ADVICE TO THE NATIONAL WATER REFORM COMMITTEE ABOUT THE NATIONAL HYDROLOGICAL MODELLING STRATEGY (NHMS)

FINAL REPORT

By
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Acknowledgments

I acknowledge and sincerely thank those people who met with me on-line or over the phone or corresponded with me in writing to provide their perspectives and aspirations regarding NHMS arrangements, activities and products. Their comments and suggestions and feedback on an earlier draft Issues Paper and a Draft Report have provided a basis for this Final Report. However, I take full responsibility for the content of this Final Report, which invariably includes my interpretation of what I "heard" from time to time.

Executive Summary

This is the Final Report to the Chair (and subsequently to the members) of the National Water Reform Committee (NWRC) providing a review of the existing and potential future arrangements, activities, and products relating to the National Hydrological Modelling Strategy (NHMS). The NHMS is taken to encompass a description of it endorsed by the NWRC in 2018 (Appendix 1 – "The NHMS will enable the support services and network to help implement, maintain and enhance hydrologic modelling to support better water management across Australia.").

This Final Report builds on independent analyses and feedback from an earlier draft Issues Paper and an earlier Draft Report. The draft Issues Paper collated and summarised perspectives about NHMS arrangements, activities and products from nominated personnel from Commonwealth, State and Territory governments and their relevant agencies, and eWater Ltd, and a small number of knowledgeable and experienced hydrological modelling water utility, private sector and research sector professionals. The Draft Report incorporated feedback on the draft Issues Paper and contained draft Summary Advice, Key Findings and Suggestions for Change.

Key Findings (Further Details in Section 4)

With Governments and others giving consideration to refreshing the National Water Initiative (NWI), it is timely to review and refresh the NHMS, its achievements against its objectives (original and revised) and its future as a key enabler of the NWI.

Based on the discussions undertaken, there is strong support for having a NHMS – the key challenge is to how to make it work most effectively and efficiently. Private sector and research sector stakeholders are also keen to be involved in that conversation with Governments.

The NHMS is broader than the Source integrated modelling system and eWater Ltd, and eWater Ltd is now broader than Source. However, the benefits of having a nationally compatible and coherent hydrological modelling platform and the skilled human capacity around that to inform often complex and contested decisions are compelling. Nevertheless, the NHMS is not just a tool. It encompasses a body of information and knowledge and needs to include necessary data collection and maintenance and have the best available science and hydrology incorporated.

It is generally accepted that the hydrological modelling required for basin-wide water resource planning and river system operations and the like in Australia is complex, and with that complexity comes higher costs than might otherwise be the case, but there are still questions as to whether the current Source Project Agreement (SPA) arrangements are providing best value for money.

What is working well?

The Source modelling platform is seen to be developed to a level where it meets the vast majority of the immediate needs of the Funding Parties to the SPA under the NHMS-Collaborative Heads Agreement (CHA) and may offer benefits to other Governments who are not signatories to the NHMS-CHA nor the SPA, but are now members of eWater Ltd.

The common hydrological modelling platform has helped with communication and understanding and has provided a recognised form of practice which has some "authority". This has assisted not only water resources planning and management but also understanding and defence of some decisions, including in legal settings. However, being completely focussed on validation can pose risks to social licence in modelling which may be mitigated by incorporating an appropriate uncertainty-focused mindset. This involves making judicious investments over time in building understanding about uncertainty relevant to decision-making and in reducing uncertainty where and when it impacts decision-making.

Major functionalities of and documentation for Source for general water resource planning and river operations applications have been developed; tested and stabilised (stability is credibility) and Source has essentially entered the maintenance mode for those functionalities. However, it is recognised that Source (software) development is an on-going work-in-progress, whereby constant updating and potentially enhancement are required to keep it abreast with technology and evolving user needs. In addition, some functionalities have not yet been fully tested so that bug fixing will still be needed for some time. Documentation of some urban system modelling approaches and some Source features also remains incomplete. An example where further integration and development are required is at the Murray-Darling Basin scale.

Formal arrangements for cooperation and collaboration between Australian Governments and a dedicated organisation - eWater Ltd – with a skilled software development team, have greatly helped to achieve these results.

Bespoke one on one contracts with eWater for new software development and enhancements have run very smoothly in the vast majority of instances. Partners realise that what they get out reflects what they put in. These new capabilities in Source, both in the core code and in the form of plug-ins, also can and often do bring benefits to others. However, funding is often needed to generalise the enhancements for broader applications and it is often difficult to obtain funding for that (and, indeed, agree on who should pay).

eWater and others have been successfully exporting Australia's modelling capability in Source and other tools internationally, particularly in the Asia-Pacific region. The Commonwealth Department of Foreign Affairs and Trade (DFAT) has been a key enabler in this endeavour. Facilitating that more broadly is also important for Australia's international modelling capability and credibility.

While there is a useful Source (surface water modelling) community of practice there is no NHMS community of practice per se.

Generally, then, of the six objectives of the NHMS, 2018 (Appendix 1), three objectives – 1 (cooperation and coordination to achieve hydrological modelling capability), 4 (functionality to meet needs) and 6 (capability exported internationally) are largely being met for existing NHMS-CHA and SPA parties. Nevertheless, there is certainly still room for improvement in, and better communication to demonstrate benefits and increase understanding about, each of them.

What is not working well?

Concerns have been raised with respect to:

- Strategic direction and governance;
- Extent and scope of the NHMS;
- Communications and relationships;
- Funding;
- Community of practice; and
- New knowledge.

Many of the matters that are not working well result from or are incidental to a lack of strategic direction for and leadership of the NHMS.

The existing governance arrangements for the NHMS-CHA, SPA and eWater are somewhat convoluted and that adversely affects transparent communication, collaboration, coordination and fully informed and informative decision-making.

eWater seems to have potentially conflicting objectives under the current arrangements: to provide (develop and maintain) a national approach to surface water modelling on a platform; and to be commercially viable (including by selling platform products and competing with the private sector for contracts in some cases). Clarifying and resolving this requires substantially more conversation, analysis and deliberation by Governments, eWater and the private sector.

Despite the recent inclusion of Tasmania and the Northern Territory as members of eWater, and the opportunities that may create, the NHMS itself is not yet fully national. There are also perceptions that Source is the only component of the NHMS and everything else is out of scope. This limits communication and collaboration with others involved in other modelling platforms. This may thwart innovation and opportunities for interoperability that may otherwise be beneficial.

Strategic discussions between eWater and its owners and others about what could and should be the scope of the NHMS products and services beyond what it is now, and how those products and services may be developed and maintained and funded into the future, have not been happening enough. This is not helpful to the NHMS, to eWater and its Government members, nor to industry and the community.

Reuse of operational models to the longer-term planning context limits planning capacity, applicability, and flexibility towards investigating the possible future pathways that may be taken. For viable pathways to equitable and sustainable conditions to be identified, it is necessary for the uncertainty that may affect projected outcomes to be holistically considered and communicated. However, the overheads of the existing Source platform, including in terms of both input/output and operational detail, are considered by some to be too high for this in certain cases, causing, for example, relatively long model runtimes and inhibiting (1) characterisation of model and predictive uncertainty and (2) large basin-scale applications.

Though agreement on the funding for the SPA until 30 June, 2023 has been reached recently, the process has been described as “protracted and painful”. To go beyond June 2023, parties will need to negotiate a new agreement before June 2023. This raises questions about the financial sustainability of the SPA arrangements with associated risks to Governments.

While a broader NHMS community of practice is not established, some jurisdictions, including Queensland, NSW and Victoria, are effectively self-organising their own networks for training, capacity and capability building to good local effect but with limited or no national leverage to date.

Significant new work under the banner of the NHMS in new knowledge, data and information, scientific capability and hydrological modelling capability has been lacking, especially in catchment and water quality modelling. A mechanism is needed to have a meaningful and influential conversation about future research and innovation needs relevant to the NHMS. Without this, opportunities for leveraging of investments and working collaboratively are missed.

Based on the comments above, it is arguable that objective 2 (meeting the hydrological modelling needs of all Governments), 3 (hydrological modelling capacity and avoidance of duplication) and 5 (appropriate funding) of the NHMS are not yet fulfilled. It is also noted that, while a number of the NHMS objectives have not been fulfilled, the States and Territories and other agencies have in many cases improved their own in-house capacity beyond that in existence in 2008.

What future challenges are emerging or may emerge?

Significant challenges include:

- Current and future climate change and consequent implications for hydrology, water security, ecosystem health, and economic, social and cultural well-being;
- Embracing the digital revolution; and
- Trust in the science and the modelling with changing human behaviours and expectations.

Given the challenges, including climate change, faced by Australia currently and in the future, the focus on the water sector is likely to be intensified. Consequently, the community's demand for more transparency and accountability of Governments' decision making will grow. More and more policy development will be required in this space and that needs to be supported by knowledge and technical developments, including hydrological modelling, to assist transparency and accountability.

What further innovations and research could be undertaken?

Sub-section A5.5 in Appendix 5 contains a long list of suggestions for further research and innovation. More work has been done in some areas than others, though there is no real strategy in place under the NHMS. These suggestions have to be considered carefully so as not to adversely impact the workability of the NHMS or the core components and functionality of Source and their continuing delivery.

In May 2021, the Commonwealth Government made a budget commitment to improving modelling capability for the whole Murray-Darling Basin. This includes enhanced and integrated river modelling across the Basin, contributing to more timely, accurate and accessible information on which to base water management decisions. This work could be considered an important sub-set of the future NHMS, meeting priority research and innovation and modelling development needs not only of the Basin, but also with some specific opportunities for transferability elsewhere.

To increase opportunities for innovation, approaches could be investigated to provide a safe space for Governments and other non-Government organisations to transparently engage with

operational model improvements and seeking to reduce uncertainties in an open source environment, without feeling obliged to immediately integrate those improvements into their legal frameworks. The approaches need to give consideration to governance and quality assurance issues, in addition to other matters. The emerging worldwide Open Modelling Foundation may be helpful in these matters and those opportunities should be further investigated.

The recent draft report on the National Water Initiative by the Productivity Commission contains information relevant to the NHMS. Connections also should be made with the work by three Australian Academies so that it is possible to collectively provide recommendations to Government about a vision and institutional settings for water related research and development and a costed strategy to achieve it. It is likely that a NHMS would be an integral part of such a broader water research and development strategy.

Other Matters

Now that Tasmania and the Northern Territory have become members of eWater, eWater membership includes the Commonwealth and all State and Territory Governments, as does NWRC membership. It is now opportune to have a strategic conversation about the NHMS as a truly national strategy and to review eWater's objectives and business model for the future, recognising that the NHMS is not all about eWater and eWater is not all about the NHMS. Whether or not the NHMS-CHA should be amended to include Tasmania and the Northern Territory as signatories, requires that further consideration be given to several matters, including participation in a national community of practice, the broader use or not of Source or other platforms, and the existing Intellectual Property clauses in the NHMS-CHA. Such an amendment could also occur with or without changes to the SPA, though access to Source and any associated costs would be a key issue.

Quality assurance of analytical modelling, including in terms of consistency, repeatability and transparency and clarity in reporting will be important to the NHMS journey. How that could be run nationally and in a suitably advisory, non-competitive way with appropriate governance requires further examination and clarification. As mentioned above, how the Open Modelling Foundation (OMF) progresses may influence future approaches to be taken (e.g. see Appendix 6).

Entities like Infrastructure Australia are interested in the NHMS so they have a frame of reference for decision making – a transparent, evidence-based, repeatable process to describe the risk profile of water sources and water using communities and industries and to evaluate project proposals.

Key Recommendations

Given the above key findings, a number of suggestions for change emerged from the discussions and further analyses. In many instances these suggestions were not necessarily fully mutually exclusive. None of the suggestions on its own would be a "silver bullet", but collectively they could make a difference.

The following key recommendations are made, with further details in Sub-sections 4.4 and 4.5

National Leadership

1. To provide the necessary NHMS national leadership, governance, collaboration and commitment, the NWRC should establish a NHMS Sub-Committee with membership from all NWRC jurisdictions.

2. The NHMS Sub-Committee should establish arrangements for appropriate involvement for eWater Ltd, the Bureau of Meteorology (BoM), CSIRO and Geoscience Australia.

Whether this is observer status on the NHMS Sub-Committee with necessary protocols to handle conflicts of interest and the like, noting that the BoM and CSIRO already have observer status on the NWRC, as does eWater Ltd for NHMS-CHA matters, or some other arrangements, is a matter for detail in the NHMS Sub-Committee Terms of Reference and operating arrangements.

3. In any event, the NHMS Sub-Committee should establish an advisory group of private sector and research sector representatives.

A refresh of the NWI, and membership of eWater now aligning with membership of the NWRC, provides an opportunity for a national conversation about the future direction of the NHMS (and Source, and potentially eWater). There are matters of science and research, product development and maintenance, service delivery (including capacity and capability building), engagement, commercialisation and financial viability to consider. The private sector and the research sector need to be involved in these conversations with Governments.

National Strategy and Work Program

4. The NHMS Sub-Committee should oversee the development and implementation of the NHMS as a **national** strategy, including a prioritised implementation program with tangible milestones and an underpinning, transparent, agreed investment framework, and arrangements for monitoring, reporting and reviewing its implementation.

It is essential that the NHMS actually be made a "strategy" with an implementation plan, i.e. not just a vision and objectives, but include details about the what, the how, the who, the when and the why to get there at what cost for what benefits.

5. The NHMS Sub-Committee should prioritise the implementation program to include further development of modelling capability, appropriately informed by science, in priority areas to be agreed, but likely considering climate change, water quality management, ecosystem response, groundwater/surface water interactions, low flow hydrology, floodplain hydrology, urban water management, socio-economics and the handling of uncertainty, to meet existing, emerging and longer-term future needs.

Community of Practice and Capacity Building

6. The NHMS Sub-Committee should also prioritise the implementation program to include a national community of practice/national hydrological modelling network, with an initial step being collaboration and coordination among the existing jurisdictional networks regarding activities and initiatives, followed by encouragement and involvement of others.

There are lessons and information to be shared across a national "network of networks" from several initiatives that have been undertaken in the last few years in this space by the Queensland Water Modelling Network, the NSW Modelling and Monitoring Hub, and the Victorian Hydrological Modelling Group and possibly others, like the Groundwater Modelling Decision Support Initiative (GMDSI), with considerable Government investment.

7. The national network should not be limited to software developers and modellers, but include policy people, decision-makers, researchers, educators, the private sector and communications/engagement people.

8. National network activities should include developing processes and procedures for enhancing good modelling practice and facilitating and embedding how to effectively do collaborative and participatory modelling.

9. The community of practice should also consider future capacity building including to get junior level people into the water modelling fraternity and ensure that the necessary skills are there for the future. Those skills are not just being able to "push the buttons in models" but rather to also being able to appropriately apply models to help solve problems, communicate well and sufficiently inform and assist decision making.

To find new modellers and upskill junior staff it would be useful to develop a tertiary short course in hydrological modelling, distributed across Australian universities. perhaps at Graduate Diploma level. Water management agencies and the private sector could contribute in-course material and assist with delivery and mentoring. This could also be an integral element of the community of practice, and over time would develop better networks.

<u>New Knowledge and Innovation</u>

10. The NHMS Sub-Committee should inform and facilitate linkages in applied research and innovation to further develop national modelling capability.

The NHMS requires applied research to translate fundamental hydrological, ecological and socio-economic understanding into modelling technology, including Source. This may be best achieved through a close relationship between model developers and those who undertake the more fundamental research on water system behaviour. There is a need for a strategic method (under the NHMS) which links this research to practical use in hydrological models. A key aspect of the NHMS would then be to collate identified research and innovation into the modelling practitioner's space, even if the fundamental research and innovation had been undertaken by others. Funding partnerships in this respect are worth pursuing.

11. The NHMS Sub-Committee should further consider options to provide a safe space for Governments and other non-Government organisations to transparently engage with new knowledge and operational model improvements and seeking to reduce uncertainties without being obliged to immediately integrate those improvements into their legal frameworks. These options should include space for both proprietary and open-source platforms with the necessary governance arrangements and processes to provide quality assurance for regulatory models.

While it may be unrealistic at this stage to expect Source, in particular, to go totally open source, nor for the NHMS to only support open-source platforms or models, there is space for both proprietary and open-source approaches, provided the necessary governance, standards, IP arrangements, documentation, communication and funding mechanisms are in place. Advice is that the universities and others would then come on board and innovate more with an open-source platform that is always developing and to which they would contribute. The Open Modelling Foundation (OMF) is an international developing activity in the direction of open source, community driven software development. Australian modelling organisations could consider whether they would benefit from involvement in the OMF, and under what arrangements.

Communications

12. More regular and effective communication channels should be established and used between the NWRC, NHMS Sub-Committee, the advisory group and the Board of eWater Ltd, as appropriate, to enable strategic alignment and to inform business development and delivery of products and services relevant to the NHMS. At a minimum, a joint strategic discussion should occur at least annually.

13. Through the national community of practice, the NHMS Sub-Committee should support communication and other initiatives to build social acceptance of the use of hydrological models, to build trust in and understanding of what models can and can't do and how that impacts the effectiveness of decision making and implementation of decisions.

These requires modelling agencies to provide more "open access" to their models, and greater transparency about the science, the methods, the data and the assumptions used and the corresponding uncertainties. As mentioned previously, the skills required for this include being able to appropriately apply models to help solve problems, to communicate well and sufficiently inform and assist decision making. These are important to the social licence to operate. Providing greater clarity in the way that models are used and where the benefits and constraints lie can lead to transformative conversations and greatly increased water literacy.

Funding:

14. The NHMS Sub-Committee should re-visit Objective 5 of the existing NHMS which requires that "*Appropriate funding is available to support the implementation, on-going maintenance and enhancement of modelling platforms and to develop a strong community of practice*".

As noted earlier, this objective has not been secured. Difficulty in securing long-term funding for the development and maintenance of Source is one manifestation of this. This needs to be addressed if the NHMS is to succeed in delivering all its objectives.

15. To inform and support that end, the owners of eWater Ltd and its Board should review eWater's objectives and business model for the future, recognising that eWater is not everything about the NHMS and the NHMS is not everything about eWater - the current and emerging NHMS is broader than the current Source and eWater products and services, and eWater's current and emerging products and services are broader than Source.

1.0 Introduction

Following the preparation of a report to its Water Sub-Group (Blackmore and Prosser, 2008), the Council of Australian Governments (CoAG) adopted a National Hydrological Modelling Strategy (NHMS) to help maintain and enhance hydrologic modelling to support better water management across Australia. The broad modelling issues articulated to be addressed by the NHMS originally included:

- A common software architecture for enterprise models;
- Professionally engineered, modern, thoroughly tested and well documented models;
- Common training arrangements;
- Methods and guidelines for model parameterisation, calibration, testing and application;
- Access to significant research capacity;
- Avoidance of duplication;
- Collective involvement in decision making and in investment in the Strategy;
- At least a ten year life to ensure delivery;
- The opportunity for consultants to use the material developed to support their business interests;
- Ability to modify the agenda in the light of new information (Blackmore and Prosser, 2008).

The enterprise models referred to were those used to support the key business or statutory functions of agencies and generally developed to:

- manage water resource entitlements and allocations;
- operate storages, rivers and supply systems;
- forecast future water supply and demand; and
- account for water use.

A key element of the NHMS has been the development and maintenance of a "modern and evolving hydrological modelling platform and support network that meets the current and future water management needs of Australia". This has taken the shape of the Source integrated modelling system (Source). Source is a hydrological modelling platform with water resources planning, operations and forecasting modes.

Following the release of the first version of Source following the end of the eWater Cooperative Research Centre in June 2012, Australian Governments (the Commonwealth, through the Murray-Darling Basin Authority (MDBA), and the Governments of the ACT, NSW, Victoria, Qld, SA and WA - since 2015) collaboratively worked through two National Hydrological Modelling Platform (NHMP) agreements with eWater Ltd (eWater) to support the development and maintenance of Source.

eWater is a not-for-profit, government-owned enterprise (owners being the Commonwealth, through the MDBA, and the Governments of the ACT, NSW, Victoria, Qld, SA and WA - since 2015) with the purpose of continuing the development, adoption and commercialisation of hydrological modelling tools originating from previous cooperative research centres, including:

- eWater Source – the NHMP
- MUSIC (Model for Urban Stormwater Improvement Conceptualisation)
- eWater Toolkit.

In 2018, the Australian governments listed above and eWater signed a NHMS Collaborative Head Agreement (CHA) under the National Collaboration Framework. The primary objective of the NHMS-CHA is to facilitate the efficient and effective collaboration between Australian Governments, eWater Ltd and possibly other parties through various Projects to achieve the broader objectives of the NHMS including for the development, maintenance, enhancement and application of Source (NHMS-CHA, 2018).

The initial term of the NHMS-CHA is five years (to 30 June, 2023). There are two options to renew for five years, with option periods each being five years as follows:

1. 1 July 2023 – 30 June 2028;
2. 1 July 2028 – 30 June 2033.

The parties to the NHMS-CHA may initiate a review any time prior to the completion of the initial term.

The parties to the NHMS-CHA agreed that it be managed by a representative body known as the Management Committee. The National Water Reform Committee (NWRC), consisting of a representative of each Australian (Commonwealth, State and Territory) Government, and currently chaired by a representative of the Commonwealth Department of Agriculture, Water and the Environment (DAWE), has taken on the role of the Management Committee for the NHMS-CHA.

The NWRC has appointed me as an Independent Advisor on the NHMS. My role is to assist the Chair of the NWRC in facilitating the joint governance of the NHMS and NHMS-CHA. Under the direction of the Chair of the NWRC, I am to undertake some or all of the following activities:

i. Develop papers which identify progress, impediments and possible remedies in implementing the NHMS and NHMS-CHA;
ii. Where required, act as a facilitator in joint discussion between partners related to the NHMS and NHMS-CHA;
iii. Canvas and collate ideas and concepts, with funding options related to further innovations and research which could enhance the NHMS, NHMS-CHA and Source development and maintenance;
iv. Carry out any study, investigation or task relating to the NHMS and/or NHMS-CHA assigned by the Chair;
v. Report to the NWRC on matters relating to the NHMS and/or NHMS-CHA.

The key elements of the activities I have been asked to undertake are to:

- Provide written and verbal advice to the Chair of the NWRC suitable for circulation to NWRC members, including for written and verbal reports to NWRC meetings (NWRC 12 held 23 April, 2021 and NWRC 13 proposed 13 August, 2021), which identify progress, impediments and possible remedies in implementing the NHMS and NHMS-CHA;
- Develop a paper which canvases and collates ideas and concepts, with funding options related to further innovations and research which could enhance the NHMS, NHMS-CHA and Source development and maintenance.

This is the Final Report resulting from the above activities.

2.0 Process to Prepare This Final Report

To initiate the review, I prepared for, and participated in, initial videoconference discussions with the MDBA and eWater and an inception meeting videoconference with staff from the Commonwealth Department of Agriculture, Water and the Environment. These helped to clarify and agree the proposed key activity process and timelines, including availability of jurisdictional contacts and reference personnel, availability of previous relevant work and existing documentation, a potential issue identification and review framework, the extent of analyses to be undertaken, and the extent of engagement with others outside of representatives of the parties to the NHMS-CHA.

