience and knowledge of policy and regulatory frameworks. Reports of this type experienced staff shortage was predominantly from the government and research / higher education sectors.

Retention of staff in consulting organisations was noted to be very challenging with 50% of interviewees from this category of employers reporting recent loss of well-performing staff to other organisations. This is particularly the case for staff who have gained 3-5 years' experience with a consulting organisation and therefore have developed valuable skills and experience compared to new graduates. Feedback suggested there is strong competition among consulting organisations to attract early- to mid-career professionals with many smaller organisations unable to match the remuneration packages offered by larger companies. This is similar to the experience of the government-client group within the water modelling and use sector.

Within government employer organisations the sporadic nature of investment in modelling activity was noted by 60% of interviewees as a key challenge in maintaining a vibrant and sustainable water modelling capacity. It was also noted that there was a lack of formal succession planning for the modelling workforce in many government organisations which in turn presents a risk for loss of historical/corporate knowledge of past modelling approaches.

Within the research and higher education organisations all respondents highlighted the challenges in recruiting suitably qualified and motivated Australian-based water modelling staff. International applicants are the dominant source of personnel for new water modelling roles. This is due to a combination of an apparent lack of interest in water modelling research positions combined with a reduced mathematics ability of Australian-based / trained applicants compared to international applicants. Feedback suggests that graduates from various programs in Europe, Asia and Russia tend to have a more developed mathematical and data analysis capability and generally do not "fear" mathematics. Similar to government organisations it was also noted that there was a lack of formal succession planning for the modelling workforce which in turn presents a risk for loss of historical/corporate knowledge of past modelling approaches including legislatively mandated legacy models or model versions and their supporting operating systems.

3.2 Current training systems and approaches

Results suggest a wide variety of training systems and approaches are implemented across the water modelling and use sector in Queensland. Common features of consulting and government employers include:

- ***Formal external training options*** – Feedback indicated that courses offered by external software developers / providers or general courses on water modelling are perceived to be of limited use or value (60% of interviewees reported this view). The clear focus of workforce training for most organisations is internal (>75% of organisations) and can be a mixture of formal and informal training. This is largely driven by the specific nature and expertise requirements of individual modelling groups. It was also noted that the cost of formal external training courses (typically >$1,000) was problematic to justify for some organisations.

- ***Internal communities of practice (CoP)*** – Most organisations (85%) have developed formal or informal communities of practice, often based around a practice leader and an internal "good practice" document (a specific guide to modelling practice that is regularly reviewed). In many organisations these CoPs are based online (using platforms such as slack, modelling wiki-pages or similar) and provide forums for staff to exchange new ideas and good work practices. In some instances these CoP also include mentoring systems (both formal and informal) to develop the broader modelling skills of newer staff. Some organisations have also implemented reverse mentoring programs where new staff provide established staff with training in new techniques (commonly the use of open-source coding packages to process and visualise results). The mentoring component of these communities was often cited as one of the most important mechanisms for ongoing training and development. The use of CoPs as a training mechanism was evenly reported across all types of employer organisations within the sector as well as the both the provider and client categories.

- ***Informal links*** – Within government and research and higher education organisations a greater prevalence of the use of informal links between different organisations to up-skill was reported. Interactions at modelling conferences (e.g., MODSIM) appear to form the catalyst for subsequent informal meetings with individuals and even whole modelling teams sometimes spending time in the office of a different organisation to collaboratively work and train their team members.

A need for improved training opportunities for decision makers and users of model outputs was also identified as a key need by a majority of stakeholder (65% of interviewees) particularly those that are clients for model-derived information (75% of clients identified this as a key training need).

In contrast to the consulting and government employers, the research and higher education organisations have a split approach to training for coursework and research programs as follows:

- ***Coursework training*** – There are currently no dedicated programs (i.e., set of courses that form a degree) or even a major stream (i.e., specific set of courses within a degree) available in Queensland (or nationally) that specifically focus on water modelling in its broader sense. Many programs offer fundamental courses in mathematics, statistics and water-related sciences such as hydrology, meteorology, hydraulics, aquatic ecology, aquatic chemistry with some introductory material on basic water modelling (usually basic model set-up, calibration and performance testing – usually of hydrological models). However, there is no single program that covers most of the areas outlined in section 3.1.2. Furthermore it is noted that stochastic modelling approaches are not covered in great detail in many university systems (introductory concepts only) and often only as part of curriculum on statistical modelling. Despite the emerging use of stochastic approaches in areas such as catchment modelling and water supply security assessments there are few examples of stochastic modelling with physically-based mechanistic models in training courses. It should also be noted that the limited space available in most undergraduate programs for water modelling courses has meant that universities have traditionally focussed on developing fundamental modelling capacity rather than developing student capabilities in software packages used in the sector. This trend is slowly changing in response to student demand for modelling skills that will enhance their employability – there is a strong perception by graduates that being proficient in a software package that is widely used in the sector significantly enhances graduate employment opportunities. Many interviewees expressed a concern that this might lead to a loss of ability to understand the fundamental theory behind commercial modelling packages which in turn could lead to a reduction in long-term capacity for high quality modelling and model development. Interviewees noted that the QWMN provides a unique mechanism for developing consensus on this issue.

- ***Research training and support*** – The highly individual and specialised nature of most research higher degree projects in Australia combined with short timeframes (typically 3 years cf. 4-5 in overseas institutions – and previously the case in Australia pre-2000) has resulted in the removal of some of the broad training offered in the water modelling area. It was noted that in the past some universities did require research students to complete coursework modules to develop skills in many of the foundation areas listed in section 3.1.2 such as mathematics, statistics, physical sciences, critical thinking and problem solving and project management, however, this is no longer the case in most organisations. As such there are generally no modelling specific training programs available for research higher degree students or post-doctoral water modellers. Individuals in these roles are expected to self-learn skills on an as needs basis. Limited research funding was also cited as a reason that formal external and/or internal training courses are not widely used in this sector. Again interviewees noted that the QWMN provides a unique mechanism for developing consensus on how to address this issue.

Many interviewees also commented on the lack of training material and opportunities in the areas of water quality and aquatic ecosystem health modelling. While material exists for most other areas of the water modelling profession (with flood modelling identified as being the best serviced area) there is a clear gap in the water quality modelling area.

Overall there was consistent feedback from organisations across all organisations that "*Individual organisations are best placed to train their staff*" and that investment in the development of external training courses as a community wide initiative is not warranted. Comparisons were also made between the current state of online training material in the water modelling sector and other technical areas:

"Online materials for learning that are currently available in the tech space are phenomenal and are available for free."

Many interviewees suggested that the water modelling community needs to explore this approach rather than the current more traditional short-course based approach to ongoing staff training and development.

3.3 Emerging issues

One of the most interesting aspects of the skills and knowledge audit interviews was the range of emerging issues that were identified by the interviewees. Many of these issues are not unique to the water modelling and use sector and are common to the related environmental, medical and digital solutions sectors. This suggests exploration of the approaches used in these sectors could provide valuable insights that could be transferred to water modelling. Analysis of this feedback identified several themes that were raised in different ways by various organisations. These broad themes are summarised in the following sections.