I accessed several historical documents mentioning the NHMS. These include:

- the original report to the CoAG Water Sub-Group (Blackmore and Prosser, 2008);
- eWater Ltd constitution (eWater, 2012);
- an unpublished internal due diligence review report on the NHMP (MDBA, 2017);
- the NHMS-CHA itself (NHMS-CHA, 2018);
- the two-page description of the NHMS endorsed by the NWRC in 2018 (Appendix 1);
- the Source Project Agreement (SPA), being a specific project of the NHMS-CHA under the National Collaboration Framework (SPA, 2018);
- the SPA Deed of Variation agreed in 2019 (SPA-DoV, 2019);
- the SPA Annual Operating Plan for Financial Year 2021 (eWater, 2020);
- several agenda papers from 2017 to date considered by the NWRC and the Steering Committee established under the NHMP agreement/SPA at their respective meetings; and
- the eWater website – www.ewater.org.au.

Together, these documents amount to hundreds of pages of information that variously outline the NHMS and NHMS related requirements and objectives, descriptions of the NHMP and other models, Source development and maintenance work programs, and the functions, roles, responsibilities, accountabilities, reporting arrangements and other matters pertaining to the governance of the NHMS. These documents reinforce the significant resources and effort that have been invested in the NHMS, NHMP and Source to date, but also the somewhat convoluted governance arrangements.

From early February to mid-March, 2021, I met via teleconference or videoconference with nominated personnel from each party to the NHMS-CHA (being the MDBA; and the Governments of the ACT, NSW, Victoria, Qld, SA and WA; and eWater), the relevant water agency in Tasmania and the Northern Territory (being member organisations of the NWRC and relatively recently agreeing to become members of eWater), the Commonwealth Department of Agriculture, Water and the Environment, and a small number of knowledgeable and experienced hydrological modelling water utility, private sector and research sector professionals to discuss their views and desires, if any, for NHMS arrangements, activities and products. Specifically, discussions involved:

- what is working well and why;
- what is not working well and why;
- what are some suggestions for change (what are those changes, when should they occur, how should they occur, who should undertake them and why should those changes be undertaken in the ways suggested);

- what future challenges may emerge to impact the NHMS;
- what further innovations and research could be undertaken to address those challenges;
- what other matters, if any, should be covered?

Each person involved in the discussion was also invited to provide me with any further verbal or written comments after each meeting. More than 60 people were involved in the 21 separate initial discussions and many discussions were followed up with additional written information and comments.

Information from the above discussions and relevant documents mentioned earlier were collated and summarised to prepare a draft Issues Paper which was sent on 22 March, 2021 to all involved in the initial discussions with a request for feedback by 12 April, 2021. Feedback was received up until 23 April, 2021 from almost all individuals/groups involved in the initial discussions. A short discussion was also held with the NWRC members at their meeting on 23 April, 2021 and information on the draft Issues Paper and the next steps was provided.

The feedback, in addition to further analyses (e.g. see references in Section 6), was then used to prepare a Draft Report, which was sent on 21 May, 2021 to all people involved in the earlier discussions. Where applicable, NWRC members were also alerted to the Draft Report. Feedback on the Draft Report, particularly the draft Summary Advice, Key Findings and the Key Suggestions for Change was requested by 14 June, 2021. A total of eleven sets of written comments were received up until 30 June, 2021.

Feedback on the Draft Report was considered and used to prepare a consolidated list of Summary Advice, Key Findings and Key Recommendations which was then provided to the people involved in the original discussions for any final comments. This list was also discussed with the Source Project Agreement Steering Committee at its meeting on 21 July, 2021. A total of nine sets of written comments were received.

Results from the above activities have been used to prepare this Final Report for submission to and consideration by the Chair of the NWRC and subsequently the NWRC members.

3.0 Description of the Main Elements of the NHMS Arrangements, Activities and Products

3.1 Elements and Objectives of the 2008 NHMS

In the paper to the CoAG Water Sub-Group (Blackmore and Prosser, 2008), it was outlined that the NHMS needed the elements shown in Figure 1 to be effective.

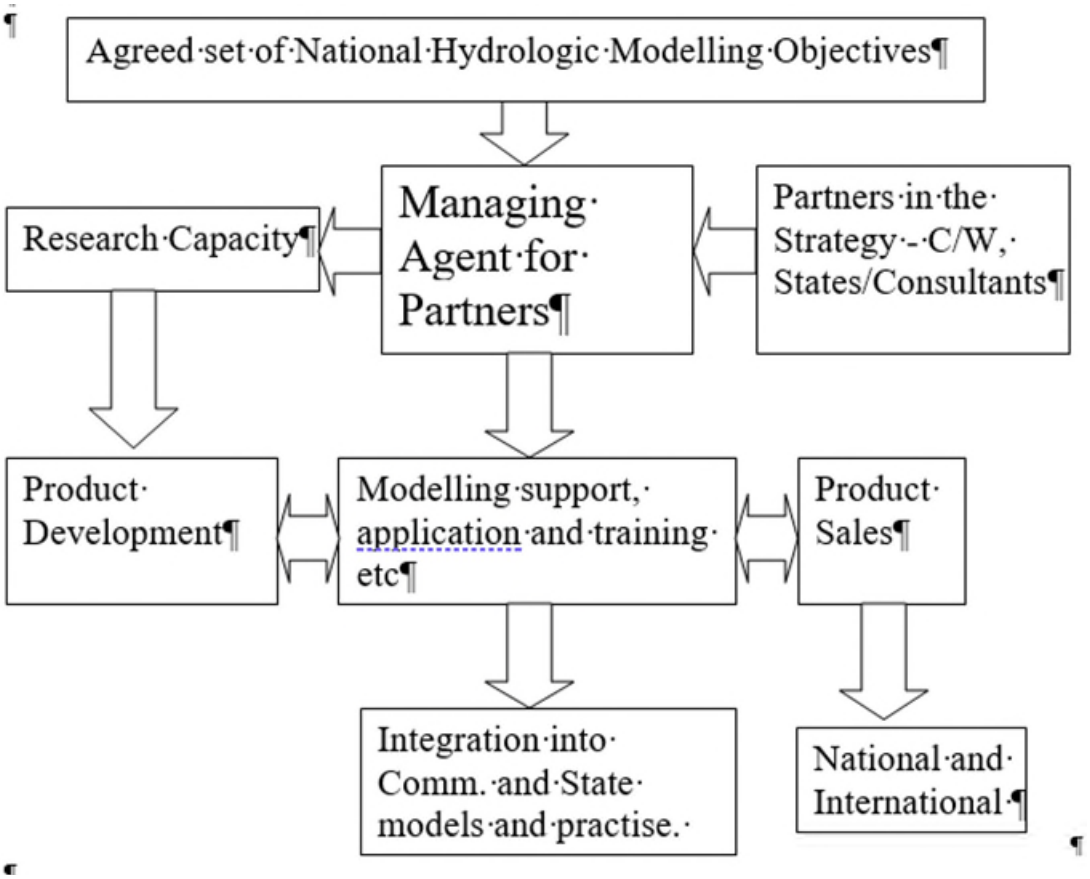

Figure 1 Main Elements of the 2008 NHMS (Blackmore and Prosser, 2008)

Products developed under the strategy were to be made freely available to Government partners.

As mentioned previously, the stated objectives that governed the design of the 2008 NHMS aimed to ensure that the range of issues could be addressed in a well-managed way through:

- Common software architecture for enterprise models;
- Professionally engineered, modern, thoroughly tested and well documented models;
- Common training arrangements;
- Methods and guidelines for model parameterisation, calibration, testing and application;
- Access to significant research capacity;
- Avoiding duplication;
- Collective involvement in decision making and in investment in the Strategy;
- At least a ten-year life to ensure delivery;
- Providing the opportunity for consultants to use the material developed to support their business interests;

- Ability to modify the agenda in the light of new information.

The paper also noted that water scarcity and the challenges posed by our hydrological variability was leading to innovation in river basin modelling and management in Australia. The Australian engineering services industry can capture many commercial opportunities internationally if we were able to put our hydrological modelling skill into a professional model architecture and support it well.

3.2 Elements of the Existing NHMS

The main elements of the existing NHMS are set out in the following:

- the two-page description of the NHMS endorsed by the NWRC in 2018 (Appendix 1);
- the NHMS-CHA (NHMS-CHA, 2018);
- the Source Project Agreement (SPA, 2018) and the 2019 SPA Deed of Variation (SPA-DoV, 2019);
- the SPA Annual Operating Plan for Financial Year 2021 (eWater, 2020);
- the eWater constitution and website – www.ewater.org.au;
- the NWRC Terms of Reference.

Below are some key points about the existing NHMS arrangements, activities and products.

3.2.1 Existing NHMS Objectives

In considering the objectives of the NHMS, in 2018 (Appendix 1), the NWRC agreed that "The NHMS will enable the support services and network to help implement, maintain and enhance hydrologic modelling to support better water management across Australia.

In doing so the NHMS will aim to ensure:

1. Governments and other relevant parties work cooperatively and on a national scale to ensure that resources and expertise are coordinated to achieve the hydrologic modelling capability to underpin world's best practice water planning and management in Australia;
2. The hydrologic modelling community is ready to meet the priority hydrologic modelling needs of governments;
3. Australia's existing hydrologic modelling expertise is effectively utilised, further capacity in the field is actively nurtured and developed, and duplication of effort is avoided;
4. The functionality and application of hydrological modelling platforms meet the needs of the Australian community;
5. Appropriate funding is available to support the implementation, on-going maintenance and enhancement of modelling platforms and to develop a strong community of practice; and
6. Australia's modelling capability is exported internationally."

3.2.2 Existing NHMS Scope

In considering the scope of the NHMS in 2018 (Appendix 1), the NWRC agreed that "The NHMS will help maintain and enhance the characteristics of both elements of hydrological modelling — the technical (modelling systems, e.g. Source, MUSIC and others) and a hydrological community of practice so that they are able to meet contemporary common modelling needs for policy

development, planning, management, operations, compliance, accounting, water markets and forecasting within the water system across a range of applications.

As outcomes, modelling platforms will support:

- water quantity planning, management and compliance (surface water including groundwater interactions);
- river operations;
- impact of climate change/variability on water resources;
- water quality assessment, management and evaluation;
- environmental water management;
- forecasting future water demand and supply (both urban and rural);
- integrated urban water planning, management and operations, and water sensitive urban design; and
- water-coupled socio-economic modelling.

As outcomes, the hydrological community of practice will deliver:

- collaboration between governments, universities and research sectors and industry for improving hydrological modelling capability;
- consistent and coordinated approaches to hydrological modelling efforts;
- avoidance of duplication and reduction in inefficiencies including by:
    - collective decision making and investment in the Strategy; and
    - facilitation of collaboration and coordination of national experts and model users;
- consistency of model application, development and documentation;
- transparency of models including their provenance;
- continuous improvement to modelling methods and processes (e.g. model parameterisation, calibration, testing and application); and
- development and innovation in modelling through access to research capacity."

3.2.3 Existing NHMS Governance

The existing NHMS governance arrangements are variously described in the NHMS-CHA, SPA, eWater constitution and the NWRC Terms of Reference. Further details of each of these documents are summarised in Appendix 2.

A high-level overview is provided in the diagram below (Figure 2), adopted and updated from the NHMP due diligence review (MDBA, 2017).

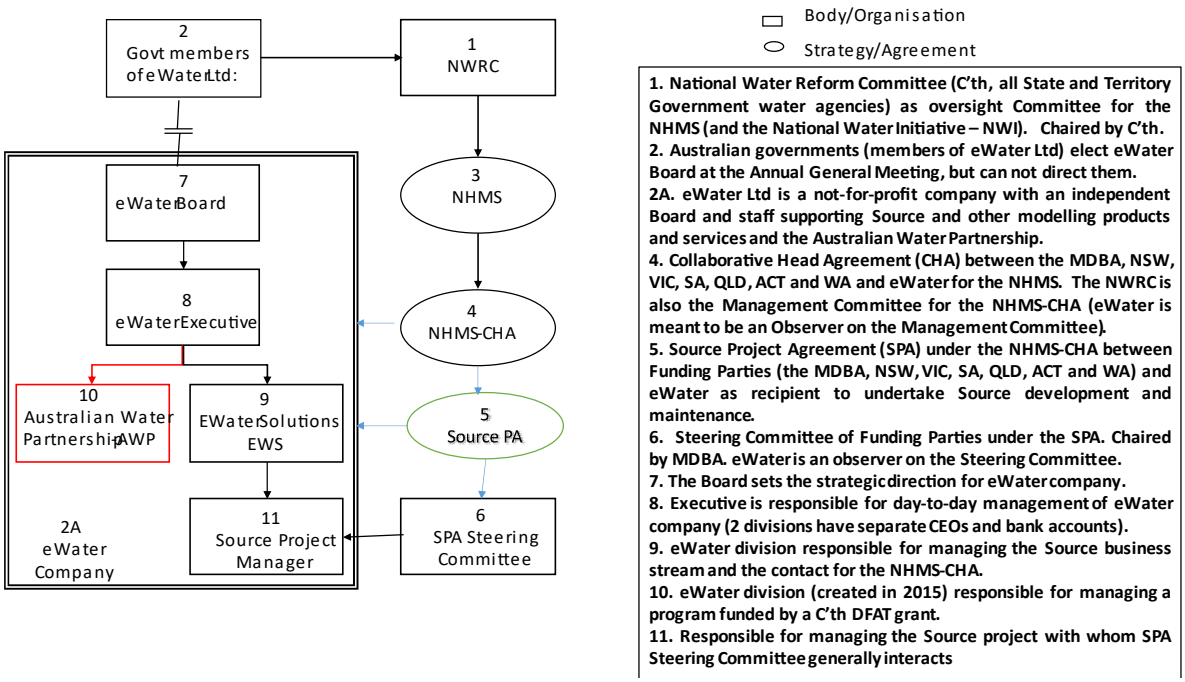

Figure 2 High-Level Overview of the Governance Arrangements for the Existing NHMS (Adopted and Updated from MDBA, 2017). (Note that under item 8, the eWater Executive does not manage the company per se, as there are two CEOs (one for AWP and one for EWS) with their own delegations. EWS has the direct connections with the NHMS-CHA and the SPA.)

The NWRC is an interjurisdictional committee that considers and progresses national water reforms of the National Water Initiative (NWI) and other national agreements. It is chaired by the Deputy Secretary responsible for water in the Commonwealth and its members are senior officials from all State and Territory water departments. The Bureau of Meteorology (BoM), CSIRO, the Productivity Commission and the National Water Grid Authority are listed as observers. The NWRC has taken oversight of the NHMS.

Not all jurisdictions are Parties to the NHMS-CHA and eWater is not a member of the NWRC (though it is meant to have observer status on the NHMS-CHA Management Committee).

Subject to the provisions of the NHMS-CHA, the Parties agreed to work and conduct Projects in a manner consistent with the Principles to Collaborate:

- Collaboration and Communication – engaging collaboratively in planning and management; ensuring our communication and feedback is timely, honest, open and effective; and, recognising that each Party operates within its own constraints and boundaries.
- Resources - ensuring resources are used efficiently and effectively and integrated (where relevant) with other related programs.
- Decision-making – operating within agreed boundaries, being flexible and adaptable and using objective and factual data as the basis of sound-decision making; sharing and utilising collective learnings.

The NHMS-CHA Parties agreed that the Management Committee established under the NHMS-CHA (currently the NWRC) be responsible for the governance and strategic management of the NHMS-CHA which includes:

i. identifying issues or responding to issues raised by Parties that may impact on the NHMS-CHA and identifying and implementing proposed solutions; and
ii. admitting (by unanimous resolution) new parties to the NHMS-CHA (on terms determined by the Management Committee).

Under the NHMS-CHA, it is also stated that:

a) All Parties recognize that open communication between eWater and the Funding Partners is the corner stone of building confidence in and promoting transparency and accountability of eWater.
b) Communication between eWater and Funding Partners in regards to the NHMS-CHA, or any Project Agreement that involves all Funding Parties, will be via the Management Committee, unless otherwise agreed by the Management Committee.
c) Communication between eWater and one or some Funding Parties in regards to a Project Agreement that involves only one or some Funding Parties will be via the management arrangement for that project established by such Funding Parties.
d) The eWater Board will meet with the Management Committee at least once a year on an occasion(s) other than the Annual General Meeting of eWater for strategic conversation on matters relating to the broad direction of eWater, and the Source modelling platform.

The SPA is the only existing Project Agreement under the NHMS-CHA that involves all the funding parties. Details of the work undertaken each year over the term of the SPA are specified in summary form in an Annual Operating Plan (AOP). The SPA has been described by eWater as a time-based contract at cost for work done according to the AOP, with no grant component nor operating margin. Main activities undertaken under the SPA include to:

a) maintain and improve the Source modelling platform;
b) enable configuration and customisation of Source for applications in selected river basins across Australia; and
c) provide professional user support for Funding Partner staff, including on-line collaborative tools and supporting documentation.

The SPA provides for a Steering Committee of Funding Partners, which reports to the Management Committee of the NHMS-CHA (currently the NWRC). The Steering Committee is responsible for the administration of the SPA and may from time to time by unanimous resolution decide to admit a new party to the SPA on terms determined by the Steering Committee. eWater is an observer on the SPA Steering Committee.

eWater is a limited by guarantee public company with a membership-based constitution. Its initial members were the Commonwealth Government and State Governments of NSW, Victoria, Qld and SA. Subsequently, the Governments of the ACT and WA became members. More recently, the Governments of Tasmania and the Northern Territory have become members.

eWater is governed by a Board consisting of up to six directors and a Chairperson. Under the constitution, the Board should contain at least three directors who are independent of the members, and one of whom must be the Chairperson. All directors must be appointed by the members by election at a general meeting.

eWater's operations are broader than those covered by the NHMS-CHA and the SPA. eWater also receives funding from sources outside the SPA including:

- Separate contracts under the NHMS-CHA with governments for assistance or bespoke development with Source, mainly for software improvement;
- Training courses (including through the eWater Academy and ICE WaRM – the International Centre of Excellence in Water Resources Management, now owned by eWater) and software licensing fees (noting that eWater also manages other software products including MUSIC for use in water sensitive urban design);
- Fee-for-service projects for clients such as the World Bank and Contracting State-Owned Corporations (i.e. Melbourne Water, WaterNSW, SA Water etc); and
- The Commonwealth Department of Foreign Affairs and Trade (DFAT) for a range of activities, including the Australian Water Partnership (AWP), support for the Mekong River Commission Secretariat and other activities.

3.4 Existing NHMS and SPA Funding

The 2017 due diligence review of the NHMP (MDBA, 2017) quoted that, up until that time, a total of $23.2 million had been invested in the Source platform by partner Governments. This did not include the research and development that occurred during the CRCs. The review suggested that the total investment in the Source platform was likely to be in excess of $50 million (with some people later suggesting it is in excess of $60 million).

Under the SPA Annual Operating Plan for Financial Year 2020-2021 (FY21), eWater will provide specified services to each Funding Party. Further details of the administration, bug resolution, community of practice, maintenance and new development services are summarised in Appendix 3. For FY21 the Source Community of Practice includes the annual Source conference as the main community event for the year and maintaining collaboration tools.

The arrangements provide for a total FY21 budget of $1,039,343 and approximately 4.0 FTE.

Funding partner Governments may engage eWater to undertake additional work on a fee-for-service basis in the areas of:

- Generic training;
- Custom or in-house training;
- Capacity building; and/or
- Additional software development.

A list of any such additional work and associated funding has not been compiled for the purposes of this Final Report. However, one funding partner Government quoted an expenditure of almost $1 million since 2015-2016 on additional bespoke Source software development contracts with eWater under the NHMS-CHA.

It is also important to note that the adoption and implementation of Source software for a particular water system (catchment or river valley) is an activity separate from its software development and maintenance by eWater. While eWater supports that activity (through software development, enhancement and maintenance), it is the responsibility of the MDBA and relevant State and Territory agencies to develop Source models for their systems. That hydrological

modelling work requires significant human and financial resources and substantial technical knowledge, experience and skill within those agencies.

3.5 Existing NHMS eWater Products

The modelling tools provided by eWater comprise:

- Source;
- MUSIC;
- Urban Developer;
- eWater Toolkit; and
- Water Quality Analyser.

Further details are provided in Appendix 4 and the eWater website – www.ewater.org.au.

Source is the only tool directly covered by the National Collaboration Framework (via the NHMS-CHA and the SPA), though the other tools have been referenced and either been connected with Source in the past or are now being increasingly connected. Source has more than 3000 users in total located in every State and Territory of Australia and about another 2500 users internationally.

Source has water planning, operations and forecasting modes and is used mostly for water resource planning and sharing, quantifying water access entitlements, assessing water entitlement trades, water accounting and analysis, river and reservoir operations, and water resource assessments.

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is Australia's leading tool for water sensitive urban design (WSUD) and analysis. Across Australia, urban developers, planners, engineers, Local Governments and development approval agencies use MUSIC to manage the impact of urban development and other land use changes on waterways. Some Local Governments and jurisdictions have mandated MUSIC for designing large-scale urban developments.

Urban Developer provides for in-depth analysis of urban water demand, to improve water efficiency and consider alternative water supplies.

The eWater Toolkit is an online resource of hydrological, ecological and catchment management models, databases and other resources produced by eWater and its partners over more than 20 years. Most of the tools are available as freeware. Access to Source and MUSIC is also through the Toolkit. The Toolkit has more than 12,000 members from over 120 countries. Toolkit membership is free. In addition to the tools, membership provides access to the eWater community forum, supporting documentation, updates and news.

Water Quality Analyser is for water managers, scientists and engineers who need to monitor in-stream water quality, estimate pollutant loads or set water quality targets. It allows users to search the database for relevant guidelines, and then tests actual time series data against the guidelines.

4.0 Perspectives about the Existing NHMS Arrangements, Activities and Products

This section summarises "what I heard and what I have concluded" from my many discussions, any written comments provided, including feedback on an earlier draft Issues Paper and an earlier Draft Report, a review of documentation available and further independent analyses. More details about inputs and perspectives provided are contained in Appendix 5.

Invariably, there is some interpretation on my part.

4.1 General and Over-Arching Comments

It is timely to review the NHMS, its achievements against its objectives (original and revised) and its future. This is especially the case since the National Water Initiative (NWI) is in the process of review and discussions are being held about how best to "refresh" the NWI. This is also in recognition that having well-established national hydrological modelling capacity and capability provide essential underpinnings to both the existing and any future NWI.

There is strong support for having a NHMS – the key challenge is to how to make it work most effectively and efficiently.

How and why the NHMS is taken forward, including what is its strategic direction and what is needed to get there, by whom and at what costs for what benefits, are now matters requiring further consideration. External stakeholders are also keen to be involved in that conversation with Governments.