3.3.1 Advances in computational systems

The majority of interviewees in the model provider category noted that the ability of the water modelling community to adapt to the continual changes in computational processes (i.e., shift from single CPU to multi-CPU high performance computing systems as well as GPU-based systems) is not as efficient as in other technical areas. This is in part due to the up-front time investment and computational skills sets required to understand and optimise performance of the various suite of water quality models for new computational architectures. There is scope in this area for more collaborative assessment of emerging computational options and the subsequent adaption of various water models to make better use of new computational systems. There is a perceived risk that the water modelling and use sector will continue to lag other computational sectors without developing the capacity to more rapidly assess and adapt to these new systems. This in turn has the potential to limit the development and impact of water model outputs by limiting the number of simulations that can be completed in a given project timeframe.

3.3.2 Big data, data analysis and coding capacity

All organisations noted the increased availability of large on-line data sets (e.g., gridded meteorological data from both re-analysis and forecast modelling systems) is driving upskilling of the workforce's capacity to use basic programming (coding) to both access these data and to undertake analysis or conversion of this data into useful information for water modelling activities. Many interviewees (55%) noted that the water modelling sector does not currently make best use of many of the large data sets that are being developed and made freely available in the climate, meteorological and oceanography communities. This is, in part, due to a lack of proficiency in coding required to access and manipulate these large data-sets. It was also noted that in many cases there is a need to develop new methods to analyse, interpret and communicate the information in these large data sets (65% of interviewees). Some organisations are beginning to recognise the opportunities in this area and are actively seeking staff with specific skills in computer coding and data science to complement their existing water modelling expertise. On the issue of coding ability and capacity within the water modelling workforce there was a sector wide recognition (and also spanning the provider-client roles) that improvements are needed (70% of interviewees).

3.3.3 Model integration

Water modelling in its broadest sense requires the integration of models that describe meteorological and climate processes with catchment hydrology, the hydrodynamics of flow in natural and artificial channels, groundwater flow and the dynamics of estuarine and near coastal regions as well as the chemical, biological, ecological and social processes that interact with these water flows. While most interviewees acknowledged the impressive gains that have been made in integrating these different modelling approaches and platforms in the past 10 years there was consistent feedback that more needs to be done. Specific areas that were identified for future development across the whole workforce included:

- ***Catchment-receiving water quality model integration*** – While there have been significant advancements towards better integrating these different models (particularly as part of the eReef Project) a number of areas that were identified where additional effort is required to achieve better outcomes. Specifically the need to better represent sub-daily flows and pollutant loads from catchment models. Better matching of the constituents simulated in catchment models and receiving water quality models was also identified (i.e., recognising a need to move past the current practice of disaggregating total constituent loads into various sub-species). Some interviewees noted that a new science is required to better understand the links between hydrology and pollutant export, transport and fate in catchment systems. Extension of these models to also allow improved simulation of pathogens was also identified as a high priority due to growing demand for model outputs to inform quantitative pathogen risk assessment studies.

- ***Global scale meteorological and climate models*** – The growing availability of various meteorological, ocean and future climate modelling products including detailed re-analysis of past conditions as well as operational forecasts and long-term future climate forecasts has provided significant new sources of information that can be used, often as input or boundary conditions, in water models. Many organisations have noted that, while they are adopting many of these products, they have been unable to allocate significant resources to systematically evaluate each product let alone the influence on the outputs of water models – there are simply too many different products to examine within the scope of any one water modelling project. It was noted that this situation is only likely to be exacerbated into the future as a greater number and more diverse products become available. As such there is an emerging need to understand which meteorological, climate or ocean modelling products are most appropriate for different water modelling applications.

- ***Integrated water cycle models and accounting methods*** – Many organisations identified a growing demand from management agencies and stakeholders for improved information to inform total water cycle management activities. While this demand is primarily driven by local government organisations as part of their planning and management of urban areas it is thought that this need will also rapidly extend into regional management activities (particularly when the next drought cycle impacts on water supply networks). Furthermore it is widely recognised that there is an emerging need to better integrate the socio-economic impacts of water modelling outcomes with regulatory and economic frameworks. It was reported by many organisations that there is a shift away from the traditional environmental impact assessment style of application of models to a focus on integration with triple-bottom-line impacts (i.e., environmental, social and economic).

- ***Data assimilation*** – Some interviewees noted the advances that had been made in the meteorological and ocean modelling fields in the area of data assimilation. There was broad recognition that there was significant scope for water modelling activities to learn from and adopt some of the data assimilation approaches used in these fields. There are some initial barriers to this adoption including a lack of knowledge and capacity within the water modelling sector to implement data assimilation methods as well as the subsequent challenges associated with communicating the results to decision makers and stakeholders.

3.3.4 Communication and decision making

There was also wide acknowledgement among those interviewed that there is a need to better communicate the outcomes of modelling projects so that they are able to more readily inform management decisions:

"Increasingly clients are not interested in the technical details of modelling approaches and simulation outcomes but instead on how to integrate findings into overall management decisions."

As such there was a wide recognition of the need to improve the ability to visualise simulation results across all areas of the water modelling and use sector. The integration of simulation results with geographic information systems (GIS) and further extension into three-dimensional visualisation in GIS environments and/or augmented reality environments was identified by many organisations as a current capacity gap. Integration with GIS environments is seen as a specific need, as it provides a mechanism for linking with other natural resource data that are used to aid decision making. Many organisations do not currently have the capacity to produce high quality and useful summaries of simulation results in a GIS environment in an efficient manner.

Browser-based models backed by cloud computing systems that allow clients and stakeholders to see the results of modelling projects in near real time was also identified as an emerging technology that has the potential to significantly shift current workflow of modelling projects. This emerging approach also significantly changes the ways in which end users of simulation outputs interact with modelling information and modelling professionals. When combined with the increased use of data assimilation and real-time forecasting models (also referred to as operational models) it is likely that in the near future it will become standard practice for clients and stakeholders will be able to access simulation results on-line in near real time. This will require complimentary investment in both methods to better communicate the outputs of model simulations but also in additional training of end-users to appropriately interpret and make use of these outputs.

These issues are also closely related to the well-recognised challenges of communicating uncertainty in simulation results and the incorporation of this uncertainty into decision making processes. The increased use of stochastic and ensemble modelling approaches, particularly to examine future climate scenarios, has provided early insights into some of the challenges associated with communication of these types of simulation outputs. All organisations identified this as an area of water modelling practice that requires additional work to ensure that the communication of uncertainty in model outputs and their subsequent use in decision making is appropriately and consistently handled across the water modelling sector.

3.3.5 Knowledge transfer and succession planning

All types of employer organisations of the modelling community reported concerns over the lack of clearly defined mechanisms to transfer knowledge about specific projects and modelling platforms to future generations of the modelling workforce. This is most acute in government organisations where many water models form the basis of water resource plans and in some cases are enshrined in legislation. The expected life of some of these plans is of the order of 20 years and therefore there is a regulatory requirement to preserve models over this period. This often necessitates the use of virtual machines to allow legacy models to operate within specific versions of operating systems that are no longer used or supported.

This creates a need for transfer of information about both the technical requirements but also the history of model development and application which is considered a knowledge set in itself. Clear mechanisms to transfer information and understanding of how and why the models were developed and applied to different scenarios including detailed knowledge of their strengths and weaknesses are hard to define. Ensuring that this type of information is available and lives within the modelling community is critical to both the ongoing custodianship of these legacy models but also to provide information to inform improvements in future modelling approaches.

At present there is no formal system for this knowledge transfer and succession. Some organisations have developed ad-hoc informal mechanisms for succession planning however it is unclear as to whether these systems are effective. In summary there appears to be sufficient concern across the entire water modelling sector to warrant additional investigation of this issue.

3.3.6 Open source software

Most organisations highlighted the emerging trend among global providers of modelling software and tools to make their products available under open source frameworks. This in turn raises issues about the nature of future investment in models and software development (i.e., is it still viable to invest in or even use licenced software). For example, most research and higher education organisations are now transitioning away from licenced water modelling software to open source platforms based on a combination of cost and a desire among students to have universally transferrable modelling capacity (i.e., not reliant on organisational software licences to use water models). Many small consulting organisations have also adopted this approach. Many organisations identified this as an issue that would benefit from further discussion within the modelling community. This is a potentially important factor when considering how future models will be developed and used along with the concurrent development of workforce capacity. It also might present challenges for mature modellers and managers who may need to transition from one modelling platform to another if an open source rival displaces an well used licenced model.

3.4 Other issues

The interview process also identified a number of additional issues that were of importance to members of the modelling community. These included:

- ***QWMN links with small consulting organisations*** – It was noted that there is a large and vibrant set of small consulting organisations that are not currently engaged with the QWMN or its activities. Specifically the urban water, stormwater and water sensitive urban design communities appear to be under-represented in QWMN activities. This could be due to the nature of the sector where specialist modelling groups need to protect niche areas and for which information sharing does not make business sense. It was suggested that this issue could be further investigated.

- ***Stochastic modelling*** – Many organisations noted that, while there is a growing recognition of the advantages of stochastic modelling approaches and an increased demand by users of model data for information developed from these approaches, stochastic modelling is not covered in great detail in most undergraduate training programs within many university systems (introductory concepts only). This in turn has the potential to create a gap in the skills of the graduate modelling workforce into the future.

- ***Broader awareness among graduates is missing*** – A trend of decreasing awareness of the influence of broader socio-economic, political and policy developments on water modelling activities was reported by many interviewees. There was a perception among those interviewed that new graduates appear to lack an awareness of political processes, their influence on policy and regulation and therefore the place of water models in decision making frameworks. Interestingly there was no consensus as to whether building this awareness was a role best suited to education providers or other parts of the water modelling and use sector.

- ***Data availability*** – Despite widespread agreement among nearly all organisations and sectors on the urgent need to make monitoring and model-derived data easily available to the whole water modelling community, it is recognised that there are still substantial challenges for data access for modelling projects. In many instances the time delays associated with accessing data make the data effectively useless (i.e., in many instances relevant data is not able to be provided in time to be considered by a given project or decision making process). All sectors of the water modelling community have expressed an urgent need to develop effective on-line data repositories that are easily accessible by all potential users in the water modelling profession.

3.5 Workforce development workshop outcomes

The outcomes of the November 2018 QWMN workshop on modelling workforce capability development reinforced many of the views expressed during the interviews (refer to McIntosh and Gibbes, 2018). In summary there is no one system or undergraduate degree that provides an optimal background for water modelling professionals. Furthermore many stakeholders have observed that the diverse backgrounds of the professionals that comprise the current water modelling community is one of its greatest strengths. If anything there was a suggestion that there might be an over-representation of "engineering hydrologists" in the community and that encouraging professionals from more diverse training backgrounds (e.g., data science often identified) could be beneficial.

Furthermore it is widely recognised that there is currently a lack of a recognised "modelling" degree (either undergraduate or post-graduate) in the Australian system. Many workshop and interview stakeholders indicated that development of specific water modelling skills is likely to be more appropriate as a post-graduate activity rather than attempting to develop a dedicated undergraduate program. That is there is a need to develop fundamental skills in mathematics, statistics and physical sciences though existing undergraduate programs first before these skills could be extended to include specific water modelling concepts.

Notwithstanding this point it was noted that the apparent trend towards decreasing knowledge of the basic processes of model development, calibration, scenario simulation and evaluation of outputs could be effectively addressed in many existing undergraduate programs. The workshop and interviews also clearly identified that all active participants in the current water modelling workforce were motivated to enter the sector by a desire to make a positive contribution to the way our society uses and manages water systems. This universal motivating trait could be better used to attract and encourage new people to the sector.

3.6 Analysis of on-line survey results from collected at QWMN forum

Survey results for 35 individuals were analysed and grouped into key themes in terms of issues that attract people to a career (61 comments) in water modelling as perceived issues or problems (45 comments) associated with the water modelling profession. Results for themes that attracted responses from more than 5% of survey participants are summarised in table 3.1.

Table 3.1 – Key themes identified in an on-line survey of attendees of the QWMN forum in February 2019

Attractions	Responses [%]	Challenges / problems	Responses [%]
Impact	45.7	Complexity & technical difficulty	28.6
Variety of work	34.3	Lack of societal awareness	25.7
Security of employment	28.6	Security of employment	22.6
Intellectual challenge	22.9	Model uncertainty	14.3
Professionalism of the sector	22.9	Remuneration	8.5
Climate change analysis	11.4	Inadequate models	8.5

These results suggest that the key perceived attractors for a career in water modelling include (in order of highest to lowest response rate):

- ***Impact*** – An opportunity to make positive contributions to the way water resources and aquatic systems are designed and managed. Respondents see a career in water modelling as a mechanism to have a positive impact on society and its approach to environmental management.

- ***Variety of work*** – The diversity of opportunities within the water modelling sector, including the ability to use different types of model and/or work on projects that address different issues or bio-physical systems was identified as contributing to overall job satisfaction.

- ***Security of employment*** – The water modelling sector is perceived as a growth area in both the short and long terms.

- ***Intellectual challenge*** – The development of the diverse range of skills required for a career in water modelling, from advanced mathematics to bio-physical process understanding to communication of large data sets with high levels of uncertainty is seen as a significant intellectual challenge. This challenge is reported as an attractive feature of the sector.

- ***Professionalism of the sector*** – Responses indicated that a perceived high level of professionalism and integrity among those operating in the sector combined with good support networks for professional advice and development made a career in the sector attractive.