The NHMS is broader than Source and eWater, and eWater is now broader than Source. However, the benefits of having a nationally compatible and coherent hydrological modelling platform and the skilled human capacity around that to inform often complex and contested decisions are compelling. Nevertheless, the NHMS is not just a tool. It has and needs to have the best available science and hydrology incorporated. Appropriate data collection and maintenance is also an important NHMS action, because, without good data, and without making best use of the data that you have, improvements in the other components are somewhat pointless.

The common platform has helped with communication and understanding and has provided a recognised form of practice which has some "authority". This has assisted not only water resources planning and management but also understanding and defence of some decisions, including in legal settings. However, being completely focussed on validation can pose risks to social licence which may be mitigated by incorporating an appropriate uncertainty-focused mindset. This involves making judicious investments over time in building understanding about uncertainty relevant to decision making and in reducing uncertainty where and when it impacts decision-making.

It is generally accepted that the hydrological modelling required for basin-wide water resource planning and river system operations and the like is complex, and with that complexity comes higher costs than might otherwise be the case, but there are still questions as to whether the current SPA costs are excessive, mitigating value for money.

The existing governance arrangements for the NHMS-CHA, SPA and eWater are somewhat convoluted and that adversely affects transparent communication, collaboration, coordination and fully informed and informative decision-making.

Overall, though it has taken longer than originally envisaged, the Source modelling platform has been developed to a level where it meets the vast majority of the current water resource planning and river system operations modelling needs of the existing Funding Parties to the existing SPA and offers benefits to other Governments who are not signatories to the NHMS-CHA nor the SPA, but are now members of eWater.

4.2 What Is Working Well?

The fact that eWater is still in operation almost nine years since the closure of the eWater CRC is a positive achievement in itself. This is partly because eWater has developed additional lines of activity other than the development and maintenance of the Source platform for jurisdictional funding partners. Some of this has also been enhanced by its relatively strong profile in some areas internationally and recognition of the positive diplomatic connections that provides to Australia.

That the 2018 NHMS-CHA has included options for recommitment and extension to 2033 is also seen positively.

Significant progress with the NHMS, and Source, in particular, has been observed over the last decade. Source has been increasingly accepted and can handle most water resource planning and river operations situations so conversions to it have been increasingly happening (though too slowly for some). Adoption has supported consistency, transparency, transferability and the sharing of approaches and information.

Major functionalities of Source for general water resource planning and river systems operations applications have been developed; tested and stabilised (stability is credibility) and Source has essentially entered the maintenance mode for those functionalities. However, it is recognised that Source (software) development is an on-going work-in-progress, whereby constant updating and potentially enhancement work are required to keep it abreast with technology and evolving user needs. An example where further integration and development are required is at the Murray-Darling Basin scale.

Documentation, including user guides, reference guides and notes, has been increasing and is generally of good quality, though there are some challenges in quality assurance, version control (very important for legislated models), and keeping documentation up to date as software and functionality changes and new plug-ins are made.

Formal arrangements for cooperation and collaboration between Australian Governments and a dedicated organisation - eWater – have greatly helped to achieve this result. The arrangements under the earlier versions of the NHMP and now the SPA have generally been successful at an operational level and generally technical level coordination among the SPA partners has been and continues to be very good.

People who have invested in Source have benefitted from that investment, though there are variable views on the resultant "value for money".

Bespoke one on one contracts with eWater for new software development and enhancements (which cover almost all new software development cases these days) have been reported to have run very smoothly in the vast majority of instances. Partners realise that what they get out reflects what they put in. These new capabilities in Source, mostly in the core code but also in the form of plug-ins, also can and often do bring benefits to others but funding is often needed to generalise the enhancements for broader use and it is often difficult to obtain funding for that (and, indeed, agree on who should pay).

Nevertheless, there are opportunities for eWater to take more initiative in coordinating and delivering cross-jurisdictional software development needs. There is some lack of clarity about where all the bespoke work is leading – i.e. what is the strategic direction and are all the enhancements going that way?

MUSIC has continued to grow (though improvements in its fundamental science inputs have lagged) and connections of it and Urban Developer with the Source platform have been made. MUSIC provides cash (gross income of $1.0 million to $1.5 million per year) to help keep eWater operating, to reduce calls for other funding, and to reinvest, though this is not widely recognised under the NHMS.

There were variable views on the community of practice. While most thought it was working ok as a Source community of practice – limited to surface water modelling and Source – it hasn't really progressed to catchment, water quality and urban water modelling, which are important elements of a NHMS broader than but related to Source. That is, there is no NHMS community of practice per se.

Nevertheless, jurisdictions have been working together on particular pieces of work of common interest, learning from each other and more people are gaining modelling understanding and experience as a result.

Some jurisdictions have relatively recently started their own water modelling networks and/or hydrological modelling communities of practice and these seem to be working very well within the respective jurisdictions. The work of the Queensland Water Modelling Network since 2017, the NSW Modelling and Monitoring Hub, the Victorian Hydrological Modelling Group and possibly others has been particularly helpful and provides an example of what can be done with the necessary investment and effort. However, to date, eWater's and some other jurisdiction's involvement or invitations for involvement in these positive initiatives have generally been seen by them to be limited or absent.

eWater and others have been successfully exporting Australia's modelling capability in Source and other tools internationally, particularly in the Asia-Pacific region. The Department of Foreign Affairs and Trade (DFAT) has been a key enabler in this endeavour. The Australian Water Partnership (AWP) has also assisted international connections in water matters. Facilitating that more broadly than eWater and/or the AWP is also very important for Australia's international modelling capability and credibility.

Generally, then, of the six objectives of the NHMS, 2018 (Appendix 1), three objectives – objective 1 (cooperation and coordination to achieve hydrological modelling capability), 4 (functionality to meet needs) and 6 (capability exported internationally) are largely being met for existing NHMS-CHA and SPA parties. Nevertheless, there is certainly still room for improvement in, and better communication to demonstrate benefits and increase understanding about, each of them.

4.3 What Is Not Working Well?

4.3.1 Strategic Direction and Governance

Arguably, things that are not working well are all issues resulting from or incidental to a lack of strategic direction for and leadership of the NHMS. Whether or not the independent advisor role can help to effectively improve the situation is a current open question.

While the development and signing of the NHMS-CHA has been acknowledged as a significant step forward, at the moment there is only one project under the NHMS-CHA which involves all funding parties - the SPA. It was envisaged that other projects could also fall under the NHMS-CHA, to implement additional functionality for all or subsets of the partners with similar interests. There are reports of times when NHMS related developments have been proposed by one party only to hear that another party had already developed and implemented a large part of it. While this is somewhat a good outcome from the NHMS perspective, a specific project agreement could have been established under the NHMS-CHA to increase collaborative opportunities and get better value from partnered projects.

It is not clear where or who is best placed to facilitate these opportunities for collaboration – e.g. broadly under the NHMS (e.g. the NWRC) or more narrowly through eWater or somehow else? In any event, there is a need for all players to have a voice in these deliberations, including the Funding Parties and eWater, and likely others, including CSIRO, Geoscience Australia and the BoM, who are progressing innovations of relevance to the strategic nature of the NHMS.

The governance arrangements involving the SPA Steering Committee, eWater Board and the NWRC as the management committee for the NHMS seem to be somewhat convoluted, with reports of disconnects between eWater and its owners/major funders, both in strategy and direction. Are the right decisions being made in the right places at the right times for the right reasons? This has implications for clarity in roles, responsibilities and accountabilities. It also has implications for communications and relationships, including seeing the NHMS as a “partnership initiative”.

Several people observed that eWater seems to have potentially conflicting objectives under the current arrangements: to provide (develop and maintain) a national approach to surface water modelling on a platform; and to be commercially viable (including by selling platform products). Source is being increasingly used by Governments, but it is less used by the private sector. Some felt that the private sector is beholden to a commercial enterprise where State approved water planning and river operations models have to be in Source and so consultants, including to the private sector, are forced to use it commercially.

Some commented that, for them, the conflict is within the business arrangements for eWater, which is being funded for Source, in particular, largely by public money, and whereby eWater actively competes for commercial contracts for providing consultancy services against private companies in some cases. Those same private companies have to pay eWater to use the software that is being used by eWater to compete against them in such cases.

How to best manage the collaboration/partnership and commercial aspects, what that may mean for eWater's role, business, finances and future, and the "closed" or alternative "open" nature of the Source platform and community are commonly raised topics, with a broad range of views. Clarifying and resolving this requires substantially more conversation, analysis and deliberation by Governments, eWater and the private sector.

4.3.2 Extent and Scope of the NHMS

Despite the recent inclusion of Tasmania and the Northern Territory as members of eWater, and the opportunities that may create, the NHMS itself is not yet fully national. With the exception of WA, all Government partners in the NHMS-CHA at present have catchments within the Murray-Darling Basin (MDB) with a relatively high management and modelling effort, and so the NHMS still gets labelled in some quarters as largely a MDB thing involving purely technical matters synonymous with Source development. This perception can be exacerbated in some quarters since the MDBA (being a Commonwealth agency but not the Commonwealth Department responsible for water matters) chairs the SPA Steering Committee and contributes half of the funds under the SPA.

There were also perceptions that Source is the only thing in the NHMS and everything else is out of scope. This limits communication and collaboration with others involved in other modelling platforms. This may thwart innovation and opportunities for interoperability that may otherwise be beneficial.

There were variable views on the benefits and risks as to whether Source should be "mandated" as the platform to be used for specific purposes in each jurisdiction. By way of comparison, some urban development decision making authorities mandate the use of MUSIC for assessments and analyses and this has led to widespread application of MUSIC by urban development applicants and their private sector consultants. This has also considerably assisted eWater's income stream. It was noted that MUSIC is used by commercial urban land developers while Source is mostly used by Governments and large water users, so Source has a much more limited market. However, interestingly, this itself may run the risk of reducing the software to a commodity rather than an innovation platform.

Strategic discussions between eWater and its owners and others about what could and should be the scope of the NHMS products and services beyond what it is now, and how those products and services may be developed and maintained and funded into the future, have not been happening enough. This is not helpful to the NHMS, to eWater and its Government members, nor to industry and the community.

Source was initially designed as a hydrological modelling platform (i.e. primarily focussed on water quantity), and has been extended for other uses, predominantly through customised plug-ins. These "other" uses have included water quality forecasting, environmental water demand, and

coupling with socio-economic processes. Through a combination of necessity and practicality the initial focus has been seen by some as being on shorter-term operational matters, for example to obtain forecasts of water availability to inform relatively short-term management actions in line with local policy. Extending its use to planning contexts where longer-term considerations are at play has often been achieved by "scaling up" these shorter-term cases to longer time frames with relatively limited consideration of the uncertainties involved. Reuse of operational models to the longer-term planning context may limit planning capacity, applicability, and flexibility towards investigating the possible future pathways that may be taken. For viable pathways to equitable and sustainable conditions to be identified, it is necessary for the uncertainty that may affect projected outcomes to be holistically considered and communicated. However, the overheads of the existing Source platform, including in terms of both input/output and operational detail, are reported by some to be too high for this in particular situations, causing, for example, long model runtimes and inhibiting (1) characterisation of model and predictive uncertainty and (2) large basin-scale applications. These are issues within the Murray-Darling Basin context.

Operational applications of hydrological models are often constrained by regulatory concerns (including specific versions of models written into law), such that there may be relatively large transaction costs involved in improvement of the model over time, and strong disincentives to public-private collaboration. External inputs are therefore difficult. One possible mechanism here would be the creation of "digital twins" in modelling, which provide up-to-date representations of a system, integrating both (near) real-time data and (collections of) models at multiple levels of fidelity (and therefore varying runtime cost). It may be possible to provide a platform that integrates data and models for specific locations and acts as a central point of contact for investigation and research activity in each region. Mandated custodians of digital twins would then provide a safe space for Governments and other non-Government organisations to transparently engage with operational model improvements and seeking to reduce uncertainties without feeling obliged to immediately integrate those improvements into their legal frameworks.

Achieving success in model building and application for challenging interdisciplinary issues is about more than getting the science and engineering right. It is also about embedding model building in a social process that links and engages scientists, decision makers, interest groups and the wider public towards achieving impact beyond merely technical performance of a model, notwithstanding the critical importance of the latter for credibility and confidence.

4.3.3 Communication and Relationships

Despite some commitments made in recent years, a number of NHMS-CHA partners and SPA parties still observe a communication gap between eWater and its members/funders. It is recognised that, while the NHMS, eWater and Source all originated in proximity of each other, they are not all one and the same.

Trust in the Source software is generally very strong but the same does not always apply to eWater's commercial advisory and consulting activities where competition and lack of transparency have been reported to cause friction among SPA partners and also with external stakeholders, including private industry.

Over time, eWater has grown in its operations where Source is just one of its several endeavours, albeit a very necessary and technical one. Correspondingly, the SPA Steering Committee that runs the Source project now largely comprises technical experts. This has resulted in a strategic-level communication gap, some levels of mistrust and perhaps a lack of understanding among some of their respective roles in directing eWater activities.

This matter has been explored in great detail in an unpublished internal due diligence review report on the NHMP (MDBA, 2017). An interim way proposed to overcome this communication gap was a strategic annual conversation between the eWater Board and the Government owners of eWater/funders of the Source project (but not at the annual general meeting).

4.3.4 Funding

Agreement on the funding for the SPA beyond 30 June, 2021 to 30 June, 2023 has only been reached recently. However, the process for that matter through the SPA Steering Committee has been described as "protracted and painful". To go beyond June 2023, parties will need to negotiate a new agreement before June 2023. This raises questions about the financial sustainability of the SPA arrangements with potential risks to Governments and to eWater.

Earlier indicative analysis as part of the business case for eWater suggested that "it is reasonable to expect a decreasing reliance on core Government partner funding over time". This would result in program costs to partners reducing over time as commercial and external contracts increase.

However, the promised revenues have not materialised according to the views and expectations of some funding partners. The margins and overheads and commercial returns for both Australian work under the SPA and international work are not necessarily understood and accepted. There is a need to review this relationship as a framework that could see either increases in the overall financial support from Government funders or a decline in service for the same cost and that is of concern to all parties.

There are also concerns about what the actual costs of services need to be to obtain satisfactory outputs. For example, in the 2017 due diligence report (MDBA, 2017), it was stated that full maintenance of Source required eight roles with a base cost of $2.3 million with modest CPI increases. (Some industry experience suggests that typically 5-8% of IT asset IP value needs to go to maintenance and renewal just to continue to have the IT product available. With investment in Source to date reported to be at least $50 million and likely more, that translates to a minimum annual cost for maintenance and basic renewal of at least $2.5 million per year.) Parties ended up agreeing to a one-year agreement that was extended to three years, and more recently five years, at a cost of about $1.067 million per year.

Consequently, there is a very widely held view that there are ongoing challenges in funding the development and maintenance of Source. Despite the 2017 due diligence report leading to putting in place a longer-term working arrangement for the NHMS through the NHMS-CHA and for the development and maintenance of Source through the SPA, there has been difficulty in securing consensus agreement for anything other than 1-2 year tranches of funding for the maintenance of Source.

Further development work has generally been bespoke and negotiated through mostly one-to-one contracts between eWater and a particular partner under the NHMS-CHA. While the funding framework around these contracts is understandable, there have been missed opportunities, including for economies of scale, because communication around the bespoke development proposals has sometimes been lacking.

At least one party has considered pulling out of the SPA and the use of Source as is, without further development or maintenance, due to frustration with eWater increasing costs of service delivery and because Governments need a stable statutory planning framework. If this were to happen, it would end many years of collaborative effort. This shows that the relationship between some of the partners and eWater is tenuous and there are real risks associated with "business as usual". The new 2021 SPA variation has bought two more years of maintenance activity, but it was reported that this may not survive beyond 2023 if changes are not made.

The ongoing cost of maintenance of Source does not seem to be seen universally as a necessary cost of water planning and management business like other costs. As one person put it, the modelling platform asset and its upkeep, while essential, is not a "ribbon cutter". It is a risk to expect eWater to be able to maintain Source with a budget that is inadequate and/or dwindling in real terms. It also risks the long-term viability of both eWater as an organisation and Source as a product. Substantial cash injections by the Commonwealth (both through the CRC program and later more directly for the initial Source development through to 2015) have been crucial to success to date. Source maintenance is vital to Governments, and this software maintenance capability is likewise vital, in a sustainable way.

On the other hand, funding partners are concerned about, in their view, the relatively high human resource costs ($ per full-time-equivalent) associated with the SPA. This raises questions about overheads, what is included or not included in apportioning costs, and how this impacts the value-for-money of the SPA.

Continuing investment in hydrometric data collection is also needed because, without it, the ability to have effective hydrological modelling platforms is proportionately constrained. This activity must occur in the States and Territories during COVID budget restrained times, making cost increases by eWater harder to bear.

4.3.5 Community of Practice

As mentioned previously, there are conflicting views on how well the hydrological community of practice is going. Both the formal and informal networks established through the annual Source conference, for example, and Source software use training have been very beneficial. (For example, the on-line Source conference in 2020 attracted more than 300 participants, including those from more than 20 other countries.) However, a function for a broader NHMS community of practice is not established and some jurisdictions are effectively self-organising their own networks to good local effect.

The scope of the national training effort by eWater has been generally limited to using software, rather than broader modelling practices and principles. The latter are largely being addressed through within-jurisdiction/industry training and mentoring.

A major concern was where do you find new modellers and how do you upskill junior staff? It was stated that most capacity building is currently in-house. A suggestion was made to develop a tertiary short course in hydrological modelling, distributed across Australian universities. perhaps at Graduate Diploma level. Water management agencies could contribute in-course material, and perhaps assist with delivery and mentoring. This could also be an integral element of the community of practice, and over time would develop better networks.

Broader participation in community of practice and/or capacity building activities is often limited by allocated funding.

4.3.6 New Knowledge

eWater and partners have made significant steps in addressing a number of science gaps identified early in the partnership arrangements. However, in addition, many agencies have been facilitating collaborative efforts to work on particular science gaps, with groups including State/Commonwealth Governments, CSIRO, universities and leading consultancy firms. These science gaps are particularly in relation to specific hydrological modelling related research and development, rather than general water related research, though, of course, the latter is also very important.

A lot of relevant more recent research work may be happening, but it has not been well harnessed in the NHMS. There were concerns that current arrangements are not capturing sufficient knowledge development beyond software. Examples included urban water supply and water balance, low flows hydrology, surface water-groundwater interactions, flood hydrology and hydraulics, groundwater, ecological water requirements, socio-economics and cultural water provisions.

Another example is climate change and water modelling work. The approaches being taken are somewhat different in different jurisdictions, with no clear national narrative around those differences. This is a risk to the coherence and justification of incorporating climate change considerations in future water modelling and water planning and management work. The relatively recent establishment of a Climate Change Sub-Committee under the NWRC may provide an avenue for further communication, collaboration and coordinated advice.

Bringing in new knowledge and planning frameworks to anticipate future stresses in water, energy and food security has also been missing the necessary conceptualisation and collaboration. There are demographic changes, and changes in agriculture, forestry and emergency services that also need to be factored in.

More connections could be made with planning to anticipate futures (drivers and impacts) in climate, land use and other cross-sectoral impacts, and to identify robust adaptive strategies. This would include modelling capability to be able to efficiency “dance” with external algorithms, including being able to easily experiment with alternative model assumptions and model structures. This further connects with the need to integrate models within decision frameworks rather than communicating scenarios in isolation, connecting notably to international literature and communities focused on adaptive and robust decision making and decision making under

uncertainty. This need has notably been emphasised by the Queensland Water Modelling Network and the Victorian Hydrological Modelling Group.

Significant new work in new knowledge, data and information, scientific capability and hydrological modelling capability has been lacking under the auspices of the NHMS, especially in catchment and water quality modelling. In pursuing this, care will be needed as hydrology and associated modelling are data-based sciences, and more modelling sophistication is not always warranted if there is not data and evidence available to support it.

4.3.7 Diagnosis

Based on the comments above, it is arguable that objectives 2 (meeting the hydrological modelling needs of all Governments), 3 (hydrological modelling capacity and avoidance of duplication) and 5 (appropriate funding) of the NHMS are not yet fulfilled. It is also noted that, while a number of the NHMS objectives have not been fulfilled, several States and Territories and other agencies have in many cases improved their own in-house capacity beyond that in existence in 2008.

4.4 Suggestions for Change

4.4.1 National Leadership

Following on from Sub-section 4.3, the central change that was suggested as needing to occur is that the NHMS has to be accepted as a **national** strategy and its implementation should be appropriately resourced.

While the NHMS should be reviewed and updated to serve the contemporary needs, it requires ongoing support, including strategic direction, effective governance and leadership, an implementation program and monitoring its implementation. This will ensure that all subordinate elements including Source enhancements and maintenance and the hydrological modelling community of practice continue to be supported. The working of the enabling entities, such as eWater, should be reviewed in order to ensure that they continue to be relevant and able to meet the contemporary national needs.

All these matters require that the NHMS be owned nationally by all Governments. To function properly, it was suggested that the NHMS should be led by the Commonwealth Government through the NWRC.

To provide the necessary national leadership, collaboration and commitment, the NWRC could consider establishing a NHMS Sub-Committee with membership from all NWRC jurisdictions, and observer status for eWater, the BoM, CSIRO and Geoscience Australia, provided the necessary arrangements are in place to handle conflict of interest matters, Intellectual Property, and the like. The NHMS Sub-Committee could establish an advisory group of private sector and research sector representatives to inform the national conversation and build commitment to ways forward.

Refreshing of the NWI, together with membership of eWater now aligning with membership of the NWRC, provides an opportunity for a national conversation about the future direction of the NHMS (and Source, and potentially eWater). There are matters of science and research, product

development and maintenance, service delivery (including capacity and capability building), engagement, commercialisation and financial viability to consider.

4.4.2 Roles and Responsibilities and Relationships

Reconsideration of governance arrangements for the NHMS as above should clarify roles and responsibilities and provide a clearer "line of sight" for future directions and decision making. At the same time, stronger collaborative relationships among the participants in the NHMS should provide a more enduring partnership. More regular and effective communication channels should be established and used between the NWRC, NHMS Sub-Committee and the Board of eWater Ltd, as appropriate, to enable strategic alignment and inform business delivery.

There is a greater role for the BoM and likely CSIRO and Geoscience Australia in the NHMS compared with what has been happening over recent years and more effort should be put to building the necessary linkages and building the working relationships.

4.4.3 Extent and Scope of the NHMS

It is essential that the NHMS actually be made a "strategy", i.e. not just a vision and objectives, but include details about how and when who is going to get there at what cost. Mechanisms need to be developed and documented with tangible milestones and an underpinning, transparent, agreed investment framework. And the strategy needs to be more inclusive.

Other recognised hydrological modelling platforms, products and processes, like those use for flood forecasting and management, and groundwater system entitlements and management, should be flagged and made transparent within the scope of a truly national "hydrological modelling" strategy. This doesn't necessarily mean that such platforms, products and processes have to be the subject of a Project Agreement under the National Collaboration Framework.

The NHMS document could, however, be transparent that these platforms, products and processes are important nationally and supported, being covered, for example, by arrangements under Australian Rainfall and Runoff (Engineers Australia and Geoscience Australia) and with MODFLOW and the work of the National Centre for Groundwater Research and Training, respectively.