- ***Climate change*** – A perception that a career in the sector will provide opportunities to further develop personal expertise in climate change and climate change adaption which in turn is seen as an intellectually interesting and high demand set of skills and knowledge (interpreted as a factor that improves employment prospects into the future).

The results presented in table 3.1 also suggest that the key perceived challenges or problems associated with a career in water modelling include (in order of highest to lowest response rate):

- ***Complexity and technical difficulty*** – A successful career in the sector requires multi-disciplinary knowledge across a range of technically demanding fields along with the ability to apply this knowledge to complex environmental system. This is perceived as a significant challenge to success in the sector.

- ***Lack of awareness in broader society*** – Responses indicated that the current lack of awareness and/or recognition of the value of water modelling (potentially stemming from a need for better communication and engagement) by decision makers, policy developers and broader society is currently limiting the potential of the sector. This suggests issues linked to a perceived lack of respect for water modelling (and by association water modellers) may be seen as a negative aspect of a career in this field.

- ***Security of employment*** – Concerns over the short-term contract nature of work in the water modelling and use sector. This was particularly associated with comments about careers in research and higher education organisations rather that the sector as a whole. Comments on security of employment (or a perceived lack thereof) was also linked to comments about a lack of opportunity to further develop skills and knowledge (in unspecified areas – not necessarily modelling) when working within the sector.

- ***Model uncertainty*** – Challenges associated with incorporating uncertainty in models and communicating the meaning of uncertainty in results to decision makers.

- ***Remuneration*** – A perception that remuneration was low relative to the diverse and complex set of skills and knowledge required for a successful career in the sector.

- ***Inadequate models*** – A perception that some models are not fit for purpose which in turn is linked to issues of trust in models and model outcomes. The relationship between these factors and the future growth/employment opportunities of the water modelling and use sector appears to be an issue of concern.

Figure 3.1 – Word cloud showing key themes identified in survey responses about the attractive and challenging features of a career in water modelling.

The survey results also suggested that the majority of respondents were interested in pursuing a career in water model with the majority indicating they envisage a career working with information developed by models rather than a model delivery role (refer to figure 3.2).

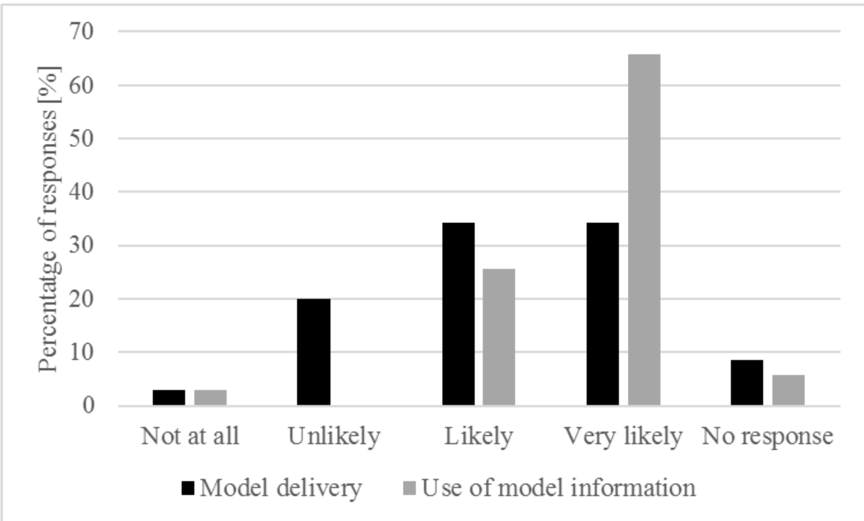

Figure 3.2 – Proportion of survey respondents that indicated their preference for pursuing a career in either delivery of models and model output and/or use of model information in their future career.

4. Discussion

4.1 Issues associated with approach and methodology

Overall the interview methodology and stakeholder workshop produced a wide range of valuable information and feedback. In hindsight the project team was overly optimistic about the ability to schedule and complete all of the planned one-on-one interviews within the project timeframe. This resulted in substantial delays to the project. Notwithstanding this limitation the decision to use one-on-one interviews appears to have been well suited to the overall project aims and the methods used do not appear to have created any issues that limit the intended use of the information and data collected. It was apparent that there was an enthusiasm among the water modelling community to have these types of conversations about workforce development and, if more time and resources were available, it is likely that there would be no shortage of individuals willing to provide feedback.

It is acknowledged that the information collected from these interviews will include biases introduced by both the interview question design, use of notes as a primary recording mechanism and the subsequent interpretation of these notes by the research team. To address this potential source of bias in future work it is suggested that the use of video/audio recording of interviews combined with the application of one of the emerging software systems for un-biased analysis of interview transcripts (e.g., QSR International's NVIVO system or similar) should be explored. This methodology would provide a mechanism to reduce potential bias introduced by the interview questions and the use of written notes as the basis for grouping concepts and gaining insights from the interview data.

Furthermore it is acknowledged that the methodology used resulted in a smaller number of responses from the "pure client" (i.e., users of model-derived information only) category. Preliminary analysis and feedback from individuals and groups that operate in this category suggests there are some unique and specific knowledge and training requirements for these types of roles that are not being met by the current training system. Specifically the activities of this group are characterised by complex multi-disciplinary tasks that are heavily linked to policy and regulatory frameworks. As such they require a level of experience and knowledge that is different from other roles in the water modelling and use sector. Further investigation of the issues specific to the "pure client" role would be useful to better characterise the current skills and knowledge gaps and emerging issues in this part of the sector.

4.2 Background training

Results suggested that new professionals to the government and consulting sectors are primarily sourced from local undergraduate university programs in mathematics, physics, physical sciences, engineering, planning and architecture. The national university systems appears to be providing graduates with the necessary skills to enter the workforce but there are significant opportunities to enhance the quality of Australian-trained graduates. Specifically there is a need to improve graduate capacity in mathematics and the physical processes that underpin water movement through the landscape as well as biological, chemical and ecological process. Furthermore the identified lack of graduates and early career professionals with a knowledge of the policy and regulatory frameworks in which water modelling outputs are used. There are also a broader set of skills such as critical thinking, problem solving, communication, coding and data analysis, that require improvement to meet both the current and the emerging challenges in the field of water modelling.

A preliminary analysis of potential responses to these issues suggests that the diverse nature of the issues combined with the timeframes that are required to acquire sufficient knowledge and skills in these area would make development of a targeted undergraduate training program (i.e., a new water modelling degree) unfeasible. This seems to suggest that the development of a recognised post-graduate coursework program in "water modelling" (or even a broader environmental modelling) in the Australian system should be explored in more detail.