While the framework of having plug-ins to the Source modelling platform is widely supported, there needs to be clear agreement as to what we want them to do (what answers are we looking for) and are they an appropriate way to do it. Already a number of the components of the existing NHMS are not actively discussed or pursued, so it is an important conversation as to what are the objectives and priorities for the next one, five or ten years and what resources are to be provided to meet them and how.

With open architecture style models becoming more prevalent, and Source has that ability, development of plug-ins needs to be better coordinated so that they are updated and updateable, with less reliance on particular individuals who did the development in the first place. Custodianship of the full extent of the tools and products is required so that they have transparency, longevity and reliability, quality assurance and quality control, and are appropriately

tailored to the questions that are being asked and need to be answered. While requiring further evaluation, this could be a role for eWater with appropriate funding.

While it may be unrealistic at this stage to expect the NHMS and Source, in particular, to go totally open source, perhaps there is space for both a proprietary and an open-source platform, especially for the more socio-economic aspects to be coupled. Uncertainty analysis also requires something that runs faster with more of the detail of Source lumped up for planning futures. Advice is that the universities and others would then come on board and innovate more with an open-source platform that is always developing and to which they would contribute.

The Open Modelling Foundation (OMF) is an international developing activity that seems to be one illustration of the fact that there is a huge drive in the direction of open source, community driven software development. Further information about the OMF is in Appendix 6. This project seeks to transform the future of modelling science. The OMF seeks to provide a framework to enable and encourage new collaboration across the vitally important modelling field where science and policy meet. The OMF reflects what is now de rigeur overseas in terms of developing open platforms that promote saliency, legitimacy, credibility (and collaboration) for any modelling that is confronted by uncertainty and stakeholder interests. Australian modelling organisations could consider whether there are benefits in them joining as members of the OMF and under what arrangements.

As mentioned previously, much more work is needed on the science and modelling for climate change, water quality management and ecosystem response within the catchment models to meet emerging and longer-term future needs. Some useful work is underway in this space of simulating catchments but more is needed and there are opportunities for increased investment, coordination and collaboration, perhaps also involving other platforms and corresponding connections.

The NHMS perhaps should include coherence in approaches to using its systems, the "art and science" of smart modelling and smart modellers, and address transparency and fitness-for-purpose. Clearly, there is both "science and art" to good hydrological modelling – it is not just being able to run a software package.

4.4.4 Funding

The objective 5 of the NHMS requires that "*Appropriate funding is available to support the implementation, on-going maintenance and enhancement of modelling platforms and to develop a strong community of practice*". As noted earlier, this objective has not been secured. Difficulty in securing long-term funding for the development and maintenance of Source is manifestation of this. This needs to be addressed if the NHMS is to succeed in delivering all its objectives.

If private industry is to be supportive of the NHMS and eWater products, then they must be seen as collaborators and not competitors and the relationship must be for the long-term. Based on the experiences of the State-based "networks", there are also opportunities for greater collaboration and partnering with the research sector and further leveraging funding for modelling science and a broader community of practice as noted below.

4.4.5 Community of Practice and Capacity and Capability Development

There was a strong suggestion that a national hydrological modelling network, perhaps providing a "network of networks", should be established, recognising the good work already going on in some jurisdictions and their and eWater's desires to seize on further opportunities, be better connected and build national capacity and capability.

Any national network should not be limited to software developers and modellers. Involvement of others, including policy people, decision-makers, researchers, educators, the private sector and communications/engagement people, are also necessary. Undertaking processes and procedures for enhancing good modelling practice and facilitating and embedding how to effectively do collaborative and participatory modelling are also important parts of the mix.

There are also opportunities to better involve water users and understand their needs and behaviours. Lessons from the Murray-Darling Basin and the catchments feeding the Great Barrier Reef show there is considerable need to build social acceptance of the use of hydrological models, to build trust in and understanding of what models can and can't do and how that impacts the effectiveness of decision making and implementation of decisions. These are important to the social licence to operate. Providing greater clarity in the way that models are used and where the benefits and constraints lie can lead to transformative conversations and greatly increased water literacy.

An important issue is how to get junior level people into the water modelling fraternity and ensure that the necessary skills are there for the future. Those skills are not just being able to "push the buttons in models" but rather to being able to appropriately apply models to help solve problems, to communicate well and sufficiently inform and assist decision-making. The NWRC could revisit the need for a Water Industry Skills Taskforce, like the one coordinated by the National Water Commission in the past.

To find new modellers and upskill junior staff it would be useful to develop a tertiary short course in hydrological modelling, distributed across Australian universities. perhaps at Graduate Diploma level. Water management agencies and the private sector could contribute in-course material and assist with delivery and mentoring. This could also be an integral element of the community of practice, and over time would develop better networks.

There are lessons to be learnt and information to be shared from several initiatives that have been undertaken in the last few years in this space by the Queensland Water Modelling Network, the NSW Modelling and Monitoring Hub, and the Victorian Hydrological Modelling Group and possibly others, like the Groundwater Modelling Decision Support Initiative (GMDSI), with considerable Government investment.

Linkages could usefully be made to the good work being undertaken at the moment under the GMDSI (Groundwater Modelling Decision Support Initiative). It is a practice of experts that have a webpage and regular webinars of important topics providing opportunities for feedback and discussion. The website has links to the initiative themes of Engagement, Education, Worked Examples, Research and Software (see https://gmdsi.org/).

4.4.6 New Knowledge

The NHMS requires applied research to translate fundamental hydrological, ecological and socio-economic understanding into modelling technology, as outlined previously. This may be best achieved through a close relationship between model developers and those who undertake the more fundamental research on water system behaviour. There is a need for a strategic method (under the NHMS preferably) which links research to practical use. By way of example, at the moment, eWater only really have experts in software development and hydrology. They do not have climate experts or water quality experts internally. Therefore, it makes sense for further developments in water quality and climate, for example, to be achieved externally to eWater - i.e. via research and academic institutions. However, there needs to be a nexus between eWater and the research and academic institutions, or the outputs from those institutions will not be in a useable format for code development by eWater or others. Funding partnerships may be one approach worth pursuing.

4.5 Future Challenges and Future Innovations and Research to Meet Them

Significant challenges include:

- Current and future climate change and consequent implications for hydrology, water security, ecosystem health, and economic, social and cultural well-being;
- Embracing the digital revolution; and
- Trust in the science and the modelling with changing human behaviours and expectations.

Given the challenges, including climate change, faced by Australia currently and in the future, the focus on the water sector is likely to be intensified. Consequently, the community's demand for more transparency and accountability of Governments' decision making will grow. More and more policy development will be required in this space and that needs to be supported by knowledge and technical developments to assist transparency and accountability.

As black-box modelling is no longer acceptable to the community, model provenance tools to handle multiple scenarios modelling by multiple agencies (and some may be on the other side of the globe) interacting with each other through cloud computing will most likely be required.

These may or may not be pursued by eWater and/or others, depending on how both collaboration and competition in enhancing and delivering the NHMS can be best managed.

A mechanism is needed to have a meaningful and influential conversation about future research and innovation needs relevant to the NHMS. Without this, opportunities for leveraging of investments and working collaboratively are missed. There is a clear need to bring key national agencies such as CSIRO, the Bureau of Meteorology, Geoscience Australia and universities, Governments and the private sector together in a strategic sense so as to avoid duplication of efforts in research, development and innovation that will be required to address the matters raised in this Sub-section.

Sub-section A5.5 in Appendix 5 contains a long list of suggestions for further research and innovation. More work has been done in some areas than others, though there is no real strategy about that. These suggestions have to be considered carefully so as not to adversely impact (dilute) the workability of the NHMS or the core components and functionality of Source and their continuing delivery. This is a matter for further consideration.

A key aspect of the NHMS would be to collate identified research into the modelling practitioner's space, even if the fundamental research had been undertaken by others.

In its *Knowledge, capacity and capability building, Supporting Paper K* to National Water Reform 2020*,* Draft Report, (Productivity Commission, 2021), the Commission states "Investments in knowledge generation have contributed to success in water reform and management over the past 17 years since the NWI was agreed. For example, outputs of the *National Hydrological Modelling Strategy*, first initiated in 2008, are still being applied to water planning, operations and governance processes through the use of eWater Source, a national hydrological modelling platform. However, many other programs of research and development have come to an end, yet water reform is still a work in progress. Further investments in knowledge generation will be key to filling existing knowledge gaps, supporting the ongoing reform process and responding to emerging challenges."

In May 2021, the Commonwealth Government made a budget commitment to improving modelling capability for the whole Murray-Darling Basin. This includes enhanced and integrated river modelling across the Basin, contributing to more timely, accurate and accessible information on which to base water management decisions. The commitment will boost the decision support tools needed to confidently advance water management and transparency in the Murray-Darling Basin. It also responds to a range of reviews and stakeholder feedback that have called for an enhanced modelling capability. This work could be considered an important sub-set of the future NHMS, meeting priority research and innovation and modelling development needs not only of the Basin, but also with some specific opportunities for transferability elsewhere.

There seems to be considerable thought being given to these matters. It will be important to connect with the work by three Australian Academies to provide recommendations to Government about a vision and institutional settings for water related research and development and a costed strategy to achieve it. It is likely that a NHMS would be an integral part of such a broader water research and development strategy.

4.6 Other Matters

Now that Tasmania and the Northern Territory have become members of eWater, eWater membership includes the Commonwealth and all State and Territory Governments in Australia, as does membership of the NWRC. It is now opportune to have a strategic conversation about the NHMS as a truly national strategy and to review eWater's objectives and business model for the future, recognising that the NHMS required is broader than the current Source and eWater products and services and eWater's current and emerging products and services are broader than Source. Whether or not the NHMS-CHA should be amended to include Tasmania and the NT as signatories, will require that further consideration be given to several matters, including participation in a national community of practice, the broader use or not of Source or other platforms, and the existing Intellectual Property clauses in the NHMS-CHA. Such an amendment could also occur with or without changes to the SPA, though access to Source and any associated costs would be a key issue.

In considering the above, it will also be important to recognise that the water agencies in the NT and Tasmania have made limited or no use of Source to date, have relatively few or quite different

regulated river systems, that surface water entitlements are managed in different and in some cases much simpler ways (notwithstanding cases of surface water/groundwater interaction), that they currently have very limited hydrological modelling staff capacity and there are real costs involved in converting any existing models to Source. Nevertheless, there are benefits from involvement in certain aspects of the NHMS, including through the community of practice and modelling lessons associated with such matters as climate change, ephemeral streams (including ecological, economic and social/cultural assessments and responses to development), managing unregulated low flows and surface water/groundwater interactions, managing high flow extractions and floodplain harvesting and associated ecological values (especially in the NT), land use change, catchment and water quality management. Applications in relatively data poor situations are particularly of interest. There are also benefits for future capacity and capability building and for individual professional development, subject to overcoming the funding challenges.

It would be useful to have a fully national water modelling warehouse and scenario recall system and a national repository of datasets and case studies of what may be best practice in particular circumstances, rather than the jurisdictions doing their own thing separately.

The NHMS provides opportunity for peer reviews which assist transparency and hopefully increase confidence in “fit-for-purpose” or “best available” modelling, given that considerable professional judgment is often required. Quality assurance, including in terms of consistency, repeatability and clarity in reporting, is essential. There should be a continuum of how good the model is, and commentary about how uncertainty is addressed, and this moves into levels of confidence about decision making.

Quality assurance of analytical modelling will be important to the NHMS journey. How that could be run nationally and in a suitably advisory, non-competitive way with appropriate governance requires further examination and clarification. How the Open Modelling Foundation (OMF) progresses may influence future approaches to be taken.

Entities like Infrastructure Australia are interested in the NHMS so they have a frame of reference for decision making – a transparent, evidence-based, repeatable process to describe the risk profile of water sources and water using communities and industries and to evaluate project proposals.

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APPENDIX 1 NATIONAL HYDROLOGICAL MODELLING STRATEGY (NHMS), 2018

Preamble

To support better planning and management of water in Australia, the Council of Australian Governments adopted a National Hydrological Modelling Strategy (NHMS) in November 2008. A key output from the NHMS is the Source modelling platform. Source has been developed by eWater in collaboration with Australian governments. Australian governments have agreed to adopt and use Source to support water planning and management. Source and other Australian water knowledge assets need to be implemented, maintained, and further enhanced to keep them evolving to meet the needs of the future. The refreshed NHMS aims to build on the advances made to date in supporting better planning and to provide the enabling framework for this purpose.

Objectives of the NHMS

The NHMS will enable the support services and network to help implement, maintain and enhance hydrological modelling to support better water management across Australia. In doing so, the NHMS will aim to ensure:

1. Governments and other relevant parties work cooperatively and on a national scale to ensure that resources and expertise are coordinated to achieve the hydrological modelling capability required to underpin world's best practice water planning and management in Australia;
2. The hydrological modelling community is ready to meet the priority hydrological modelling needs of governments;
3. Australia's existing hydrological modelling expertise is effectively utilised, further capacity in the field is actively nurtured and developed, and duplication of effort is avoided;
4. The functionality and application of hydrological modelling platforms meet the needs of the Australian community;
5. Appropriate funding is available to support the implementation, on-going maintenance and enhancement of modelling platforms and to develop a strong community of practice; and
6. Australia's modelling capability is exported internationally.

Scope

The NHMS will help maintain and enhance the characteristics of both elements of hydrological modelling — the technical (modelling systems, e.g. Source, MUSIC and others) and hydrological community of practice so that they are able to meet contemporary common modelling needs for policy development, planning, management, operations, compliance, accounting, water markets and forecasting within the water system across a range of applications.

As outcomes, modelling platforms will support:

- water quantity planning, management and compliance (surface water including groundwater interactions);
- river operations;
- impact of climate change/variability on water resources;
- water quality assessment, management and evaluation;
- environmental water management;
- forecasting future water demand and supply (both urban and rural);

- integrated urban water planning, management and operations, and water sensitive urban design; and
- water-coupled socio-economic modelling.

Modelling platforms will be:

- robust, reliable, dependable and repeatable;
- highly automated / efficient work flows;
- relevant for pertinent/key aspects of water quantity, quality and environment;
- suitable for all regions of Australia;
- capable of consistent model development and application;
- adaptable and updateable in the light of new policy, drivers, or knowledge;
- interoperable, flexible and able to link to new and existing models and other information systems;
- professionally created, modern, thoroughly tested and well documented models; and
- able to provide continuity of development and user-support services over the life of the model platform.

As outcomes, the hydrological community of practice will deliver:

- collaboration between governments, universities and research sectors and industry for improving hydrological modelling capability;
- a consistent and coordinated approach to hydrological modelling efforts;
- avoidance of duplication and reduction in inefficiencies including by:
    - collective decision making and investment in the Strategy; and
    - facilitation of collaboration and coordination of national experts and model users;
- consistency of model application, development and documentation;
- transparency of models including their provenance;
- continuous improvement to modelling methods and processes (e.g. model parameterisation, calibration, testing and application); and
- development and innovation in modelling through access to research capacity.

The hydrological community of practice will be:

- strong in capability developed through knowledge sharing, education and professional training;
- portable and collegiate for domestic work; and
- able to avail opportunities from Australia's international activities.

Governance

A national Steering Committee comprising the appropriate Commonwealth and State agencies and other key stakeholders will be established to advise on resources and oversee the implementation of the Strategy.

Reporting and Review

The Steering Committee will annually report on the progress of implementing the NHMS to the National Water Reform Committee.

The NHMS will be reviewed every five years to ensure that it reflects the contemporary needs.

APPENDIX 2 SUMMARY DESCRIPTION OF THE GOVERNANCE ARRANGEMENTS FOR THE EXISTING NHMS

The National Hydrological Strategy Collaborative Head Agreement (NHMS-CHA)

In 2018, (the Parties of) the:

- Murray Darling Basin Authority;
- Australian Capital Territory represented by the Environment, Planning and Sustainable Development Directorate;
- State of New South Wales represented by the Department of Industry (Lands & Water Division);
- State of Victoria represented by the Department of Environment, Land, Water and Planning;
- South Australian Minister for Water and the River Murray represented by the Department for Environment and Water;
- State of Queensland represented by the Department of Natural Resources, Mines and Energy;
- State of Western Australia represented by the Department of Water and Environmental Regulation; and
- eWater Ltd

signed a NHMS Collaborative Head Agreement (CHA) under the National Collaboration Framework with the primary objective to facilitate the efficient and effective collaboration between Australian governments, eWater and possibly other parties through various Projects to achieve the broader objectives of the NHMS including for the development, maintenance, enhancement and application of Source.

The activities that governments, individually or in any combination thereof, could commission eWater to undertake through one or more Project Agreements under the NHMS-CHA can relate, but be not limited, to:

a) support Source implementation and use;
b) provide ongoing maintenance of Source in order to fix bugs, make useability and efficiency improvements, and to improve model performance as identified;
c) provide new functionality required to enable Source implementation and use;
d) maintain code quality and code documentation of Source; and
e) provide collaborative tools and related support for Source users in their agencies.

Subject to the provisions of the NHMS-CHA, the Parties agreed to work and conduct Projects in a manner consistent with the Principles to Collaborate:

- Collaboration and Communication – engaging collaboratively in planning and management; ensuring our communication and feedback is timely, honest, open and effective; and, recognising that each party operates within its own constraints and boundaries;
- Resources - ensuring resources are used efficiently and effectively and integrated (where relevant) with other related programs;
- Decision-making – operating within agreed boundaries, being flexible and adaptable and using objective and factual data as the basis of sound-decision making; sharing and utilising collective learnings.

The NHMS-CHA has an initial term until 30 June, 2023 unless terminated in accordance with the NHMS-CHA.

The Parties agreed to conduct a review of the NHMS-CHA and any Projects commenced under it at least three months prior to the expiry of the initial term. The purpose of the review is to determine whether to extend the initial term of the Collaborative Head Agreement. As part of this review process, the Parties will:

i. evaluate the effectiveness of the NHMS-CHA and any Projects to date; and
ii. consider whether any changes are required to the NHMS-CHA or any Projects.

The initial term may be extended with the unanimous agreement of the Parties. There are two options to renew the NHMS-CHA for five years, with option periods each being five years as follows:

1. 1 July 2023 – 30 June 2028;
2. 1 July 2028 – 30 June 2033.

The Parties agreed that the NHMS-CHA will be managed by a representative body known as the Management Committee.

The Parties agreed that the Management Committee be responsible for the governance and strategic management of the NHMS-CHA which includes:

i. identifying issues or responding to issues raised by Parties that may impact on the NHMS-CHA and identifying and implementing proposed solutions; and
ii. admitting (by unanimous resolution) new parties to the NHMS-CHA (on terms determined by the Management Committee).

Under the NHMS-CHA, the Management Committee is to comprise Representatives (or Alternatives) appointed by each of the Parties. The eWater representative will have an observer status at the Management Committee meetings.

At its meeting 8 in 2019, the NWRC agreed to amend its terms of reference to include oversight of the NHMS and to act as the Management Committee of the NHMS-CHA, with support from the Murray-Darling Basin Authority and an independent hydrological expert.

Under the NHMS-CHA, it is stated that:

a) All parties recognize that open communication between eWater and the Funding Partners is the corner stone of building confidence in and promoting transparency and accountability of eWater.
b) Communication between eWater and Funding Partners in regards to the NHMS-CHA, or any Project Agreement that involves all Funding Parties, will be via the Management Committee, unless otherwise agreed by the Management Committee.
c) Communication between eWater and one or some Funding Parties in regards to a Project Agreement that involves only one or some Funding Parties will be via the management arrangement for that project established by such Funding Parties.
d) The eWater Board will meet with the Management Committee at least once a year on an occasion(s) other than the Annual General Meeting of eWater for strategic conversation on matters relating to the broad direction of eWater, and the Source modelling platform.

The Parties to the NHMS-CHA agreed that each Project that involves all Funding Parties will be managed by a Steering Committee which may comprise representatives appointed by the Project Parties for that Project. The Management Committee or a sub-committee constituted by it may take up the role of a Steering Committee for a Project that involves all Funding Parties. The management arrangement for a Project involving only one or some of the Funding Parties will be at the discretion of the Funding Parties involved that may include a Management Committee's representative by invitation.

In regards to Intellectual Property, the NHMS-CHA states that:

a) Intellectual Property related to Source generated or resulted from any activity undertaken under the NHMS-CHA or a Project Agreement will be merged with the Intellectual Property existing in Source prior to the commencement of this Agreement and will be maintained as a whole.
b) Intellectual Property Rights in Source will continue to be vested in eWater.
c) eWater grants each government party to this Agreement that is also a party to a Project Agreement to support Source development maintenance or enhancement, a permanent, irrevocable, royalty-free, non-exclusive licence (including a right of sublicence) to use, reproduce, communicate, and adapt the Intellectual Property Rights in Source for any purpose.
d) The governments who are granted licence under (c) above may only sublicence the Intellectual Property Rights in Source with the written agreement of the other governments and eWater. The other governments or eWater may, by written direction, place reasonable conditions or restrictions on sublicensing.
e) The governments acknowledge that the licence granted under (c) above does not include a right to commercialize Source.

Finally, the NHMS-CHA and, unless expressly specified to the contrary in a Project Agreement, each Project Agreement, do not create and are not intended to create legally binding obligations between the Parties.

The Source Project Agreement (SPA)

In 2018, (the Parties of) the:

- Murray Darling Basin Authority;
- Australian Capital Territory represented by the Environment, Planning and Sustainable Development Directorate;
- State of New South Wales represented by the Department of Industry (Lands & Water Division);
- State of Victoria represented by the Department of Environment, Land, Water and Planning;
- South Australian Minister for Water and the River Murray represented by the Department for Environment and Water;
- State of Queensland represented by the Department of Natural Resources, Mines and Energy;
- State of Western Australia represented by the Department of Water and Environmental Regulation; and
- eWater Ltd

signed a Source Project Agreement under the National Collaboration Framework with objectives to:

a) support Source implementation and use by Funding Parties;
b) provide ongoing maintenance of Source in order to fix bugs, make useability and efficiency improvements, and to improve model performance as identified by Funding Parties;
c) maintain code quality and code documentation of Source; and
d) provide collaborative tools and related support for Source users in Funding Party agencies.

The SPA is the only existing Project Agreement under the NHMS-CHA that involves all funding parties.

The 2018 SPA had an initial term from 1 July 2018 – 30 June 2019 and two option periods of two years in duration from 1 July 2019 to 30 June 2021 and 1 July 2021 to 30 June 2023.

A Deed of Variation to the SPA was signed by the same Parties in 2019 to amend the initial term to 1 July 2018 – 30 June 2021 and provide one option period of two years in duration from 1 July 2021 to 30 June 2023,

Detail of the work undertaken each year over the term of the SPA are specified in a summary form in an Annual Operating Plan. Main activities undertaken under the SPA include to:
a) maintain and improve the Source modelling platform;
b) enable configuration and customisation of Source for applications in selected river basins across Australia; and
c) provide professional user support for Funding Partner staff, including on-line collaborative tools and supporting documentation.

The SPA provides for a Steering Committee which reports to the Management Committee of the NHMS-CHA. It also provides for the establishment of a Technical Support Group (TSG), to support the short-term prioritisation of maintenance needs and support collaboration between Project Parties.

The Steering Committee has one representative and an alternative from each Funding Party, nominated by the relevant Funding Party. (The representatives do not have to be employees of the Project Parties.) The MDBA representative chairs the Steering Committee and eWater has only an observer status at the Steering Committee.

The MDBA provides executive support to the Steering Committee and maintains the records of its meetings. Decisions of the Steering Committee are by consensus.

The Steering Committee may from time to time by unanimous resolution decide to admit a new party to SPA on terms determined by the Steering Committee.

The Steering Committee is responsible for the administration of the SPA including:
a) approval of the Annual Operating Plan;
b) monitoring co-ordination of operational activities and processes as established through the Annual Operating Plan;
c) approval of the Annual Report (containing the succeeding Annual Operating Plan);
d) providing strategic direction to the Recipient (eWater);
e) noting progress against the milestones;

f) receiving notification of release of funding;
g) the governance and strategic management of the SPA;
h) addressing cross-jurisdictional issues and conflicts referred to it and recommending corrective action through appropriate negotiation and/or escalation;
i) negotiating and tracking any contributions between Project Parties;
j) managing any changes to the Project or the SPA;
k) reporting to the Management Committee of the NHMS-CHA;
l) identifying and administering the policies and procedures for:
(i) Data ownership, definition, access and transfer protocols;
(ii) Data quality and integrity standards;
(iii) management of and access to Data;
(iv) protection of Data;
(v) technical standards for information transfer/access;
(vi) authentication of Data by the receiving Project Party;
(vii) operating infrastructures and transmission protocols;
(viii) quality assurance systems;
(ix) performance control system;
(x) performance audits; and
(xi) co-ordinating the Risk Management Plans.

Under the SPA, eWater is responsible for:

i. undertaking the Source development and maintenance work as specified in the Annual Operating Plan and in any variation communicated to it by the Steering Committee or any relevant Sub-committee;
ii. providing material, personnel, equipment and other essential resources required to complete the agreed work;
iii. delivering milestones as specified;
iv. preparing and submitting to the Steering Committee all reports and papers including any amendment required in relation to the Project;
v. following any direction or guidelines of the Steering Committee for preparing any paper or report, if not specified in the SPA;
vi. invoicing each Funding Party directly; and
vii. ensuring transparency and accountability in its dealing with Funding Parties and in communication to the Steering Committee, in particular,
(A) doing all things necessary to ensure that all payments from the funding that eWater makes to third parties (including subcontractors) are correctly made and properly authorised and that eWater maintains proper and diligent control over the incurring of all liabilities;
(B) ensuring that the funding is held in an account in eWater's name and it solely controls, with an authorised deposit-taking institution authorised under the Banking Act 1959 (Cth) to carry on banking business in Australia;
(C) unless otherwise specified, ensuring that the account referred to in clause (A) above is:
(I) established solely for the purposes of the activity under the SPA;
(II) separate from eWater's other operational accounts; and
(III) an account that complies with any other requirements specified in the SPA;
(D) notifying the Funding Parties, prior to the receipt of any funding, of details sufficient to identify the account;

(E) if the account changes, notifying the Funding Parties within 10 business days of the change occurring, provide the Funding Parties with details of the new account; and
(F) Identifying the receipt and expenditure of the funding separately within eWater accounts and records so that the funding is identifiable at all times.

eWater Ltd

eWater Ltd is a not-for-profit enterprise owned by the:

- Commonwealth Government, represented by Murray Darling Basin Authority;
- Australian Capital Territory Government, represented by the Environment, Planning and Sustainable Development Directorate;
- New South Wales Government, represented by the Department of Planning, Industry and Environment;
- Victorian Government, represented by the Department of Environment, Land, Water and Planning;
- South Australian Government, represented by the Department for Environment and Water;
- Queensland Government, represented by the Department of Regional Development, Manufacturing and Water; and
- Western Australian Government, represented by the Department of Water and Environmental Regulation.

eWater Ltd was initially created as a company to manage the eWater Cooperative Research Centre (CRC) that was formed in 2005 by merging two CRCs—the CRC for Catchment Hydrology (1992-2005) and the CRC for Freshwater Ecology (1993-2005).

Post the cessation of the eWater CRC, from July 2012, eWater has been a limited by guarantee public company with a membership-based constitution. Its initial members were the Commonwealth Government and State governments of NSW, Victoria, Qld and SA. Subsequently, the governments of the ACT and WA became members. More recently, the governments of Tasmania and the Northern Territory have become members.

However, under its constitution, the number of members of eWater is unlimited. In considering an application for membership, the eWater Board will:

a) consider whether the organisational objectives and activities of the applicant are consistent with the Objects of the company; and
b) seek and consider the views of the existing members.

Under its constitution, the Objects for which the company is established are to support the environmentally sustainable use of water in Australia and around the world, primarily by building capability in water resources modelling and management. Activities undertaken to achieve the Objects include, but are not limited to:

i. Developing and supplying water modelling software, and other technologies and data that strengthen its application and utility;
ii. Providing support to users to set up, further develop and apply modelling software;
iii. Research, education and training required to maintain and improve modelling software and software applications capability;
iv. Providing advice to public and private water management organisations and water users;

v. Continuing any of the activities of the eWater CRC and its predecessors, including developing and supplying intellectual property from these organisations; and
vi. Any other activities reasonably required to meet the Objects of the company.

The income and property of the company is to only be applied in furtherance of the Objects and no portion shall be distributed directly or indirectly to the members of the company except as bona fide compensation for services rendered or expenses incurred on behalf of the company. eWater has a status of a 'not for profit' organisation registered with the Australian Taxation Office (ATO).

eWater is governed by a board of directors (the Board) consisting of up to six Directors and a Chairperson. Under the constitution, the Board should contain at least three directors who are independent of the members, and one of whom must be the Chairperson. All directors must be appointed by the members by election at a general meeting. In nominating and appointing directors, the Board and the members endeavour to ensure that the Board includes:

a) at least three persons experienced in the field of water science and/or management; and
b) persons with other relevant expertise and experience including:
   i. corporate governance, finance and/or risk management;
   ii. commercialisation of intellectual property, especially software;
   iii. research, education and/or training; and
   iv. international affairs, development and/or commerce.

A director who is an employee or a director of a member may not disclose to that member any information (confidential or otherwise) about the affairs, finances and accounts of the company that comes into the director's possession from time to time, without the approval of the Chairperson. In reaching a decision, the Chairperson will reasonably consider whether:

a) the exercise of such a right is inconsistent with the constitution or the director's fiduciary or other legal duties; or
b) the Board, acting reasonably and in the best interests of the company, has directed that such information not be disclosed to the relevant member.

The Board sets the strategic direction for the company, manages risks and delegates the operations to the Chief Executive (CEO).

Initially, eWater's main role was to develop and support the implementation of Source. However, it now operates through its two unincorporated subsidiaries—eWater Solutions (eWS) and the Australian Water Partnership (AWP).

The modelling tools provided by eWater comprise:

- Source;
- MUSIC;
- Urban Developer;
- eWater Toolkit; and
- Water Quality Analyser.

More information about these tools is provided in Appendix 4 and on the eWater website– www.ewater.org.au.

eWS is responsible for the operational delivery of the eWater software and modelling business incorporating the products and services relating to Source and the 'Toolkit' suite of water and environmental management tools and resources. The most widely used tool under the Toolkit is the stormwater modelling product, MUSIC.

The AWP is the Commonwealth Government's Department of Foreign Affairs and Trade (DFAT) initiative for sharing Australia's water sector expertise in the Indo-Pacific region through co-investment and fee for service collaborations where appropriate. eWater has been contracted by DFAT as the AWP's implementation partner.

Consequently, eWater's operations are broader than those covered by the NHMS-CHA and the SPA. eWater also receives funding from sources outside the SPA including:

- Separate contracts with governments for assistance with Source;
- Training Courses (including through the eWater Academy and ICE WaRM – the International Centre of Excellence in Water Resources Management, now owned by eWater) and software licensing fees (noting that eWater also manages other software products including MUSIC for use in water sensitive urban design);
- Fee-for-service projects for clients such as the World Bank and Contracting State-Owned Corporations (i.e. Melbourne Water, WaterNSW, SA Water etc); and
- DFAT for AWP and other activities.

Staff of eWS comprises the Chief Executive Officer and just over 20 others, who are mostly hydrologists and software developers.

The National Water Reform Committee

The National Water Reform Committee (NWRC) is an interjurisdictional committee that considers and progresses national water reforms as detailed in its agreed work program to progress the National Water Initiative and other national agreements. The work program promotes sustainable water use across Australia to enhance social, human health economic and environmental outcomes for current and future generations, and sustainable water management through inter-jurisdictional development, oversight, coordination and implementation of water reform policy.

The NWRC has been established by Commonwealth, State and Territory ministers with responsibility for water. The NWRC provides an advisory and oversight role for all ministers.

Current membership of the NWRC comprises representatives from the:

- Commonwealth Department of Agriculture, Water and the Environment;
- Qld Department of Regional Development, Manufacturing and Water;
- NSW Department of Planning, Industry and Environment;
- ACT Environment, Planning and Sustainable Development Directorate;
- Victorian Department of Environment, Land, Water and Planning;
- Tasmanian Department of Primary Industries, Parks, Water and Environment;
- SA Department for Environment and Water;
- WA Department of Water and Environmental Regulation; and
- NT Department of Environment, Parks and Water Security.

The NWRC is chaired by a representative of the Commonwealth Department which also provides the Secretariat. The NWRC meets three times a year or as otherwise agreed and decision-making is by consensus.

Note that not all of these organisations/jurisdictions are Parties to the NHMS-CHA and eWater is not a member of the NWRC (though it is meant to have observer status on the NHMS-CHA Management Committee).

Members from the Bureau of Meteorology, CSIRO, the National Water Grid Authority and the Productivity Commission provide guidance and expertise to the Committee and have observer status only. Observers may participate in meetings at the invitation of the NWRC.

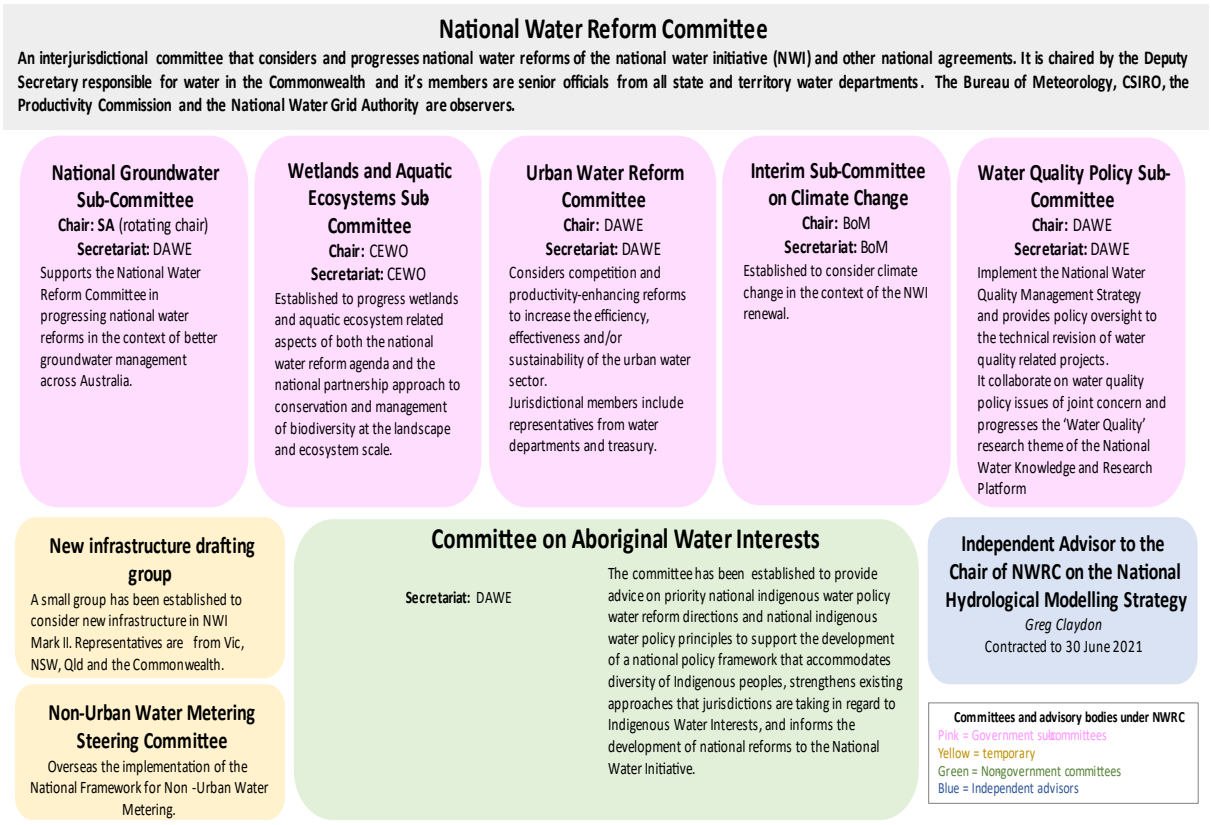
Bodies subordinate to the NWRC mainly take the form of sub-committees. The NWRC may establish and/or dissolve whatever sub-committees it considers necessary to achieve its objectives on an as-needs basis. As at March 2021, the endorsed supporting committees are:

1. National Groundwater Sub-Committee;
2. Water Quality Policy Sub-Committee;
3. Wetlands and Aquatic Ecosystems Sub-Committee;
4. National Urban Water Reform Sub-Committee;
5. Interim Sub-Committee on Climate Change;
6. Committee on Aboriginal Water Interests.

As agreed at NWRC 8, the NWRC acts as the Management Committee for the National Hydrological Modelling Strategy, with support from the Murray-Darling Basin Authority and an independent hydrological expert.

A summary of the NWRC arrangements is shown in the diagram below.

National Water Reform Committee: committees and advisory bodies



APPENDIX 3 – SUMMARY OF FUNDING ARRANGEMENTS FOR THE NHMS AND EXISTING SPA

The 2017 due diligence review of the NHMP (MDBA, 2017) quoted that, up until that time, a total of $23.2 million had been invested in the Source platform by partner governments. This did not include the research and development that occurred during the CRCs. The review suggested that the total investment in the Source platform was likely to be in excess of $50 million (with some people later suggesting it is in excess of $60 million).

Under the 2018 SPA, funds of $1.065 million were provided by partner governments to eWater in Financial Year 2018-2019 (FY 19) for activities under the SPA.

The 2019 Deed of Variation for the SPA foreshadowed funds of $2.138 million in total in FY20 and FY21

Under the SPA Annual Operating Plan (AOP) for FY21, eWater will provide the services to each Funding Party at a Tier 1 Level of Service except where a Funding Party has nominated otherwise. A Tier 1 Level of Service comprises:

- Resources for bug fixing, maintenance and administration as nominated in the AOP;
- New development resources as nominated in the AOP;
- Wiki priority page considered in sprint planning and prioritisation voting rights at the Technical Support Group (TSG);
- Membership of the SPA Steering Committee;
- Source Beta and Production Release Domain License for Funding Party Domain;
- Access to development systems including issue tracking, on-line documentation and continuous integration server;
- Continued IP Access via NCF or eWater Ltd Company Membership

Where a Funding Party has nominated to receive a Tier 2 Level of Service, eWater will provide the services to that Funding Party at a Tier 2 Level of Service. A Tier 2 Level of Service comprises:

- Resources for bug fixing, maintenance and administration as nominated in the AOP;
- Membership of the SPA Steering Committee;
- Observer (non-voting) status at the TSG;
- Source Beta and Production Release Domain License for Funding Party Domain;
- Access to development systems including issue tracking, on-line documentation and continuous integration server;
- Continued IP Access via NCF or eWater Ltd Company Membership.

The high-level objectives of the SPA Annual Operating Plan for FY21 are:

- support Source implementation and use by Funding Parties;
- provide ongoing maintenance of Source to fix bugs, make useability and efficiency improvements, and to improve model performance as identified by Funding Parties;
- provide new functionality required to enable implementation of Source in preparation of Water Management Plans by Funding Parties;
- maintain code quality and code documentation of Source;
- provide collaborative tools and related support for Source users in Funding Party agencies;

- Document and report on levels of effort expended in the areas of maintenance, bug fixing, new features and community and Project administration.

For FY21 the Source Community of Practice includes the annual Source conference as the main community event for the year and maintaining collaboration tools.

For FY21, funding tiers in the SPA Annual Operating Plan have been nominated as follows:

Jurisdictions	Tier 1 Budget	Tier 2 Budget (75%)	Nominated Tier
MDBA	$500,000	$375,000.00	1
NSW	$186,874	$140,155.50	1
VIC	$144,496	$108,372.00	1
QLD	$118,630	$88,973.50	2
SA	$50,000	$37,500.00	1
WA	$55,000	$41,250.00	1
ACT	$14,000	$10,500.00	1
Total	$1,069,000	$801,750.00	

This provides for a total FY21 budget of $1,039,343 and approximately 4.0 FTE of effort in FY21. These ratios translate to an estimated apportionment of resources as shown below:

Task	Estimated FTE FY20	*Actual FTE FY20	Estimated FTE FY21
Administration	0.2	0.2	0.2
Bug Resolution	1.1	0.9	1.1
Community of Practice	0.2	0.18	0.2
Maintenance	2.1	2.12	2.3
New Development	0.2	0.38	0.2
Total	3.8	3.79	4.0

Capability/skills area	Estimated FTE FY 19/20	*Actual FTE FY 19/20	Estimated FTE FY 20/21
Hydrology/ Documentation	0.9	0.8	0.9
Software development	2.9	2.99	3.1
Total	3.8	3.79	4.0

* Estimates have been used for the month of June.

Funding partner Governments may engage eWater to undertake additional work on a fee-for-service basis in the areas of:

- Generic training;

- Custom or in-house training;
- Capacity building; and
- Additional software development.

A list of any such additional work and associated funding has not been compiled for the purposes of this Final Report. However, one funding partner Government quoted an expenditure of almost $1 million since 2015-2016 on additional bespoke Source software development.

It is also important to note that the adoption and implementation of Source software for a particular water system (catchment or river valley) is an activity separate from its software development and maintenance by eWater. While eWater supports that activity (through software development, enhancement and maintenance), it is the responsibility of the MDBA and relevant Government agencies to develop Source models for their systems. That hydrological modelling work requires significant human and financial resources and substantial technical knowledge, experience and skill within those agencies.

The quantum of funding to be provided under the SPA (and, indeed the option to extend the SPA) beyond 30 June, 2021 has only recently been agreed by the Funding Partners and eWater.

APPENDIX 4 – SUMMARY OF EXISTING EWATER PRODUCTS

The modelling tools provided by eWater comprise:

- Source;
- MUSIC;
- Urban Developer;
- eWater Toolkit; and
- Water Quality Analyser.

Further details are available on the eWater website - – www.ewater.org.au.

Source is the only tool directly covered by the National Collaboration Framework (via the NHMS-CHA and the SPA), though the other tools have either been connected with Source in the past or are now being increasingly connected. Source has more than 3000 users in total in every State and Territory of Australia and about 2500 users internationally.

Source is a modelling platform with planning, operations and forecasting modes. It is eWater's definitive integrated water resource management (IWRM) modelling software with varying levels of capability for:

- integrated water resource assessments and analysis of water supply and demand balances, including agricultural, hydropower, urban, industrial and environmental requirements and demands;
- water balance studies from catchment to river basin scale;
- water accounting and analysis;
- river operations, encompassing low to high flow events, salt loads and system optimisation;
- inflow forecasting and multi-objective reservoir operations;
- resource assessment and allocation policy development and planning;
- trade-off analysis to balance sharing and equitable use of scarce water resources;
- low flow and drought management (not directly, but through derived analysis perhaps based on the modelling outputs);
- water quality analysis based on catchment land use scenarios;
- impacts of climate change (with data inputs and analyses from elsewhere) and transboundary transfers;
- urban water systems optimisation, planning and operations including analysis of multiple supply options (reservoir/recycling/stormwater/desalination); and
- conjunctive groundwater-surface water use analysis.

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is Australia's leading tool for water sensitive urban design (WSUD) and analysis.

Across Australia, urban developers, planners, engineers, Local Governments and development approval agencies use MUSIC to manage the impact of urban development and other land use changes on waterways. Some Local Governments and jurisdictions have mandated MUSIC for designing large-scale urban developments.

MUSIC can model a wide range of treatment devices to identify the best way to capture and reuse stormwater runoff, remove its contaminants, as well as reduce runoff frequency. With MUSIC water treatment devices can be evaluated to achieve WSUD and integrated water cycle management (IWCM) goals.

MUSIC enables users to:

- simulate urban stormwater systems from the individual lot to suburb scale;
- estimate the potential for stormwater harvesting and reuse and understand the effects on downstream flows and water quality;
- model pollutants, including suspended solids, total phosphorus and total nitrogen;
- compare the water-quantity, quality and cost/benefit objectives of different treatment options, such as swales, bio-retention system, rainwater tanks, wetlands;
- design urban development proposals that meet WSUD standards.

In May 2020, eWater released a new version of MUSIC – MUSICX. MUSICX has been re-designed and re-written into the same coding platform as Source. MUSICX maintains all the capability of earlier versions of MUSIC but gives users additional functionality and the benefits of modern software architecture, making it easier to update the tool and incorporate new industry practices, knowledge, data and science.

It is very important to note here that no new science has gone into MUSICX – the work has been around recoding in a more sustainable coding platform and changes in some functionality. It does have some future potential through integration into Source models, but there are some significant issues to resolve (e.g. changes in scale between MUSIC models and Source models) even though this functionality is being actively promoted.

MUSICX can be run as a stand-alone tool or as a plug-in to Source. Integration of MUSICX with the Source platform provides overall functionality and features, with variable capability, such as:

- additional rainfall-runoff modelling options (recognising that these have not been validated with the pollutant export algorithms within MUSIC, so that the original science underpinning MUSIC may not necessarily be upheld in these versions);
- user plug-ins to replace in-built algorithms for rainfall-runoff, pollutant generation, treatment function, and demand functions;
- options to model other pollutants;
- a Graphic User Interface (GUI) for data input, tabular input/output, group edit and advanced graphics;
- a Function Manager to support more complex model building;
- an in-built Results Manager for further data analysis and results interpretation, if required by users beyond wanting to know if they have achieved the relevant development objectives for water quality.

Urban Developer provides for in-depth analysis of urban water demand, to improve water efficiency and consider alternative water supplies.

One proven response to diminishing water supply is an integrated approach to water resource management. In this method, water managers consider all demand and supply elements of the

urban water cycle to make the best use of all possible water sources (potable water from reservoirs, groundwater, desalination and elsewhere, stormwater, wastewater and recycled water).

The Source Urban Developer plug-in is designed to specifically help water managers investigate and design IWCM solutions in urban areas. Elements of the urban water cycle can be brought together within the tool to study interactions between all water sources, across a range of temporal and spatial scales and explore such questions as:

- How much water is being used by different types of households?
- What are the most effective efficiency options?
- What opportunities exist to use alternative water supplies, such as rainwater tanks or recycled stormwater?
- How much can we reduce our need for traditional reticulated water supplies?