Whilst potentially presenting an exciting opportunity it is unclear as to whether there is a sufficient local student market to support such a post-graduate program. Clear feedback from all areas of the sector indicated that specific training in water modelling is likely to be more appropriate as a post-graduate activity rather than attempting to develop a dedicated undergraduate program. Based on the feedback received through this project the investigation of options to address this gap appears to be warranted. Options identified by respondents that could be explored include work-based modes of learning, continuing professional development (CPD) course offerings and collaborative micro-credential systems as well as a dedicated post-graduate training program. Examination of methods to better utilise the apparent intrinsic motivation of professionals in the modelling workforce to make a positive contribution to the way our society uses and manages water systems and its role in attracting new recruits to the sector appears to be warranted.

Some interesting ideas about the use of an innovative hybrid model that draws on the expertise in all areas of the sector (consulting, government, research/higher education) to develop and deliver a bespoke training program that directly responds to the needs of the modelling community were put forward by many stakeholders (55% of interviewees). This could provide an opportunity to improve both technical (e.g., coding, big data analytics, use of novel computing systems) as well as the necessary broader skills (e.g., project management, improved understanding of political, economic, social and regulatory environments in which water models operate) of the water modelling workforce. There was also an implicit attitude that success in any training will require the use of a "learning by story-telling" (also referred to as active learning or problem-based learning in some areas) if these broader skills are to be developed efficiently throughout the workforce. Some training delivery options that might align well with this type of hybrid model include the emerging set of innovative micro-credentialing schemes that could allow training modules to contribute to post-graduate qualifications or industry-based accreditation systems such as those that operate in various areas of the science and engineering professions.

Investment in internships was identified by a majority of stakeholders (70% of interviewees) as one mechanism that has been used in the past to facilitate the development of some of the broader skills listed in section 3.1.2 (items a-g). In particular an internship program that allows both new graduates and mid-career professionals to gain experience in the government sector was identified as valuable for the ongoing development of the water modelling workforce for a range of reasons. In particular this would provide an opportunity for professionals to develop the broader awareness, multi-disciplinary knowledge and familiarity with policy and regulatory frameworks that are highly regarded across the whole sector and in particular in the model client category.

The heavy reliance of the research and higher education sector on internationally trained personnel to fill all modelling positions, from research higher degree to post-doctoral research fellows as well as teaching and research academics, was a cause of concern among many practitioners from all sectors. This appears to stem from the reduced mathematical capability of Australian-trained graduates compared to those from European, Russian and Asian-based training systems. In the longer term this suggests a need to engage with both secondary and tertiary education providers to address this apparent “fear” of mathematics. It was noted by most stakeholders that proficiency in mathematics is necessary for success in the sector and therefore students should be encouraged to develop the proficiency early rather than avoiding it.

4.3 Communities of practice and mentoring vs formal training opportunities

The use of communities of practice (CoP), both internal within organisations and between multiple organisations, was clearly identified as the single most useful mechanism for the ongoing development of skills within the water modelling sector (85% of interviewees with consistent results across all categories). The role of mentors within these CoPs was also viewed as critical to their success (75% of interviewees). While this finding is interesting it is unclear as to whether these types of CoPs could be enhanced through strategic sector-wide support. Specifically it is unclear as to whether it is the demand-driven process that has led to their establishment and success within organisations can be replicated more broadly. These ideas warrant additional exploration with a view to understanding whether the QWMN can contribute to these successful initiatives.

Conversely it could be argued that provision of low-cost or no-cost formal training opportunities in some of the broader skills identified previously such as project management and understanding of political, economic, social and regulatory environments in which water models operate could be complimentary to the more organically-established CoPs. There may be a case for free formal training offered by the modelling community to be recognised as a good investment to enhance the overall capacity and quality of the modelling workforce. Based on the feedback collected in this project there appears to be an opportunity and the appropriate level of enthusiasm to blend skills from across all types of employer (government–industry–research and higher education) to develop and deliver a set of training programs to meet current and future sector needs. Some stakeholders have suggested that this could represent a significant opportunity for innovation led by the QWMN. There appears to be sufficient enthusiasm to explore these concepts in more detail.

4.4 Workforce succession planning and model custodians

Succession planning for the water modelling workforce was identified by many stakeholders as an issue of concern in the government and research and higher education sectors. Specifically there is concern over the ability to transfer the organisational knowledge of how certain models have been used as well as why they are used in certain situations. This is quite critical in some government organisations where there is a requirement to maintain specific models as they form that basis of regulatory decisions and planning documents.

While the specific succession planning needs are likely to vary between groups it was apparent that there is an opportunity to develop more formal model custodian roles that could facilitate this process. These roles could sit within an individual organisation or could be more widely distributed across the modelling community. There is a view that there could be significant advantages in distributing these roles between the different sectors of the modelling community (i.e., government, consulting, research and higher education). There is also scope for linking custodian roles with sector-wide internship or staff-exchange schemes as a mechanism to distribute knowledge and capacity among the modelling community (and in theory making the community and its transfer of knowledge more resilient).

Given the frequent identification of workforce succession planning as an issue in multiple organisations there may be scope of the QWMN to investigate the advantages and disadvantages of a model custodian arrangement that is based within the modelling community to facilitate resolution of some of the succession planning concerns raised by stakeholders.

5. Conclusions and recommendations

Information on the current recruitment practices and ongoing skills and training needs for Queensland's water modelling workforce was developed through a series of one-on-one interviews with selected practitioners across the government, consulting and research and higher education organisations of the sector. Results suggest that the water modelling workforce in Queensland is stable and that there are no immediate or urgent issues in the areas of training and skills development that are limiting the performance of the sector. New professionals to government and consulting organisations are primarily sourced from local undergraduate university programs in mathematics, physics, physical sciences, engineering, planning and architecture. The national university systems appears to be providing graduates with the necessary skills to enter the workforce but there are significant opportunities to enhance the quality of Australian-trained graduates. However there were reported challenges in recruitment of suitably qualified candidates from the Australian training system for entry into research/University positions, there were no reports of a graduate skills or knowledge shortage in the Queensland (or national) water modelling and use sector. This project did identify a shortage of early to mid-career professionals that have suitable experience in the technical aspects of modelling and the broader policy and regulatory frameworks in which model-derived information is used. This appears to be particularly acute in the client category (c.f. model provider category) of government organisations.

The dominant mechanism for providing ongoing training and skills development within the sector is via internal communities of practice (CoP) that exist both formally and informally within organisations and between organisations within the same sector. These CoP are characterised by a readily identifiable practice leader or champion, an internal "best practice" document and the extensive use of mentors. Many CoP also make extensive use of on-line systems for sharing information and solving problems. The use of short courses offered by external training providers (e.g., software developers) as a mechanism for training the modelling workforce was reported to be in decline.

A wide range of emerging issues were identified with a need to better develop the programming, data analysis and visualisation/communication capacity of the workforce – particularly for working with "big data" highlighted as a key need. A need to improve the sector's approach to succession planning for the modelling workforce was also identified. More broadly, while the Queensland water modelling community is well positioned to take advantage technological innovations to improve capacity, there is a widespread need for additional investment in the science that underpins the models that are applied right across the sector.

Issues specific to each of the different types of employer organisations and provider-client categories of the water modelling and use sector that were identified through this project are summarised in the following sections.