IWCM requires a holistic approach to water quality and quantity, across all scales. By combining three of eWater's tools: Source, MUSICX and Urban Developer, water managers have a means to design integrated water management solutions. Designed to complement each other, MUSICX and Urban Developer are able to draw together information on water quantity (Urban Developer) and water quality (MUSIC) to develop IWCM solutions in urban areas. These models can now be linked to Source catchment and river system models, providing the tools to explore possible interactions and to identify and test IWCM options across catchment and local scales.

The eWater Toolkit is an online resource of hydrological, ecological and catchment management models, databases and other resources produced by eWater and its partners over more than 20 years. Most of the tools are available as freeware. Access to Source and MUSIC is also through the Toolkit. The Toolkit has more than 12,000 members from over 120 countries.

Toolkit membership is free. In addition to the tools, membership provides access to the eWater community forum, supporting documentation, updates and news.

eWater has upgraded many of the most popular Toolkit products to plug-ins that can be used with the freely available public version of Source. Known as community plug-ins, these are available through the eWater Wiki. Community plug-ins are available for many different purposes, including incorporating different rainfall-runoff models, water quality management and processing data.

Community plug-ins are compiled and distributed with Source, however they are not actively maintained by the development team. Community members are welcome to add plug-ins to this list and share them with other community members. The eWater core software development team does seek to ensure that, with each new release of eWater software, the plug-ins are re-compiled against each released version so that the process doesn't need to be completed manually each time there is a new release. For individuals to add their plug-in into the community plug-ins that are compiled and distributed they need access to the Source code.

(There were some comments that this is probably one of the biggest disappointments in the deployment of Source. The plug-in architecture is a potential "crowd sourced" platform of model development if it is actively supported. As there is no commercial return on it, basically it has been left to its own devices. Source users realise that financial constraints are the reason for this, but it has the potential to significantly increase the capability of the platform, if the plug-ins could be

more actively managed. While this may require significant resources, it could be evaluated whether this could be cost-beneficial over the long term.)

Water Quality Analyser is for water managers, scientists and engineers who need to monitor in-stream water quality, estimate pollutant loads or set water quality targets. It provides an interface that brings together an array of tools to:

- collate water quality data from multiple sources;
- process data;
- analyse water quality data and identify trends;
- compare water quality data with statutory guidelines;
- visualise water quality data;
- synthesise data for reporting.

Water Quality Analyser is used by State and Local Governments, natural resource management agencies and research institutions as well as by consultants, landholders, and community-based groups.

Water Quality Analyser allows users to search the database for relevant guidelines, and then tests actual time series data against the guidelines. It builds on default guideline values under the National Water Quality Management Strategy as well as some State-specific values.

APPENDIX 5 – DETAILS OF COMMENTS PROVIDED TO THIS REVIEW

This appendix outlines "what I heard" from my many discussions, any written comments provided, and a review of documentation made available.

Invariably, there has been some interpretation on my part, especially from the original videoconferences and teleconferences, so further input and suggestions for clarification were obtained through feedback on the earlier draft Issues Paper and the earlier Draft Report. This appendix incorporates that feedback.

A5.1 General and Over-Arching Comments

It was agreed that it is timely to review the NHMS, its achievements against its objectives (original and revised) and its future. This is especially the case since the National Water Initiative (NWI) is in the process of review and discussions are being held about how best to "refresh" the NWI. This is also in recognition that having well-established national hydrological modelling capacity and capability provide essential underpinnings to both the existing and any future NWI.

There was strong support for having a NHMS – the key challenge is to how to make it work most effectively and efficiently. Specifically, many felt that the NHMS structure and deliverables, and the roles and responsibilities of the leadership and management groups need to be better defined so the strategy can be implemented better, and that it needs to have a home (ownership) and stable (known) ongoing funding.

All agreed that the NHMS is broader than Source and eWater, and eWater is now broader than Source. However, the benefits of having a nationally compatible and coherent hydrological modelling platform and the skilled human capacity around that to inform often complex and contested decisions about water entitlement and water security planning and management, water resources management, river operations, water accounting, water quality management and the like are compelling. Nevertheless, the NHMS is not just a tool - it has and needs to have the best available science and hydrology incorporated. Appropriate data collection and maintenance is also an important NHMS action, because, without good data, and without making best use of the data you have, improvements in the other components are somewhat pointless.

The common platform has helped with communication and understanding and has provided a recognised form of practice which has some "authority". This has assisted not only water resources planning and management but also defence of some decisions, including in legal settings.

It was generally accepted that the hydrological modelling required for basin-wide water resource planning and river system operations and the like is complex, and with that complexity comes higher costs than might otherwise be the case, but there are still questions for some as to whether the current SPA costs are excessive, mitigating value for money.

The existing governance arrangements for the NHMS-CHA, SPA and eWater are somewhat convoluted and that adversely affects transparent communication, collaboration, coordination and fully informed and informative decision-making.

Overall, though it has taken longer than originally envisaged, the Source modelling platform has been developed to a level where it meets the vast majority of the current water resource planning and river system operations modelling needs of the existing Funding Parties to the existing SPA and offers benefits to other Governments who are not signatories to the NHMS-CHA nor the SPA, but are now members of eWater.

How and why the NHMS is taken forward, including what is its strategic direction and what is needed to get there, by whom and at what costs for what benefits, are now matters requiring timely consideration. External stakeholders are also keen to be involved in that conversation with Governments.

In that context, the NHMS should not be about duplicating existing activity, rather it could be seen as providing the glue that brings existing activity together, providing line of sight to what is happening across agencies, research, and practitioners.

A5.2 Comments About What Is Working Well

The fact that eWater is still in operation almost nine years since the closure of the eWater CRC was seen by some as a positive achievement in itself. This is partly because eWater has developed additional lines of activity other than the development and maintenance of the Source platform for jurisdictional funding partners. Some of this has also been enhanced by its relatively strong profile in some areas internationally and recognition of the positive diplomatic connections that provides to Australia.

That the 2018 NHMS-CHA has included options for recommitment and extension to 2033 was also seen positively.

Significant progress with the NHMS, and Source, in particular, has been observed over the last decade. Source has been increasingly accepted and can handle most existing water resource planning and river system operations situations so conversions to it have been increasingly happening. Documentation, including user guides, reference guides and notes, has been increasing and is generally of good quality, though there are some challenges in quality assurance, version control (very important for legislated models), and keeping documentation up to date as software and functionality changes and new plug-ins are made.

People who have invested in Source have benefitted from that investment, though there were variable views on the resultant “value for money”.

Generally, it was felt that, of the six objectives of the NHMS, 2018 (Appendix 1), three objectives – objectives 1 (cooperation and coordination to achieve hydrological modelling capability), 4 (functionality to meet needs) and 6 (capability exported internationally) were largely being met. However, some thought there was still room for greater cooperation and coordination to be truly effective. Some view objective 6 as a “bonus” and not a “core” objective, running a risk of being pursued at the expense of other objectives, while others have seen it as essential to “keep eWater’s lights on”. These objectives either relate directly to the development of the Source modelling platform; or are a consequence of it.

Notwithstanding some challenges (see sub-section A5.3 below), overall, most partners believed that Source development is sufficient to inform current priority water planning and management activities and has ended up progressing well. There have been formal arrangements for cooperation and collaboration between Australian governments and a dedicated organisation - eWater to achieve this result. The "contractual" arrangements under the earlier versions of the NHMP and now the SPA have generally been successful at an operational level and generally technical level coordination has been and continues to be very good. For example, the Technical Support Group under the SPA has been working well, setting priorities for maintenance, and eWater's existing software team has been highly regarded.

Bespoke one on one contracts under the NHMS-CHA with eWater for new software development and enhancements (which cover almost all new software development cases these days) have been reported to have run very smoothly in the vast majority of instances. These new capabilities in Source, usually in the core code but also in the form of plug-ins, also can and often do bring benefits to others but funding is often needed to generalise the enhancements for broader use and it is often difficult to obtain funding for that (and, indeed, agree on who should pay). Some felt that the more recent connections with Urban Developer were particularly good.

Some jurisdictions have internal capacity for bespoke software developments – each jurisdiction likely has some bespoke needs to fit their particular water legislation and water resource planning and management needs. Nevertheless, some thought that there were opportunities for eWater to take more initiative in coordinating and delivering cross-jurisdictional software development needs. There were some comments, also, as to the lack of clarity about where all the bespoke work is leading – i.e. what is the strategic direction and are all the enhancements going that way?

Common interests and economies of scale, particularly for modelling software for water resource planning, have largely been realised. Partners realise that what they get out reflects what they put in, and they can proactively contribute to priorities and approaches. (This can also be an issue, i.e. catchments can be overlooked without proactive input.)

Major functionalities of Source for general water resource planning and river systems operations applications have been developed; tested and stabilised (stability is credibility) and Source has essentially entered the maintenance mode for those functionalities. The software support group at eWater has been well organised and well led and responsive. Nevertheless, it is recognised that Source (software) development is an on-going work-in-progress, whereby constant updating and potentially (re)development and enhancement work are required to keep it abreast with technology and evolving needs. An example where further integration and development are required is at the Murray-Darling Basin scale.

However, some argued that there is a growing tension between the need for stability and version control for legislated models with the release of new versions of the software. The latter sometimes changes the model output and may introduce bugs which must be picked up by the jurisdictions and then fixed by eWater. When eWater is working on those fixes, it is not working on other maintenance or new development as the SPA or other contracts require.

Source has been developed to the point that it has been able to be widely adopted and implemented in the Murray-Darling Basin jurisdictions (as distinct from whole-of-Basin) and more

broadly across Queensland, South Australia and Western Australia and implementation is progressing in other parts of New South Wales and Victoria. There was a suggestion, or perhaps more correctly a stated perception, from some, since specific evidence was not provided, that, overall, across the nation the pace of adoption has been way too slow for whatever reasons – lack of resources, leadership, commitment by water management agencies based on priorities? Nevertheless, adoption has supported consistency, transparency, transferability and the sharing of approaches and information.

MUSIC has continued to grow (though improvements in its fundamental science inputs have lagged) and connections of it and Urban Developer with the Source platform have been made. MUSIC provides cash (e.g. gross income of up to$1.0 million to $1.5 million per year) to help keep eWater operating, to reduce calls for other funding and to reinvest, though this is not widely recognised under the NHMS.

There were variable views on the community of practice. While most thought it was working ok as a Source community of practice – limited to surface water modelling and Source – it hasn't really progressed to water quality and urban water modelling and the like, which may be important elements of a NHMS broader than but related to Source. That is, there is no NHMS community of practice per se.

Nevertheless, jurisdictions have been working together on particular pieces of work of common interest, learning from each other and more people are gaining modelling understanding and experience as a result.

It was recognised that some jurisdictions (e.g. Qld, NSW and Victoria) have relatively recently started their own water modelling networks/hydrological modelling communities of practice and these seem to be working very well within the respective jurisdictions. The work of the Queensland Water Modelling Network since 2017, the NSW Modelling and Monitoring Hub and the Victorian Hydrological Modelling Group was cited by many as particularly helpful and provided an example of what can be done with the necessary investment and effort. However, eWater's and other jurisdiction's involvement or invitations for involvement in these positive initiatives have generally been seen by them to be limited or absent.

eWater and others have been successfully exporting Australia's modelling capability internationally, particularly in the Asia-Pacific region. The Department of Foreign Affairs and Trade (DFAT) has been a key enabler in this endeavour. Continuous Government support in terms of finances, formal working arrangements (e.g. contracts/national collaboration framework agreements and a steering committee) and a dedicated organisation (eWater) have been instrumental in this success. The Australian Water Partnership (AWP) has also assisted international connections in water matters. Facilitating that more broadly than eWater and/or the AWP is also important for Australia's international modelling capability and credibility.

A5.3 Comments About What Is Not Working Well

A5.3.1 Strategic Direction and Governance

The NHMS as per its name and content is a strategic policy-level document. Its scope is wider than Source (as a tool or technology or technical platform). However, it was unclear if it was perceived that way at all levels in all jurisdictions. A key driver behind asking the NWRC to take "management ownership" of the NHMS was to lift the level of conversation from technical/operational level issues to strategic and policy level issues. However, it has taken more than two years to make some headway in this direction, noting that the NWRC has a full agenda and may not have the current wherewithal to provide the necessary strategic direction. Some felt that the things that were not working well were all issues resulting from or incidental to this gap in considerations. Whether or not the independent advisor role can effectively improve the situation is a current open question.

While the development and signing of the NHMS-CHA has been acknowledged as a significant step forward, at the moment there is only one project under the NHMS-CHA that involves all funding partners - the SPA. It was envisaged that other projects could also fall under the NHMS-CHA, to implement additional functionality for all or subsets of the partners with similar interests. There were reports of times when NHMS related developments have been proposed by one party only to hear that another party had already developed and implemented a large part of it. While this is arguably somewhat a good outcome from the NHMS perspective, a specific project agreement under the NHMS-CHA could have been established to increase collaborative opportunities and get better value from partnered projects. It was not clear where or who was best placed to facilitate these opportunities for collaboration – e.g. broadly under the NHMS (NWRC) or more narrowly through eWater? In any event, there is a need for all players to have a voice in these deliberations, including the Funding Parties and eWater, and likely others, e.g. CSIRO, Geoscience Australia and the BoM, who are progressing innovations of relevance to the strategic nature of the NHMS.

The governance arrangements involving the SPA Steering Committee, eWater Board and the NWRC as the management committee for the NHMS seem to be somewhat convoluted, with reports of disconnects between eWater and its owners/major funders, both in strategy and direction. Are the right decisions being made in the right places at the right times for the right reasons? This has implications for clarity in roles, responsibilities and accountabilities. It also has implications for communications and relationships, including seeing the NHMS as a "partnership initiative", as outlined further later in this Sub-section.

Several people observed that eWater seems to have potentially conflicting objectives under the current arrangements: to provide (develop and maintain) a national approach to surface water modelling on a platform; and to be commercially viable (including by selling platform products). Source is being increasingly used by Governments, but it is less used by the private sector. Some felt that the private sector is beholden to a commercial enterprise as State approved water planning and river operations models have to be in Source and so consultants, including to the private sector, are forced to use it commercially.

Some commented that, for them, the conflict is within the business arrangements for eWater, which is being funded for Source, in particular, largely by public money, and whereby eWater actively competes for commercial contracts for providing consultancy services against private companies in some cases. Those same private companies have to pay eWater to use the software that is being used by eWater to compete against them in such cases. That can be a significant issue, though perhaps similar to universities and private industry competing for commercial contracts.

Others similarly observed that eWater's potentially conflicting objectives include their need to be commercially viable by not only selling products, but also by providing consultancy services in competition with consulting companies who are users of eWater products, especially Source, in some cases. This has the potential to cause conflicts of interest as well – as eWater can maintain a position of advantage through their knowledge and limited-disclosure of the internal workings of their products. A common issue raised by modellers was that the internal workings of Source are not yet fully documented. Such information can only be accessed by contacting eWater and eWater's software developers may need to review the program code to answer such questions.

How to best manage the collaboration/partnership and commercial conflicts, what that may mean for eWater's role, business, finances and future, and the "closed" or alternative "open" nature of the Source platform were commonly raised topics. There were a broad range of views from the status quo, to pursuing a bigger business and platform, and alternatively, to reducing to a leaner business and platform. There was variable support for an "open source" software environment, supporting innovation and industry, for example. Some had significant concerns with such an environment, due, for example, to risks of inadequate checks and balances and modelling integrity. Clarifying and resolving this requires substantially more conversation, analysis and deliberation by Governments, eWater and the private sector. Some further comments are made in Sub-section A5.3.2 below and in Sub-section A5.6.

It was noted that, to date, the NWRC meets relatively infrequently, and this may have implications on what decisions need to be made, how and when. What is the NWRC's role in endorsing or otherwise decisions made by others?

A5.3.2 Extent and Scope of the NHMS

Despite the recent inclusion of Tasmania and the Northern Territory as members of eWater, and the opportunities that may create, the NHMS itself is not yet fully national. With the exception of WA, all Government partners in the NHMS-CHA at present have catchments within the Murray-Darling Basin (MDB) with a relatively high management and modelling effort, and so the NHMS still gets labelled in some quarters as largely a MDB thing involving purely technical matters synonymous with Source development. This perception can be exacerbated in some quarters since the MDBA (being a Commonwealth agency but not the Commonwealth Department responsible for water matters) chairs the SPA Steering Committee and contributes half of the funds under the SPA.

There were also perceptions that Source is the only thing in the NHMS and everything else is out of scope. This limits communication and collaboration with others involved in other modelling platforms. This may thwart innovation and opportunities for interoperability that may otherwise be beneficial.

Some commented that the existing Source platform has been more fully developed for users of rules-based modelling, which is mainly used for the modelling of rural/irrigation systems, while not complete for the alternative goal-based modelling, which is commonly used in modelling urban systems. Likely reasons for this include that the initial developments were driven by organisations that use rules-based modelling. However, if Source is to be adopted more broadly Australia-wide, it will need to cater for both groups of users. There were also comments that it is critical for Source software to have functionality for modelling all aspects of current water management rules and

policy, and not rely so much on work-around solutions and plug-ins, to achieve the NHMS objective of consistency, transparency and defensibility.

There were variable views on the benefits and risks as to whether Source should be "mandated" as the platform to be used for water resource planning and management, including water entitlement specification and management, water trading oversight and water accounting, in each jurisdiction. By way of comparison, it was noted that some urban development decision making authorities mandate the use of MUSIC for assessments and analyses and this has led to widespread application of MUSIC by urban development applicants and their private sector consultants. This has also considerably assisted eWater's income stream. It was noted that MUSIC is used by commercial urban land developers while Source is mostly used by Governments and large water users, so Source has a much more limited market. However, interestingly, this itself may run the risk of reducing the software to a commodity rather than an innovation platform.

Strategic discussions between eWater and its owners about what could and should be the scope of the NHMS products and services beyond what it is now (i.e. mostly Source for surface water modelling with linkages to MUSICX and Urban Developer), and how those products and services may be developed and maintained and funded into the future, have not been happening. This is not helpful to the NHMS nor to eWater and its members. There may or may not be other service providers for elements of the NHMS and this has to be explored to give confidence that future needs can and will be met.

It was noted that, at its core, Source was initially designed as a hydrological modelling platform (i.e. primarily focussed on water quantity), and has been extended for other uses, predominantly through customised plug-ins. These "other" uses have included water quality forecasting, environmental water demand, and coupling with socio-economic processes. Through a combination of necessity and practicality the initial focus has been seen by some as being on shorter-term operational matters, for example to obtain forecasts of water availability to inform relatively short-term management actions in line with local policy. Extending its use to planning contexts where longer-term considerations are at play has often been achieved by "scaling up" these shorter-term cases to longer time frames with relatively limited consideration of the uncertainties involved. It was stated that reuse of operational models to the longer-term planning context may limit planning capacity, applicability, and flexibility towards investigating the possible future pathways that may be taken. The view was that. for viable pathways to equitable and sustainable conditions to be identified, it is necessary for the uncertainty that may affect projected outcomes to be holistically considered and communicated. However, it was considered by some that the overheads of the existing Source platform, including in terms of both input/output and operational detail, are too high for this in particular situations, causing, for example, long model runtimes and inhibiting (1) characterisation of model and predictive uncertainty and (2) large basin-scale applications. This is an issue at the Murray-Darling Basin scale.

Governments stated their need for a stable statutory water resource planning framework, underpinned by stable, creditable, transparent, authoritative hydrological modelling, to provide necessary confidence to decision-makers and acceptable certainty for water users and investment.

On the other hand, some advocated the need for the strategy to explicitly tackle building industry and Government capability in something that might be called "establishing model credibility,

salience and legitimacy", or "uncertainty literacy". They were concerned that the paradigm to date has been to validate-and-defend models and the legislation of official models, with a focus on maturity (e.g. see Guillaume et al, 2017). However, there is increasing recognition that this paradigm is typically not sufficient to achieve credibility, salience and legitimacy (and therefore social license) of modelling (e.g. see Hamilton et al, 2019). Whether it appears through "uncertainty analysis", "deep uncertainty" or "participatory modelling", they consider there is a need for sufficient flexibility for models to be modified to suit the task at hand, and to be able to explore what alternative models might also fit available facts (e.g. see Guillaume et al, 2016).

It was suggested that this could be approached from the point of view of transitioning from a validation-focused to an uncertainty-focused mindset, which involves making judicious investments over time in quantifying and reducing uncertainty. This approach generally means moving away from using Source in its current form because meta-models that run faster are needed, in addition to working in a scripting environment that allows for reproducibility of model-based analyses and rapid development of model variants. Tighter integration of existing databases with the modelling framework itself is also required in such instances. While Source may be used in this context, many of the capabilities have been reported to be retrofitted, computationally inefficient, and far from user friendly. Efforts have consequently been made to replicate Source functionality in a compatible, separate, more efficient, and open-source package. This deserves further exploration and is discussed further in Sub-section A5.4.3.

In view of the above, it was stated that there could be a risk that, if the Source platform entrenches the authority (legal and regulatory) of certain models in their current forms, this will actually be at the expense of effectively managing uncertainty, credibility, salience, and legitimacy. While further clarity about how the (authoritative) models are used may lead to greater legal and regulatory acceptance, this may in fact undermine social license in the long run if the credibility of the authoritative models is defended rather than embracing the need for exploring, understanding and reducing uncertainty.

At the same time, operational applications are often constrained by regulatory concerns (including specific versions of models written into law), such that there may be relatively large transaction costs involved in improvement of the model over time, and strong disincentives to public-private collaboration. External inputs are therefore difficult. Substantial benefits could be expected from creating a space within which PhD students, for example, could be able to experiment with and contribute to improvements to specific place-based models. Comments were made that one possible mechanism here would be the creation of "digital twins" in modelling, which provide up-to-date representations of a system, integrating both (near) real-time data and (collections of) models at multiple levels of fidelity (and therefore varying runtime cost). The digital twin would provide an environment that encouraged contrasting data with models and therefore sought continuous improvement. This would help to both identify opportunities for research to reduce uncertainty and facilitate engagement on new innovations in a place-based context.

Comments were made that the BoM's work with the Australian Water Resources Assessment (AWRA) model combined with data assimilation was already in this direction, but it was limited to a single model with relatively coarse scale modelling. It was suggested that an alternative would be to empower an agency to be the coordinator or custodian of local digital twins, i.e. providing a platform that integrates data and models for specific locations and acts as a central point of contact

for research activity in each region. Mandated custodians of digital twins would then provide a safe space for Governments and other non-Government organisations to transparently engage with operational model improvements without feeling obliged to immediately integrate those improvements into their legal frameworks.

Achieving success in model building and application for challenging interdisciplinary issues is about more than getting the science and engineering right. It is also about embedding model building in a social process that links and engages scientists, decision makers, interest groups and the wider public towards achieving impact beyond merely technical performance of a model, notwithstanding the critical importance of the latter for credibility and confidence.

Evaluation of modelling success needs to consider a broader set of criteria, and emphasises the importance of contextual factors in determining the relevance and outcome of the criteria. These evaluation criteria may be grouped into eight categories: project efficiency, model accessibility, credibility, saliency, legitimacy, satisfaction, application, and impact. Evaluation should be part of an iterative and adaptive process that attempts to improve model-based outcomes and foster pathways to better futures (e.g. see Hamilton et al, 2019).

Clearly, there is both "science and art" to good hydrological modelling – it is not just being able to run a software package.

A5.3.3 Communication and Relationships

Despite some commitments made in recent years, a number of NHMS-CHA partners still observed a communication gap between eWater and its owners. It was recognised that while the NHMS, eWater and Source all originated in proximity of each other, they are not all one and the same.

A major challenge reported by some has been the relationship between eWater and its owner State Governments, who also happen to be substantial funders of Source development and maintenance, though the Commonwealth Government (via the MDBA) provides half the SPA cash funding. It was suggested that, if a State perceives eWater as essentially a Commonwealth aligned organisation based in Canberra, then that could potentially constrain relationships and openness of communications and information sharing.

It was observed that trust in the Source software is very strong but the same does not apply to eWater's commercial advisory and consulting activities where it was reported that competition and lack of transparency can cause friction among SPA partners and also with external stakeholders, including private industry.

Originally, eWater largely serviced the needs of its owner Governments (e.g. through Source development). However, over time, eWater has grown in its operations where Source is just one of its several endeavours, albeit a very necessary and technical one.

Correspondingly, the Source Steering Committee that runs the Source project now largely comprises technical experts. This has resulted in a strategic-level communication gap between the State Government owners and eWater. This has led to some levels of mistrust between the eWater

Board and the SPA Steering Committee and perhaps a lack of understanding among some of their respective roles in directing eWater activities.

This matter has been explored in great detail in an unpublished internal due diligence review report on the NHMP (MDBA, 2017). An interim way proposed to overcome this communication gap was a strategic annual conversation between the eWater Board and the Government owners of eWater/funders of the Source project (but not at the annual general meeting).

An open and transparent approach to develop, review and make models available was generally supported. This means they are in the public domain, are open to scrutiny, there are "official" versions, and known "official" ways to change them.

A5.3.4 Funding

The most immediate concern at the time of preparing the draft Issues Paper was the lack of agreement on the funding for the SPA beyond 30 June, 2021. However, that was resolved through the SPA Steering Committee, though it was described as "protracted and painful". To go beyond June 2023, parties will need to negotiate a new agreement before June 2023. This raises questions about the financial sustainability of the SPA arrangements.

Reference was made to the "eWater 2012-2022 – Draft Business Case Proposal to support implementation of the COAG National Hydrological Modelling Strategy" (not sighted in the preparation of this Final Report) and the indicative costs of the ten-year funding window. In this proposal it was reported that eWater was to return a profit in time and the indicative analysis suggested that "it is reasonable to expect a decreasing reliance on core government partner funding over time". This would result in program costs to partners reducing over time as commercial and external contracts increase.

However, nine years after the start of the proposal, it was reported that some funding parties feel they are being pushed to "prop up" eWater and increase commitments rather than decrease them. The promised revenues have not materialised according to the views and expectations of some funding partners, although it was reported that the margins and overheads and commercial returns for both Australian work under the SPA and international work via the AWP were not clear nor necessarily understood and accepted. There is a need to review this relationship as a framework that could see either increases in the overall financial support from funders or a decline in service for the same cost and that is of concern. Funding parties stated that they do need to satisfy procurement and audit requirements for their expenditures.

There were also concerns about what the actual costs of services need to be to obtain satisfactory outputs. For example, in the 2017 due diligence report (MDBA, 2017), it was stated that full maintenance required eight roles with a base cost of $2.3 million with modest CPI increases. (Some industry experience suggests that typically 5-8% of IT asset IP value needs to go to maintenance and renewal just to continue to have the IT product available. With investment in Source to date reported to be at least $50 million and likely more, that translates to a minimum annual cost for maintenance and basic renewal of at least $2.5 million per year.) Parties ended up agreeing to a one-year agreement that has been extended to three years, and more recently five years, and has reportedly delivered most of the required outputs at a cost of about $1.067 million per year.

Consequently, there is a very widely held view that there are ongoing challenges in funding the development and maintenance of Source. Despite the 2017 due diligence report leading to putting in place a longer-term working arrangement for the development and maintenance of Source through the NHMS-CHA and the SPA, there has been difficulty in securing consensus agreement for anything other than one to two-year tranches of funding for the maintenance of Source. Further development work has generally been rather bespoke and negotiated through mostly one-to-one contracts between eWater and a particular partner. Several partners commented that, while the funding framework around these contracts is understandable, there have been missed opportunities, including for economies of scale, because communication around the bespoke development proposals has sometimes been lacking.

It was reported that at least one party had considered pulling out of the SPA and the use of Source as is, without further development or maintenance, due to frustration with eWater increasing costs of service delivery and because Governments need a stable statutory planning framework. If this were to happen, it would end many years of collaborative effort. This shows that the relationship between some of the partners and eWater is tenuous and there are real risks associated with "business as usual". The new 2021 SPA variation has bought two more years of maintenance activity, but it was reported that this may not survive beyond 2023 if changes were not made.

The ongoing cost of maintenance of Source does not seem to be seen universally as a necessary cost of water planning and management business like other costs e.g. staff salary, water infrastructure maintenance costs etc which also rise due to inflation. As one person put it, the modelling platform asset and its upkeep, while essential, is not a "ribbon cutter". While all costs of eWater have gone up, the funding governments have not all agreed to index their financial contributions to eWater for maintaining Source. This has decreased the funding of Source maintenance in real terms and it is unlikely that the costs of maintenance will decrease in the short to medium terms. It is a risk to expect eWater to be able to maintain Source with a budget that is dwindling in real terms. It also risks the long-term viability of both eWater as an organisation and Source as a product. There is a belief among some that both eWater and Source ought to be seen as critical national assets that need to be protected for strategic reasons. There were comments that Source maintenance is vital to Governments, and this software maintenance capability is likewise vital, in a sustainable way. Some went so far as to say that it would be catastrophic if Source software maintenance capacity/capability is lost.

On the other hand, funding partners are concerned about, in their view, the relatively high human resource costs ($ per full-time-equivalent) associated with the SPA. This raises questions about overheads, what is included or not included in apportioning costs, and how this impacts the value-for-money of the SPA.

The financial and human resource costs for managing the NHMS and for developing and maintaining Source have been seen by some to be inequitably proportioned among the partners. This has been identified as a particular risk to the MDBA and eWater itself, though all entities are reporting to be under increasing financial pressures to at least some degree, particularly since the COVID-19 pandemic. Substantial cash injections by the Commonwealth (both through the CRC program and later more directly for the initial Source development through to 2015) have been crucial to success to date.

Available funds do not enable support to be provided to non-SPA funding parties such as smaller water authorities and small and medium enterprises in the private sector. This has limited broader use of Source in some instances, though it is not always necessary to use a relatively complex hydrological modelling platform like Source to adequately inform water resource decision making, especially in simpler systems.

An important point was also made that continuing investment in hydrometric data collection is also needed because, without it, the ability to have effective hydrological modelling platforms is proportionately constrained. This activity must occur in the States and Territories during COVID budget restrained times, making cost increases by eWater harder to bear.

A5.3.5 Community of Practice

There are conflicting views on how well the hydrological modelling community of practice is going. Some felt that both the formal and informal networks established through the annual Source conference, for example, and the Source software training have been very beneficial, while others felt that the coordination function for the community of practice is not well established.

In some instances, eWater involvement in broader coordination projects that impact partners is occurring without partners' awareness while some jurisdictions are effectively self-organising their networks without eWater involvement. In any event, there are concerns that the existing NHMS capacity building forums are not sufficiently inclusive of others besides the existing NHMS-CHA and SPA partners, and that the annual Source conference misses some strategic opportunities. Nevertheless, the on-line Source conference in 2020 attracted more than 300 participants, including those from more than 20 other countries.

There were suggestions that the scope of national capacity building effort by eWater has been limited to using software, rather than broader modelling practices and principles. The latter are largely being addressed through within-jurisdiction/industry training and mentoring. Perhaps this training could be expanded in a way similar to the national groundwater school, bringing in industry experts, having outcome/career driven courses in hydrological modelling applied to catchment management, river operations, water supply, water quality management and the like, and expanding the network that way. Some jurisdictions have more work to do than they can deal with given their current capacity, but the capability of the private sector market is also concerningly thin.

It was recognised that broader participation in community of practice and/or capacity building activities is often limited by allocated funding.

A major concern was where do you find new modellers and how do you upskill junior staff? It was stated that most capacity building is currently in-house. A suggestion was made to develop a tertiary short course in hydrological modelling, distributed across Australian universities. perhaps at Graduate Diploma level. Water management agencies could contribute in-course material, and perhaps assist with delivery and mentoring. This could also be an integral element of the community of practice, and over time would develop better networks.

There were also comments about arrangements for cultivating and applying procedural knowledge for modelling processes (e.g. see Fu et al, 2020). For example, organisations and the water modelling community as a whole could focus on improving human capacity and the knowledge base, the operational framework surrounding modelling activities (e.g. guidelines, standards, model management and technical support services), and the cyberinfrastructure and tools available for modelling (e.g. model codes, data management and analysis tools, workflow tools, and computational resources). In that way, development of new models and modelling frameworks could be encouraged as our knowledge and technology evolve. In addition, public repositories of data and data curation services may provide a way for new or customised models to fast-track their testing. A research structure that includes open sharing of all elements of the scientific process (ideas, models, tools, and data) would assist linking theoretical developments and model infrastructure. This could also include assessment protocols for model performance for a rigorous validation of models (both quantitative and qualitative methods) to create standards, a common vocabulary supporting comparisons and synthesis between model applications. as well as digital catchment observatories as platforms for engagement and knowledge exchange between scientists, policy makers and local communities.

A5.3.6 New Knowledge

There was agreement that eWater and partners have made significant steps in addressing a number of science gaps identified early in the partnership arrangements. These science gaps are particularly in relation to specific hydrological modelling related research and development, rather than general water related research, though, of course, the latter is also very important.

Some argued that a lot of relevant more recent research work may be happening, but it has not been well harnessed in the NHMS. There were concerns that current arrangements are not capturing sufficient knowledge development beyond software. Examples included urban water supply and water balance, low flow hydrology, surface water/groundwater interaction, flood hydrology and hydraulics, groundwater, ecological water requirements, socio-economics and cultural water provisions.

However, in addition, many agencies are facilitating collaborative efforts to work on particular science gaps, between groups including State/Federal Governments, CSIRO, universities and leading consultancy firms. Another example is climate change and water modelling work. It was noted that eWater are not collaborating in many of these efforts, and are not pivotal in the successful completion of these endeavours. It was also noted that the approaches being taken to climate change in water modelling are somewhat different in different jurisdictions, with no clear national narrative around those differences. This was seen as a risk to the coherence and justification of incorporating climate change considerations in future water modelling and water planning and management work. The relatively recent establishment of a Climate Change Sub-Committee under the NWRC may provide an avenue for further communication, collaboration and coordinated advice.

Since 2012, the CRC for Water Sensitive Cities (CRCWSC) has developed new knowledge, products and tools, including modelling tools, that are relevant to the NHMS and eWater tools like MUSIC and Urban Developer (and consequently Source with more recent enhancements). However, it is not clear whether or how CRCWSC outputs like SWUMBA, INFFEWS and the Scenario Tool will be or

should be connected to or incorporated in the NHMS and eWater portfolios. Again, availability of funds is a key issue.

(SWUMBA is the CRCWSC's Site-scale Urban Water Mass Balance Assessment tool for water flows into, through and out of an urban area. The tool generates a comprehensive account of all water flows in both the natural and human-made (including urban infill) water cycles (rainfall, evapotranspiration, stormwater runoff, imported water, decentralised water, wastewater, etc.).

INFFEWS is the CRCWSC's Investment Framework for Economics of Water Sensitive Cities economic evaluation package, which includes a value tool that provides a way of valuing the benefits of water sensitive projects that are not traded in markets, such as the social and environmental benefits, and a Benefit Cost Analysis (BCA) tool.

The Water Sensitive Cities Scenario Tool simulates urban development and the performance of water management interventions dynamically over time. It is accessed online via a web browser and uses GIS to inform its modelling for planning and assessing water sensitive development scenarios and options, including impacts on urban heat and urban water cycles at lot, precinct and catchment scales.).

Bringing in new knowledge and planning frameworks to anticipate future stresses in water, energy and food security has also been missing the necessary conceptualisation and collaboration. There are demographic changes, and changes in agriculture, forestry and emergency services that also need to be factored in.

There were several comments that significant new work in new knowledge, data and information, scientific capability and hydrological modelling capability for catchments, land uses, physical processes, pollutant generation, climate and ecological responses associated with water quality management, especially for receiving water bodies, is required. Working on constituent averages at stream gauging stations over daily time steps is no longer satisfactory for such management, given public scrutiny and expectations around algal blooms, fish kills, estuary and reef health and the like. Capability in sub-daily (down to less than hourly) time-steps is needed, but it will take more funding. Modelling of these systems and their interfaces has been limited by computational capacity in the past, but that is becoming less of a constraint. In pursuing this, care will be needed as hydrology and associated modelling are data-based sciences, and more modelling sophistication is not always warranted if there is not data and evidence available to support it.

A5.4 Comments About Suggestions for Change

A5.4.1 National Leadership

Following on from the comments in sub-section A5.3, points were made that the central change that needs to occur is that the NHMS needs to be accepted as a national strategy and its implementation should be appropriately resourced. While the NHMS may need to be reviewed and updated to serve the contemporary needs, it requires ongoing support, including strategic direction, effective governance and leadership and monitoring its implementation. This will ensure that all subordinate elements including Source enhancements and maintenance and the hydrological modelling community of practice continue to be supported. The working of the

enabling entities, such as eWater, should be reviewed in order to ensure that they continue to be relevant and able to meet the contemporary national needs.

All these matters require that the NHMS be owned nationally by all Governments. However, it has been suggested by some that, to function properly, the NHMS must be led by the Commonwealth Government.

It was noted that a refresh of the NWI, together with membership of eWater now aligning with membership of the NWRC, provides an opportunity for a national conversation about the future direction of the NHMS (and Source, and potentially eWater). There are matters of science and research, product development and maintenance, service delivery (including capacity and capability building), engagement, commercialisation and financial viability to consider.

In any event, it was suggested that a national Steering Committee comprising the appropriate government agencies and other key stakeholders across Australia needs to be maintained by the NWRC to advise on resources and oversee the implementation of the NHMS. The national Steering Committee needs to undertake monitoring, evaluation and reporting of the NHMS and initiatives that support the NHMS using agreed program logic and a performance framework to demonstrate the value for money achieved and the meeting of industry needs. The national Steering Committee should also provide forward work planning and expected annual outcomes over biennial cycles.

A5.4.2 Roles and Responsibilities and Relationships

Reconsideration of governance arrangements for the NHMS should clarify roles and responsibilities and provide a clearer "line of sight" for future directions and decision making. At the same time, stronger collaborative relationships among the participants in the NHMS should provide a more enduring partnership and avoid sectarianism.

Some suggested that there is a greater role for the BoM and likely CSIRO and Geoscience Australia in the NHMS compared with what has been happening over recent years and more effort should be put to building the necessary linkages and building the working relationships. As mentioned previously, the idea of a "digital twin" approach to modelling was put forward to provide more interplay between data and models, and space for research, experimentation and innovation. Some suggested that eWater could have a hosting and custodial role in that and/or be a knowledge broker while others did not see this as a role for eWater.

There was a suggestion that eWater could take more a role in quality control and oversight and less of a role in software development and selling it. For example, there are lots of other models around, including open-source ones. What has to be done to ensure there are appropriate linkages and coordination for the benefit of the nation?

A5.4.3 Extent and Scope of the NHMS

There were comments that it is essential that the existing NHMS actually be made a "strategy", ie not just a vision and objectives, but include details about how and when who is going to get there at what cost. Mechanisms need to be developed and documented with tangible milestones and an

underpinning, transparent, agreed investment framework. And the strategy needs to be more inclusive.

There were suggestions that other recognised hydrological modelling platforms, products and processes, like those used for flood forecasting and management, and groundwater system entitlements and management, should be flagged and made transparent within the scope of a truly national "hydrological modelling" strategy. This doesn't necessarily mean that such platforms, products and processes have to be the subject of a Project Agreement under the National Collaboration Framework. The NHMS document could, however, be transparent that these platforms, products and processes are important nationally and supported, being covered, for example, by arrangements under Australian Rainfall and Runoff (Engineers Australia and Geoscience Australia) and with MODFLOW and the work of the National Centre for Groundwater Research and Training, respectively. It was acknowledged that this suggestion needs considerably more analysis before being acted on.

While the framework of having plug-ins to the Source modelling platform is widely supported, some cautioned against their proliferation without clear agreement as to what we want them to do (what answers are we looking for) and are they an appropriate way to do it. Already a number of the components of the existing NHMS are not actively discussed or pursued, so it is an important conversation as to what are the objectives and priorities for the next one, three or five years and what resources are to be provided to meet them and how.

With open architecture style models becoming more prevalent and Source has that ability, development of plug-ins needs to be better coordinated so that they are updated and updateable, with less reliance on particular individuals who did the development in the first place. Custodianship of the full extent of the tools and products is required so that they have transparency, longevity and reliability, quality assurance and quality control, and are appropriately tailored to the questions that are being asked and need to be answered. Further evaluation is required as to whether this could be a role for eWater with appropriate funding.

While it may be unrealistic at this stage to expect Source, in particular, to go totally open source, or for the NHMS to support only open-source approaches and models, perhaps there is space for both proprietary and open-source platforms, especially for the more socio-economic aspects to be coupled. Uncertainty analysis also requires something that runs faster with more of the detail of Source lumped up for planning futures. Advice is that the universities and others would then come on board and innovate more with an open-source platform that is always developing and to which they would contribute.

The Open Modelling Foundation (OMF) is an international developing activity that seems to be one illustration of the fact that there is a huge drive in the direction of open source, community driven software development. Further information about the OMF is in Appendix 6. This project seeks to transform the future of modelling science. The OMF seeks to provide a framework to enable and encourage new collaboration across the vitally important modelling field where science and policy meet. The OMF reflects what is now de rigeur overseas in terms of developing open platforms that promote saliency, legitimacy, credibility (and collaboration) for any modelling that is confronted by uncertainty and stakeholder interests. Australian modelling organisations could consider whether there are benefits in them joining as members of the OMF and under what arrangements.

Several people held the view that much more work is needed on the science and modelling for water quality management and ecosystem response within the catchment models to meet emerging and longer-term future needs. Some useful work is underway in this space of simulating catchments but more is needed and there are opportunities for increased investment, coordination and collaboration, perhaps also involving other platforms and corresponding connections.

Comments were made that it would be good to have national guidelines for surface water modelling broadly, in the same vein that they exist for groundwater modelling, as long as there is an appropriate balance between "standards" and opportunities for innovation. Again, the OMF may help here.

There were some comments that, from here forward, the NHMS perhaps should focus less on the platform and more on the consistency and coherence in approaches to using it, the "art and science" of smart modelling and smart modellers, and on transparency (e.g. in data inputs, in the modelling approach including the science underpinning it, in outputs and associated uncertainties with openness in the communication of results) and fitness-for-purpose. Source is now such a large modelling system – larger than is needed in many catchments and river systems, and in those systems, the modelling should be "as simple as possible – but no simpler!" New users do find the whole model difficult to understand. In fact, perhaps less than a handful of people understand the whole model and that is a risk.

A5.4.4 Funding

The objective 5 of the NHMS requires that "*Appropriate funding is available to support the implementation, on-going maintenance and enhancement of modelling platforms and to develop a strong community of practice*". As noted earlier, this objective has not been secured. Difficulty in securing long-term funding for the development and maintenance of Source is manifestation of this. This needs to be addressed if the NHMS is to succeed in delivering all its objectives.

Specific project agreements under the NHMS-CHA is one way of securing long-term funding, provided that each Government commits to contribute adequate funds on a long-term basis towards projects relating to implementing the NHMS, including funding the agreed enhancements and maintenance of Source.

Comments were made that if private industry is to be supportive of the NHMS and eWater products, then they must be seen as collaborators and not competitors and the relationship must be for the long-term. Based on the experiences of the State-based "networks", there are also opportunities for greater collaboration and partnering with the research sector and further leveraging funding for modelling science and a broader community of practice, as noted below.

A5.4.5 Community of Practice and Capacity and Capability Development

There was generally support for a national hydrological modelling network, perhaps providing a "network of networks", recognising the good work already going on in some jurisdictions and their and eWater's desires to seize on further opportunities, be better connected and build national capacity and capability in hydrological modelling.

Experience has shown that a good community of practice provides substantial opportunities for in-kind support with the potential to leverage funds, including leveraging Government investments. Some commented about the excellent Government/industry partnerships associated with Australian Rainfall and Runoff guidance, practice and capacity, though the questions to be answered in flood modelling may be clearer and narrower than those applying to water resources planning and management, water entitlement modelling, river operations modelling, catchment and water quality modelling, water security and water sensitive urban design modelling and the like. The Groundwater Modelling Decision Support Initiative (GMDSI), described below, was also mentioned as being a very good example of a very positive and useful network.

Sustainable funding of this kind of network is therefore a key issue. As mentioned, there are opportunities to take a leveraging and cost-sharing approach to maintenance of a national community of practice. Financial contributions from the Commonwealth and State and Territory Governments may be quite modest when combined, and could, for example, involve matching of private and academic sector contributions. It was observed that the small grant program of the QWMN has demonstrated the potential for substantial leveraging of small financial contributions.

Any national network should not be limited to software developers and modellers. Involvement of others, including policy people, decision-makers, researchers and communications/engagement people, is also necessary. Undertaking processes and procedures for enhancing good modelling practice and facilitating and embedding how to effectively do collaborative and participatory modelling are also important parts of the mix.

There are also opportunities to better involve water users and understand their needs and behaviours. Lessons from the Murray-Darling Basin and the catchments feeding the Great Barrier Reef show there is considerable need to build social acceptance of the use of hydrological models, to build trust in and understanding of what models can and can't do and how that impacts the effectiveness of decision making and implementation of decisions. These are important to the social licence to operate. Providing greater clarity in the way that models are used and where the benefits and constraints lie can lead to transformative conversations.

As alluded to previously, it is also important to recognise that modelling is transitioning from the traditional paradigm that focuses on the model and its quantitative performance to a more holistic paradigm that recognises successful model-based outcomes are closely tied to undertaking modelling as a social process, not just as a technical procedure (e.g. see Hamilton et al, 2019). That has made it necessary to redefine evaluation of success in modelling as a multi-dimensional and multi-perspective concept. It has also required an enhanced framework for identifying and measuring the effectiveness of modelling that serves the broader paradigm. Under this framework, evaluation considers a larger set of success criteria, and emphasises the importance of contextual factors in determining the relevance and outcome of the criteria. These evaluation criteria may be grouped into eight categories: project efficiency, model accessibility, credibility, saliency, legitimacy, satisfaction, application, and impact. Consequently, model evaluation, and the capacity and capability to do it, should be part of an iterative and adaptive process that attempts to improve model-based outcomes and foster pathways to better futures.