5.1 Government organisations

The results of this project suggest that government organisations of the water modelling industry is characterised by a diverse range of modelling capability and a reasonably even age structure. Government organisations appear to be making good use of informal communities of practice and appears to be leading the upskilling of its workforce in emerging areas such as coding, data analytics and data assimilation. This is despite the apparent challenge of irregular investment in modelling workforce recruitment that in turn inhibits the adoption of a more systematic approach to workforce development. Related issues of succession planning and knowledge transfer were also expressed as a key concern of leading professionals in this category of employer organisation. There is also an apparent lack of professionals with suitable experience across the combined areas of technical competency in model application and broader knowledge of the policy and regulatory environments in which model-based information is used. The strategic use of internships at both the early and mid-career level combined with collaboration with consulting and research/higher education organisations to develop innovative whole-of-sector training opportunities has been suggested as a mechanism that could address many of these issues. The feasibility of these ideas warrants further investigation.

5.2 Consulting organisations

Overall the results of this project suggest that consulting organisations are the dominant recruiter of new graduates to the water modelling profession and have developed effective mechanisms to fill knowledge and skills gaps in undergraduate training programs. This group of employer organisations has made effective use of internal communities of practice and mentoring systems. A key area for further investigation identified by many consulting organisations is the need to develop mechanisms to retain early (i.e., > 5 years' experience) to mid-career staff once they have developed capacity in water modelling. As with government organisations the strategic use of internships at both the early and mid-career level combined with collaboration with the government and research/higher education sectors to develop innovative cross-sector training opportunities has been suggested as a mechanism that could address many of these issues.

The competitive business environment that characterises the consulting market also appears to be presenting barrier to collaboration in some areas. Specifically there appear to be opportunities to enter into collaborative arrangements with other consulting organisations as well as the government and research / higher education organisations to share the costs associated with adaption of water models to emerging computational architectures (e.g., GPUs) and systems that allow closer client-model interactions (e.g., browser based water modelling and data analytics). The feasibility of these ideas warrants further investigation.

5.3 Research and higher education organisations

This category of employers within the water modelling and use sector is characterised by an age profile that is skewed toward mid-career and late-career professionals. There is a reported lack of opportunity for continuing positions for early-career professionals. Furthermore the sector experiences challenges in recruiting Australian-trained candidates to fill research higher degree and post-doctoral research roles. In the area of undergraduate research and training there are substantial pressures that are resulting in a reduction in opportunities to offer effective training in the fundamental mathematics, bio-physical science, computational science and data analysis required for advanced water modelling. There is also a lack of information about the potential market and viability of a recognised post-graduate coursework offerings specialising in water modelling. These issues appear to be sector-wide which suggests there are opportunities for collaboration both within this category of organisations and also with government and consulting organisations to establish mechanisms to address these issues in a manner that meets the expectations of the whole sector.

5.4 Model provider organisations

The dominant category from which information and advice was developed for this project was the model provider category. This section of the water modelling and use sector appears to be robust with few significant knowledge, skills and training risks identified. A key challenge for this category is how to best adapt to new computational approaches in a cost-effective manner. There is a view that the current approach of individual organisations carrying the cost of research and development could be improved.

This category of the water modelling and use sector also identified an urgent need for additional investment in the science that underpins the models that are applied right across the industry. This is needed to ensure continual improvement in modelling capacity and outputs. Specifically, improved knowledge of the processes that drive water and water quality in natural systems is needed so that models can be advanced and trust in model-derived information is maintained and enhanced in the broader socio-economic system.

5.5 Model client organisations

The model client category is one of the most challenging categories of organisations in terms of skills and knowledge requirements. Recruitment of staff with requisite skills in technical aspects of modelling combined with an understanding of the broader policy and regulatory frameworks in which model-derived information is used is challenging. This is particularly due to the extended time frames that are involved in developing this expertise. As such this category is unique in experiencing acute challenges in attracting and maintain staff with suitable expertise. When combined with the challenges associated with succession of knowledge and sporadic investment in workforce capacity is likely to require innovation and careful planning to address. Options to internally up-skill existing staff as well as opportunities to make use of collaborative arrangement with other sectors of the water modelling and use sector (e.g., internships for early to mid-career professionals) could be explored among other options.

5.6 Concluding remarks

Based on the feedback from stakeholders there is a general sense that the Queensland water modelling and use sector has well-established foundations. This base, combined with an apparent enthusiasm in individuals to contribute to the improvement of the workforce, suggests that Queensland is well positioned to develop and deliver a range of innovative training and workforce development opportunities. Specifically this training would be able to directly address the common set of current and emerging needs identified by stakeholders in areas of technical skill development as well as broader understanding of the role of water modelling in policy, regulation and management structures. At the same time this would provide an opportunity to transfer knowledge (both technical and organisational history) from experienced modelling practitioners to the next generation of water modellers. These aspects warrant further consideration and investigation.

Finally there is also a sector-wide recognition that there are still substantial challenges in access data for modelling projects. In many instances the time delays associated with accessing data make the data effectively useless (i.e., in many instances relevant data is not able to be provided in time to be considered by a given project or decision making process). All types of organisations within water modelling and use sector have expressed an urgent need to develop effective on-line data repositories that are easily accessible by all potential users in the water modelling profession. How to best respond to these issues warrants further consideration and investigation.

5.7 Recommendations

Through the development of this report a number of areas were identified that could benefit from additional examination as part of the QWMN's response to this skills and knowledge audit. Some key points (in no specific order) include:

- Modelling activities in broader context – Analysis of audit results suggests there is a need to improve the water modelling workforce's broader knowledge of the policy, regulatory and socio-economic environments in which model-based information is used. This also includes elements of succession planning and knowledge transfer (i.e., passing on an understanding of how and why different models have been used to support decisions). There appears to be support among the water modelling and use sector for an industry-wide training and development initiative, potentially embedded as part of future community of practice / mentoring initiatives, to address this gap. Other options including cross-organisation internships for early- and mid-career professionals as well as development of new collaborative training opportunities delivered by consortiums of the consulting industry, government and higher education providers. Different initiatives could be tailored for both model providers and model client groups within the sector with a specific need to focus on the government-client group. These ideas merit further exploration.

- Graduate and early career training – Results suggest there is a need to increase coverage of the basic processes of model development, calibration, scenario simulation and evaluation of model outputs within existing higher education programs. There is a view among many of the interviewees that these universal modelling skills should be embedded within foundation courses in mathematics, statistics and hydrology. There is also a need to develop better prepared domestic candidates for research and higher education roles. Opportunities for collaboration among all organisations within the water modelling and use sector to develop specific post-graduate training opportunities in water modelling could be further investigated. This may also allow a consistent sector-wide approach to developing skills such as critical thinking, teamwork, independence, project management and communication in a water-modelling-specific context.

- Big data challenges – All organisations noted the increased availability of large on-line data sets (e.g., gridded meteorological data from both re-analysis and forecast modelling systems) is driving upskilling of the workforce's capacity to use basic programming (coding) to both access these data and to undertake analysis or conversion of this data into useful information for water modelling activities. Furthermore it is apparent that the water modelling sector does not currently make best use of the many large data sets that are being developed and made freely available in the climate, meteorological and oceanography communities. There may be opportunities for a sector-wide approach to addressing both the need for improved programming (coding) capacity within the workforce as well as developing methods for integrating and analysing information across different modelling domains.

- Foundation science – The water modelling sector clearly identified a need for additional ongoing investment in the science that underpins the models that are applied right across the industry. This is essential for continual improvement in modelling capacity and outputs. Improved knowledge of the processes that drive water and water quality in natural systems is needed so that models can be advanced and trust in model-derived information is enhanced in the broader community. It is suggested that future water modelling workforce development initiatives also include specific consideration of mechanisms for investing in foundation science and data collection.

- Data sharing and access –There is a sector-wide recognition that there are still substantial challenges in access data for modelling projects. In many instances the time delays associated with accessing data make the data effectively useless. All organisation types within the water modelling community have expressed an urgent need to develop effective on-line data repositories that are easily accessible by all potential users in the water modelling profession. How to best respond to these issues warrants further consideration and investigation.

- Future audits – Initial feedback from stakeholders involved in the process of collating and analysing information for this project indicates there is enthusiasm for this type of activity to be repeated periodically. This could provide a valuable mechanism for the water modelling and use sector to systematically identify emerging issues and challenges within the sector. It is recommended that further investigation of potential approaches and the frequency of future audits be considered.

Acknowledgements

The authors gratefully acknowledge the interviewees who generously contributed their time for both the interviews and subsequent follow-up questions as well as the providing review comments on this report. Similarly the input of the attendees at the November 2018 workshop and the water modelling professionals that completed the online survey for the February 2019 networking event is appreciated. The support, advice and valuable feedback from the QWMN project steering group and other stakeholders including Jean Erbacher, Paul Lawrence, Jenny Riches, Sarah Stevens, Ian Gordon, Evan Thomas, Frederick Bennet, John Ruffini, Rhiannon Tooker and Piet Filet was much appreciated. This research was supported by funding provided as part of the QWMN External Engagement Program.

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<u>Appendix A – Terms of reference for skills and knowledge audit</u>

Summary

A key task of the Education Research and Training (ERT) component of the Queensland Water Modelling Network (QWMN) External Engagement Program is to undertake a water modelling skills and knowledge audit to characterise both current and future water modelling workforce needs along with the full range of current formal education and training opportunities of relevance to those needs within Queensland. This document provides an overview of the draft terms of reference (ToR) for this skills and knowledge audit. The draft ToR have been developed based on discussions with the project team at the ERT workshop on 9 August 2018 as well as initial feedback from the Queensland Department of Environment and Science. The draft ToR are provided to allow feedback from stakeholders prior to commencement of the audit.

1. Terms of Reference

Overarching Scope – The skills and knowledge audit will seek to characterise both current and future water modelling workforce skill and knowledge needs along with the full range of current formal education and training provision by Universities and other relevant organisations within Queensland. The audit will also attempt to identify informal training activities including in-house courses and online communities that are currently used within the industry.

Key Project Phases – The audit will comprise three key phases: i) Initial data collection; ii) Evaluation of initial findings via a workshop/forum; iii) Review and reporting. The scope of each of these phases is outlined below.

Phase 1 Data Collection – A series of structured short interviews with selected modelling practitioners from the five broad sectors of the water modelling industry: i. State Government agencies; ii) Local Government agencies; iii) Large consulting organisations; iv) Small consulting organisations; and iv) Research and higher education organisations will be used as the primary mechanism for collating data on current water modelling workforce skill and knowledge needs. Where possible small groups of practitioners from each sector will be interviewed together. An adaptive approach will be used with the interviews with a view to expanding the list of interviewees based on recommendations for the initial set of interviewees. The audit will specifically avoid using workshops. A workshop/forum will form part of the second phase of the project.

Phase 2 Stakeholder Workshop/Forum – The initial findings from the data collection phase will be evaluated via a workshop scheduled as part of the QWMN 2018 Forum. The aim of this workshop will be to map out career water modelling pathways in QLD and to identify key workforce challenges in terms of recruitment and retention, skills, knowledge and capability. The Forum will provide an opportunity to both validate initial results and extend insights into workforce and career challenges and development needs.

Phase 3 Review and Reporting – The focus of the audit will be on skills and knowledge for developing, using and interpreting water models and their outputs. A written summary of the skills and knowledge areas along with a summary of any current gaps will be recorded. In doing so the skills and knowledge needs for building and maintaining whole of sector workforce capability will be captured. This information will be presented in a written report that will undergo at least one round of review and comment by the project steering committee (and the broader set of QWMN stakeholders if deemed appropriate). A final report will then be submitted as per the program implementation plan (12/12/18), accompanied by presentations and/or workshops as deemed appropriate for the communication of the project outcomes.

Key Stakeholders – In the first instance interviews will be held with a sub-set of the participants of the QWMN Technical Forum held 14-15 November 2017 (see following section for list). Part of the interview methodology will ask interviewees to nominate additional members of the modelling community for interview. The project team will liaise closely with the QWMN project team from Queensland Government Department of Environment and Science to progressively update the interview list as the project evolves. This audit will focus on modelling practitioners and will not specifically attempt to engage with the wider set of professionals that use the outputs of models for various purposes. Engagement with users of modelling information constitutes a separate follow-on project to the skills audit.

Geographic Scope – The audit will focus on the current or likely future skill and knowledge gaps in the Queensland water modelling industry – these gaps will be identified through the interview process by asking interviewees from across the industry based on their organisations experience and workforce planning insights. Where appropriate information will be sourced from national and international leaders in water modelling however the primary focus will be an assessment of the views of Queensland-based practitioners. As part of this process, the relative position of the Queensland-based industry to national and international leaders will be assessed with a specific view to understanding what would be required for Queensland to become recognised as a global centre of excellence.

Methods to address future skill and knowledge gaps – The audit will also seek to identify how best to fill current or likely future skill and knowledge gaps in Queensland using a range of organisations and mechanisms to ensure sustained workforce capability. This will include consideration of both formal and informal methods as well as an assessment of the current capability of the existing modelling community to build the required workforce capability.

2. Draft List of initial phase 1 interviewees

Commonwealth Government Organisations

Peter May – Director, Science to Services, Science and Innovation, Bureau of Meteorology,

Dr Amgad Elmahdi – Head of Water Resources Section, Bureau of Meteorology

State Government Agencies and Associated Organisations

Chas Egan – Hydrologist, Queensland Hydrology Science Division, Department of Environment and Science

Robin Ellis – Principal Scientist (Modelling) Soil and Land Resources Science Division, Department of Environment and Science

David Waters – Principal Scientist, Department of Natural Resources, Mines and Energy

John Ruffini – Director, Water Planning Services, Science Division, Department of Environment and Science

David Wiskar – General Manager, Water Policy, Department of Natural Resources, Mines and Energy

Sanjeev Pandey, Office of Groundwater Impact Assessment, DNRME

Local Government Organisations

Adam Berry - Director, SynergysTBA? INPUT NEEDED

Ouswatta Perera – Senior Engineer, Flooding and Planning, Natural Environment, Water & Sustainability Branch, City Planning and Sustainability Division, Brisbane City Council

Mark Askins – Team Leader, Water Supply Modelling, Seqwater

Rob Fearon – Water Directorate, or President of Australian Water Association, Qld Branch??

Large consulting companies

Dr Michael Barry – Technical and Innovation Manager Market Lead – Water Quality BMT WBM Pty Ltd

Ed Beling – Principal, BEng (Civil) MSc (Marine Science) MIEAust CPEng RPEQ Intrawater Pty Ltd

Peter Comino – Lead Water Resources Engineer, Cardno

Small consulting companies

Blake Boulton – Water modelling solutions

Tony McAlister Director – WATER TECHNOLOGY

Dr Nick Marsh – Managing Director Truii

Dr Joel Stewart – Director, Catchment Research Pty Ltd

Tony Weber – Alluvium Consulting Fortitude Valley, Brisbane

Sophie Buchanan – Senior Stormwater Engineer, Innovyze

Cedric Robillot - Great Barrier Reef Foundation

Research and Higher Education Organisations

Prof. Ashantha Goonetilike – QUT

Dr Mike Hertzfeld – CSIRO Marine Laboratories

Professor Peter J Mumby – Marine Spatial Ecology Lab, School of Biological Sciences, Goddard Building, The University of Queensland

Dr Kate O'Brien – Associate Professor in Chemical-Environmental Engineering, School of Chemical Engineering, The University of Queensland

Nigel Ward – eResearch Manager, Queensland Cyber Infrastructure Foundation

Professor Bofu Yu – Head of School of Civil Engineering at Griffith University

It should also be noted that members of the QWMN External Engagement Program (EEP) will also be interviewed as part of the internal implementation of the project by the project team. This includes Professor Peter Grace (QUT), Professor David Hamilton (Griffith), Mark Pascoe (IWC), Dr Keith Pembleton (USQ), Dr Lucy Reading (QUT) and Dr Barbara Robson (JCU).

Appendix B – QWMN Skills and Knowledge Audit: Framework questions for interview

Summary of material sent to potential interviewees and which formed the basis of the interview.

Introduction – Forms part of the initial email sent

The Queensland Water Modelling Network (QWMN) is undertaking a skills and knowledge audit to characterise both current and future water modelling workforce needs along with the full range of current formal education and training opportunities of relevance to those needs within Queensland. You have been identified as a key contact person to be interviewed as part of the audit. If you agree to participate, I will arrange a time to meet for a short (30-40 minute) interview to discuss your views on the current and future needs of the water modelling workforce. Your input will be anonymous and will contribute to a written report that will summarise the outcomes of the audit.

Key areas for discussion

1. Historical approach to workforce development

- What are the types of water modelling that your organisation is currently involved with?
- How do you currently recruit staff for water modelling roles in your organisation?
- What specific skills or background knowledge is of most importance when recruiting staff to water modelling roles?
- What is the age profile of your current water modelling workforce?

2. Current training systems and opportunities

- Do you run internal training in any area of water modelling?
- Do your staff attend training provided by external organisations (software providers, industry organisations, universities)?

3. Emerging issues

- Are there any emerging issues that you anticipate will impact on your water modelling activities?
- Do you have strategies in place to address these emerging issues and if so are you interested in partnering with other organisations?
- Are there any specific recommendations that you would make for improving the water modelling workforce within Australia?

Appendix C – Summary of on-line survey questions used in analysis

Responses from four questions from a seven question on-line survey of attendees at a QWMN networking function for young professionals held in February 2018 were analysed to identify key themes.

The selected questions included:

What do you see as being the main attractions or upsides associated with employment in water modelling in QLD – either as a modeller or a professional who uses water modelling information in other roles?

What do you see as being the main problems or downside associated with employment in water modelling in QLD – either as a modeller or a professional who uses water modelling information in other roles?

How likely are you to pursue water modelling in QLD as a main part of your career?

How likely are you to pursue a career where the use of water modelling information would be an important component?

Open format text responses were received for the first two questions. The second two questions allowed the user to select from the following responses:

Poor (categorised as “not at all”)
Low (categorised as “unlikely”)
Moderate (categorised as “likely”)
High (categorised as “very likely”)
No response

Appendix D – List of contributors

Structured interviews

Dr Michael Barry, Senior Principal Engineer, BMT

Mr Tony Weber, Practice Leader, Alluvium

Mr Tony McAlister, Director, Water Technology

Mr Ed Beling, Director, Intrawater Pty Ltd (also commenting on past experience at Arup)

Dr Chas Egan, Senior Hydrologist, Queensland Hydrology

Dr Mike Herzfeld, Group Leader, CSIRO Marine Research

Professor Ashantha Goonetilleke, Professor – Water and Environmental Engineering, QUT

Professor Bofu Yu, Professor – Civil and Environmental Engineering, Griffith University

Professor Peter Mumby, Professorial Research Fellow, The University of Queensland

A/Professor Kate O'Brien, A/Prof Chemical & Environmental Engineering, The University of Queensland

Mr David Waters, Principal Scientist, Catchment Modelling, QDNRM

Dr Chantal Donnelly, Group Leader, Water Resources, Australian Bureau of Meteorology

Mr Ian Gordon, Director – Water Operations Support, QDNRME

Dr Nick Marsh, Managing Director, Truii

Mr Rob Ellis, Principal Scientist (Modelling), QDES

Mr Adam Berry, Director, Synergys (also commenting on past experience at Ipswich City Council)

Mr John Ruffini, Director – Water Planning Services, QDES

Mr Ouswatta Perreira, Senior Engineer, Water and Sustainability Branch, Brisbane City Council

Dr Paul Maxwell, Principal Scientist Research and Monitoring, Healthy Land and Water

Dr Ian Ramsay, Science Leader – Environmental Monitoring and Assessment, QDES

Professor David Lockington, Chair in Hydrology, The University of Queensland

Mr Daniel Sheehy, Senior Environmental Engineer, WRM

Non-structured interviews (data not including in analysis – supporting context and ideas used)

Mr Mark Askins, Team Leader – Water Supply Modelling, Seqwater

Professor Tom Baldock, Professor – Coastal Engineering, The University of Queensland

Dr David Callaghan, Senior Lecturer – Civil Engineering, The University of Queensland

Mr James Dowdeswell, Technical Director Hydrogeology, GHD

Dr Phillip Jordan, Principal Hydrologist, Hydrology and Risk Consulting

Mr Jackson Rees, Graduate Civil Engineer, AECOM