There are also lessons to be learnt and information to be shared from several initiatives that have been undertaken in the last few years in this space by the Queensland Water Modelling Network, the NSW Modelling and Monitoring Hub, and the Victorian Hydrological Modelling Group and possibly others, like the Groundwater Modelling Decision Support Initiative (GMDSI), described below. People noted the high interest in and usefulness of webinars about hydrological models and modelling run by the QWMN, the Australian Water School and others during the past COVID-19 year and hoped they would be able to be continued. Even so, people are busy doing their own stuff and it can be a challenge to find the time and the finances to be involved.

In addition to the annual Source conference, conferences like MODSIM could be used more to lift the profile of the NHMS, identify future needs and to share lessons in a more effective way.

Specific reference was made to the good work being undertaken at the moment under the GMDSI (Groundwater Modelling Decision Support Initiative). It is a practice of experts that have a webpage and regular webinars of important topics providing opportunities for feedback and discussion. The website has links to the initiative themes of Engagement, Education, Worked Examples, Research and Software (see https://gmdsi.org/).

There were comments that training and development of hydrological modelling skills is a largely underdone area at the national level. There is a strong demand but very little capacity to supply work-ready technically skilled human resources. The current technical training arrangements are largely ad-hoc, in-house within entities and fall far short of national needs. The growing adoption of Source and other tools from the eWater modelling suite has opened the real opportunity of training and raising a work force that is fully interoperable. There was a suggestion that consideration should be given as to whether there is scope to develop tertiary (short) courses in water planning and management modelling that could jump start early career modellers. Having said that, it was reported that at least 20 universities in Australia have included Source in their curricula, though the courses are often more related to catchment modelling rather than river modelling. Hence the need for more courses and training in the latter, in particular.

A5.4.6 New Knowledge

The NHMS requires applied research to translate fundamental hydrological, ecological and socio-economic understanding into modelling technology, as outlined previously. It was suggested that this is best achieved through a close relationship between model developers and those who undertake the more fundamental research on water system behaviour. There is a need for a strategic method (under the NHMS preferably) which links research to practical use. By way of example, at the moment, eWater only really have experts in software development and hydrology. They do not have climate experts or water quality experts internally. Therefore, it makes sense for further developments in water quality and climate to be achieved externally - i.e. via research and academic institutions. However (and this is the key part), there needs to be a nexus between eWater and the research and academic institutions, or the outputs from those institutions will not be in a useable format for code development by eWater or others. Further consideration will have to be given as to what the mechanism for this nexus would be, but it would really be great if the NHMS could address this explicitly. Maybe the funding arrangements for the research proposals could necessarily have to include partnership with eWater for the product delivery? This could all fall under a broader strategy for the NHMS - which is identified as being somewhat lacking in clarity.

A5.5 Comments About Future Challenges and Future Innovations and Research to Meet them

Given the challenges, including climate change, faced by Australia currently and in the future, the focus on the water sector is likely to be intensified. Consequently, the community's demand for more transparency and accountability of governments' decision making will grow in the future. More and more policy development will be required in this space and that needs to be supported by knowledge and technical developments to assist transparency and accountability. Integrated groundwater-surface water resource re-assessment that is informed by proper climate change and hydrological modelling comes into mind in this context. As black-box modelling is no longer acceptable to the community, model provenance tools to handle multiple scenarios modelling by multiple agencies (and some may be on the other side of the globe) interacting with each other through cloud computing will most likely be required.

There is a clear need to bring key national agencies such as CSIRO, the Bureau of Meteorology, Geoscience Australia and universities together in a strategic (nonbureaucratic) sense so as to avoid duplication of efforts in research, development and innovation that will be required to address the matters raised in this Sub-section. The required research and innovation are particularly in specific hydrological modelling related research and development, recognising that general water related research is also very important.

Recognizing we are in the 4th industrial revolution or digital revolution, there were several comments about future influences and innovations including:

- the impacts of super-computing;
- having Source in LINUX versions;
- other new technologies for modelling;
- "cross-platform" connections;
- machine learning;
- more use of Cloud computing;
- better optimisation tools;
- better spatial tools including connections with Geoscience Australia tools; and
- tools for analyses of remote sensed data.

It was noted that these may or may not be pursued by eWater and/or others. There were different views on what eWater should or should not get into. Some views on this matter depended on how both collaboration and competition in enhancing and delivering the NHMS could be best managed.

A mechanism is needed to have a meaningful and influential conversation about future needs relevant to the NHMS. Without this, opportunities for leveraging of investments and working collaboratively are missed. From a process perspective, there was a suggestion that a high level technical and policy group with appropriate representation is needed to identify existing and emerging knowledge and modelling requirements such as:

- catchment responses to climate change (and bushfires);
- potentially linking weather and climate forecasts from the BoM to inform planning and operations of systems with diverse water sources;
- forecasting water demand and use as weather (short-term) and climate (long-term) change;

- better science to inform catchment, sediment transport and water quality modelling, and impacts on receiving waters;
- relationships between water quality and ecological health;
- incorporating Indigenous water requirements including cultural flows;
- water coupled socio-economics (including impacts as water users' behaviours change);
- surface water-groundwater interactions;
- low flow hydrology;
- floodplain hydrology;
- water and energy nexus;
- enhancements in environmental water management, including near-real-time ecological responses to hydrological changes (noting that it was reported that there seems to be limited or no use of Source by the current environmental water holders in Australia);
- urban whole of water cycle and integrated water management directions (comprising networked drinking water supplies and alternative water supplies e.g. manufactured water, stormwater and recycled water) and system level responses;
- methods for dealing with and communicating uncertainty, including identification of sources, their relative strengths and criticality to the modelling purpose/needs, and methods to reduce the crucial ones;
- new or better ways of understanding and explaining uncertainty (in data, in models, in communications) to decision makers (ignorance of it is not bliss) and managing risk and optimisation, and informing investments in monitoring and data collection networks and water literacy initiatives;
- automated assessment frameworks attached to hydrological modelling frameworks to translate hydrological change into inferred outcomes at the catchment and whole-of-basin scales, considering:
    - Environmental outcomes, ecosystem response, ecosystem functions;
    - Cultural values and outcomes;
    - Social (including ecosystem services) outcomes;
    - Economic outcomes;
    - Water quality;
    - Critical water needs.

This is a long list and more work has been done in some areas than others, though there is no real strategy about that. These suggestions have to be considered carefully so as not to adversely impact (dilute) the workability of the NHMS or the core components and functionality of Source and their continuing delivery. This is a matter for further consideration.

In May 2021, the Commonwealth Government made a budget commitment to a significant improvement in whole-of-basin river modelling capability. The commitment will boost the decision support tools needed to confidently advance water management and transparency in the Murray-Darling Basin. It also responds to a range of reviews and stakeholder feedback that have called for an enhanced modelling capability. This work could be considered an important sub-set of the future NHMS, meeting priority research and innovation and modelling development needs not only of the Basin, but also with some specific opportunities for transferability elsewhere.

This is an example of how modellers, researchers and others may work together to provide, for example:

- An integrated modelling framework in which basin models can be managed and operated;
- Basin river models delivering desired capability and application;
- Basin river models operating in a common modelling platform;
- A web-portal via which regulated models can be remotely accessed, managed and operated (by authorised persons);
- New reporting and data visualisation tools – to enable access to model results (by authorised persons);
- A public facing data and reporting access portal which provides an avenue for increased transparency (accessible by the public).

This conversation would extend beyond the existing SPA Steering Committee and could draw on the community of practice for inputs as many different skill sets are involved. For the NHMS, perhaps this work could be collated by the NHMS independent advisor and, aligned with comments in the recent Productivity Commission Report on the National Water Initiative, advice provided to the NWRC annually on national priorities for new knowledge, new modelling capacity and capability. This could then provide important context for establishment of other higher-level initiatives, e.g. Australian Research Council proposals and the like, and inform organisations like CSIRO and the BoM about the highest national priority requirements of them to support the NHMS in the Murray-Darling Basin and elsewhere.

There was a suggestion that there is an opportunity to leverage modern water data collection and dissemination capabilities with improved modelling approaches to provide enhanced real-time water information that is tailored to water users and water resource managers. Indeed, there were several suggestions that the NHMS needs to include consideration of data collection and the implications that the availability (or paucity) of data have on the fit-for-purpose use of modelling tools for decision making.

As models can generate a vast amount of output data and information, there were suggestions for improved information and related communications packages to better inform decision makers and the public.

Several jurisdictions have been grappling with how to best integrate/connect overland flow/floodplain flows and extractions modelling with hydro-dynamic floodplain management modelling (inflows, velocities, inundation areas and times, return flows) and river/catchment models. Various approaches have been taken and there are opportunities for learning from each other and perhaps standardising.

Specific needs were expressed to couple (but not necessarily dynamically linking) Source catchment modelling with estuary response and other receiving waters models, which will be helped by a sub-daily time step capability in Source. It was stated that the ability to link these catchment and Source water models to the receiving water models is critical to ensure good understanding and management of catchments and the water within them. This is also crucial to ensure that the most benefit is being achieved from modelling efforts. This will require a lot of work, including in water quality modelling at sub-daily time scales, and for modellers from different backgrounds to come together with an agreed purpose.

More connections could be made with planning to anticipate futures (drivers and impacts) in climate, land use and other cross-sectoral impacts, and to identify robust adaptive strategies. This will include modelling capability to be able to efficiency "dance" with external algorithms, including being able to easily experiment with alternative model assumptions and model structures. This further connects with the need to integrate models within decision frameworks rather than communicating scenarios in isolation, connecting notably to international literature and communities focused on adaptive and robust decision making and decision making under deep uncertainty. This need has notably been emphasised by the Queensland Water Modelling Network.

An important point was made that enabling scientists to leverage each other's expertise and work in ways not currently possible can catalyse a surge of innovative scientific research and new applications of modelling to societal and environmental challenges, benefiting communities in Australia and throughout the globe.

At the technical level, suggestions were made that open and collaborative plug-in development processes (mentioned further in Sub-section A5.6) may improve code quality and runtime. To further address runtime issues, it may be helpful to leverage model emulation where applicable. This would likely necessitate further research to identify where/when emulators can be employed, and how best to operationalise them.

There were some comments about other specific technical matters, including the desirability of having available an ensemble modelling approach to tackle the issue of model structure uncertainty. More broadly, it was noted that there are various uncertainty methods available, and tools could be developed to support more accessible uncertainty analysis of the models in Source. Uncertainty analysis results should be fed back into catchment monitoring practices and model improvement.

A5.6 Comments About Other Matters

Now that Tasmania and the Northern Territory have become members of eWater, eWater membership includes the Commonwealth and all State and Territory Governments in Australia, as does the NWRC. Questions were raised as to whether it is now opportune to consider amending the NHMS-CHA to include Tasmania and the NT as signatories, recognising that consideration will have to be given to such matters as participation in a national community of practice, the broader use or not of Source or other platforms, and the existing Intellectual Property clauses in the NHMS-CHA. Such an amendment could also occur with or without changes to the SPA, though access to Source and any associated costs would be a key issue.

In considering the above, it will also be important to recognise that water agencies in the NT and Tasmania have made limited or no use of Source to date, have relatively few or somewhat different regulated river systems, that surface water entitlements are managed in different and in some cases much simpler ways (notwithstanding cases involving considerable surface water/groundwater interactions), that they currently have very limited hydrological modelling staff capacity and there are real costs involved in converting any existing models to Source. Nevertheless, there are benefits from involvement in certain aspects of the NHMS, including through the community of practice and modelling lessons associated with such matters as climate change, ephemeral streams

(including ecological, economic and social/cultural assessments and responses to development), managing unregulated low flows and high flow extractions and floodplain harvesting and associated ecological values (especially in the NT), land use change, surface water – groundwater interactions, catchment and water quality management. Applications in relatively data poor situations are particularly of interest. There are also benefits for future capacity and capability building and for individual professional development, subject to overcoming the funding challenges.

With population growth and climate change leading to longer term water pressures on water scarcity in urban areas, and a greater focus on whole of water cycle management urban model interactions (e.g. MUSIC, Source), this may require greater attention to the given to the emergent needs of urban water utilities as an increasing focus area of eWater to grow the user base.

Some questioned whether the current SPA is the best approach. Should the BoM be more/directly involved? Is it trying to get eWater to do too much - software development, research, functionality improvements? After this current two-year renewal, should eWater focus on software development, and governments look for other vehicles for coordination to progress gaps and leverage collaboration and outcomes in NHMS implementation (e.g. climate change coherence, socio-economic, surface water – groundwater interactions and the like)? What are the alternative approaches and what are those vehicles?

Maybe this is inevitable - that the demands of water managers and the community on the models will always become more complex requiring further software and model improvements and we all should just allow for this?

There were some comments that it would be useful to have a fully national water modelling warehouse and scenario recall system and a national repository of datasets and case studies of what may be best practice in particular circumstances, rather than the jurisdictions doing their own thing separately. This might be helpful as there would then be more opportunities to appropriately "pick, plug and play" with models to suit the issue at hand.

While it was acknowledged that the Source models are "accredited" for water resource planning purposes in the Murray-Darling Basin under the Basin Plan arrangements, there were variable views about the benefits and risks as to whether such accreditation should extend to Source or other hydrological modelling in other catchments and basins. The NHMS does provide opportunity for peer reviews which assist transparency and hopefully increase confidence in "fit-for-purpose" or "best available" modelling, given that considerable professional judgment is often required. Quality assurance, including in terms of consistency, repeatability and clarity in reporting, is an essential element from a statutory planning perspective.

Further to this issue, it was noted that the Source platform was originally selected due to its "adaptability to include new policy, drivers, or knowledge [and] flexibility and capability to link to new and existing models and other information systems" (e.g. see https://ewater.org.au/about-us/nhms/). As noted previously, flexibility and extension of Source beyond its original scope as a hydrological model is chiefly provided through a system of plug-ins. While this may be a sound approach, the development of plug-ins, and contributions to Source itself, are spread across various departments, organisations, and sub-groups within these. Each of these modelling efforts may adopt a disparate number of development methodologies/approaches, and technologies, with

limited opportunity for reuse and knowledge sharing. Given the number of separate efforts involved it is often difficult to assess the quality and applicability of these plug-ins, particularly as use cases change and evolve.

The suggestion here was not that all development should be centralised. It is natural for some amount of specialised functionality to be required and is unavoidable given the unique conditions and policy concerns within each geographic area. Rather, the level of collaboration and coordination across the modelling groups, and their organisations at large, could be improved such that common concerns are effectively and efficiently addressed (e.g. see Jakeman et al, 2019).

It was also noted that one aim with the adoption of a single modelling platform (i.e., Source) by Governments, as specified in 2008 by COAG, was to enable greater transparency and efficiency. Although great care and effort has been taken to document Source to the degree it has been, some considered that it was somewhat strange that a closed-source proprietary system was selected with majority control of its development and improvement handled by a single entity. To address the limitations on development transparency, accessibility, and overall modifiability of the Source platform by interested parties, it was suggested, as noted previously, that an open-sourced version, with no limitations on functionality, is needed. The view was that opening Source would go a long way to increasing the volume of use and level of interest amongst the larger water modelling community. The SWAT model was cited as an example. (The Soil and Water Assessment Tool (SWAT) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. SWAT is a public domain software enabled model actively supported by the USDA Agricultural Research Service at the Blackland Research & Extension Center in Temple, Texas, USA).

In the shorter term, it was argued that open development practices could be further adopted for any Source related work funded by Australian governments; both with regard to plug-in development and contributions to Source itself. This would involve ensuring the development process is documented and relevant data and resulting code be publicly accessible. Improving the accessibility of individual efforts would thus improve Source's transparency, capabilities and applicability across Australian catchments and for further use in domestic and international contexts. In the longer term, an open-sourced version of Source or functionally equivalent platform would enhance prospects for adoption, particularly internationally. It was also noted that a greater degree of openness and transparency would facilitate later research and development processes. Greater collaboration would improve the efficiency of development and quicken any return on investment.

There were variable views about the benefits and risks of "accrediting" hydrological modellers, perhaps in a more specific way as applies to Chartered Professional Engineers or Registered Professional Engineers. An important issue is how to get junior level people into the water modelling fraternity and ensure that the necessary skills are there for the future. Those skills are not just being able to "push the buttons in models" but rather to being able to appropriately apply models to help solve problems and sufficiently inform decisions. A comment was made that, in the past, there was a Water Industry Skills Taskforce, coordinated by the National Water Commission, and it may be useful to revisit the need.

Notwithstanding the different views on accreditation, there were comments that quality assurance of analytical modelling will be important to the NHMS journey. How that could be run nationally and in a suitably advisory, non-competitive way with appropriate governance requires further examination and clarification. How the Open Modelling Foundation (OMF) progresses may influence future approaches to be taken.

There were a few comments that the success or otherwise of the One Basin CRC bid and the recent Commonwealth budget commitment to enhance whole of basin modelling capability may help or hinder the NHMS, depending on how any hydrological modelling related parts are handled. Additional CRC or other Commonwealth funding may well help to fill gaps in knowledge and address future challenges by providing innovations, as outlined above, to the benefit of many. Alternatively, it may continue to focus effort on the Murray-Darling Basin to the detriment of broader stakeholder continued involvement and interest in the NHMS. Further, if the NHMS doesn't meet the needs of the Basin, it could be by-passed.

Entities like Infrastructure Australia are interested in the NHMS so they have a frame of reference for decision making – a transparent, evidence-based, repeatable process to describe the risk profile of water sources and water using communities and industries and to evaluate project proposals.

In its *Knowledge, capacity and capability building, Supporting Paper K* to National Water Reform 2020*,* Draft Report, (Productivity Commission, 2021) states "Investments in knowledge generation have contributed to success in water reform and management over the past 17 years since the NWI was agreed. For example, outputs of the *National Hydrological Modelling Strategy*, first initiated in 2008, are still being applied to water planning, operations and governance processes through the use of eWater Source, a national hydrological modelling platform. However, many other programs of research and development have come to an end, yet water reform is still a work in progress. Further investments in knowledge generation will be key to filling existing knowledge gaps, supporting the ongoing reform process and responding to emerging challenges."

The key points from that paper were:

- Knowledge generation has been integral to water reform achievements under the National Water Initiative. And, ongoing investment will underpin the success of future water reform efforts, particularly in the face of emerging challenges such as climate change. – It will provide a foundation for evidence-based decision making, innovation, continuous improvement and the development of community water literacy to, for example, support water planning, inform decisions about the use of environmental water and help utilities meet growing water and service demands.
- Efficient investment would be supported by a formal process of research priority setting and improved coordination between jurisdictions.
- Inclusion of an expectation in governing documents that regulated utilities invest in research and development activities to improve service delivery would empower utilities and ensure that economic regulators include associated expenditure when making price determinations.
- Provision of good information is not enough to realise evidence-based policy.
- Decision makers need to know information exists. Success requires sound relationships between knowledge generators and users. Institutional mechanisms like communities of

practice and Cooperative Research Centres can support the development and maintenance of these relationships.

- Decision makers also need the capacity and capability to use information. Governments need to ensure that water planners, managers, regulators and policy makers have both the resources and the knowledge, skills and experience required to effectively implement the National Water Initiative.
- The staff of water utilities also need support, training, skills and qualifications to be able to effectively discharge their functions.

There seems to be considerable thought being given to these matters. Comments were made about the work by three Australian Academies to provide recommendations to Government about a vision and institutional settings for water related research and development and a costed strategy to achieve it. It is likely that a NHMS would be an integral part of such a broader water strategy.

APPENDIX 6 – SUMMARY INFORMATION ABOUT THE OPEN MODELLING FOUNDATION (OMF)

An International Network for Computational Modelling Standards in the Social, Ecological, Environmental, and Geophysical (SEEG) Sciences

We inhabit a world in which the dynamics of a globally networked society are inextricably entangled with biophysical forces in a planetary complex system. Humankind is now confronted with being the de facto 'manager' of this unprecedented socio-ecological system that is evolving at an increasingly rapid pace. Computational modelling, digital data, and data science are increasingly critical tools that augment innate human capacities to support policy and planning, scenario development, environmental management, resource investment, and security preparedness. These powerful scientific tools help us to understand the social and biophysical dynamics of earth systems and generate forecasts about future conditions of these systems under a range of climate, bio-geophysical, and socio-economic conditions.

Because of the critical role of modelling for both science and policy making, a comprehensive strategy for building and deploying next generation modelling technologies is a global grand challenge for a sustainable future. The networks in the OMF envision future SEEG modelling as an evolving ecosystem of models, developed by diverse scientists and teams around the world, and broadly reusable across multiple science and policy domains. In such an ecosystem, models also would be more readily interoperable as components in more complex meta-models to represent dynamics of coupled systems at multiple scales from local to planetary. Such an ecosystem requires common standards so that models are created in a way that enables SEEG scientists to access and clearly understand each other's work, use and build on each other's code, and potentially connect each other's models in a commonly understood way.

A global scientific network of networks is proposed to enable new dimensions of collaboration among existing, international communities engaged in modelling human and earth systems, spanning the social, ecological, environmental, and geophysical (SEEG) sciences. Common standards for modelling across the SEEG sciences are fundamental for creating an interdisciplinary lingua franca to support next generation integrative science to meet the planetary, social and environmental challenges we face in coming decades. Successful development and administration of such standards require a new, international, cooperative enterprise, involving numerous existing scientific networks and other stakeholders. The participants in this proposal lead established scientific networks, involving thousands of researchers around the world, that will jointly establish the Open Modelling Foundation (OMF) to coordinate such a standards-based, FAIR-aligned approach to enable scientists to create next generation modelling technology for coupled human and earth systems.

The OMF will:

1) develop accessibility standards so that model code can be easily discovered and retrieved from persistent Internet locales;
2) develop standards for comprehensive documentation to enable models to be widely used and replicated;
3) identify and adopt technology standards to facilitate reusability;
4) develop and adopt standards for APIs and common ontologies so that models can be more readily interconnected in an open model ecosystem;

5) create cyberinfrastructure to help modelling scientists implement technologies to make their models reusable and interoperable;
6) create educational programs and professional incentives to encourage modellers to adopt such standards.

Additional modelling science organisations will be invited to join the OMF and many have already expressed interest in doing so. Enabling scientists to leverage each other's expertise and work in ways not currently possible can catalyse a surge of innovative scientific research and new applications of modelling to societal and environmental challenges, benefiting communities throughout the globe.

This project seeks to transform the future of modelling science, expanding humanity's ability to understand and manage the planetary socio-ecological system we have created. The OMF will provide a framework to enable and encourage new collaboration across this vitally important field where science and policy meet. It will do this, not by attempting to impose a single 'best' way to model coupled human-earth systems, but by forging a bottom-up alliance of scientific communities that share the goals of understanding this complex planetary system and enabling humanity to sustainably manage it for the future. The need to make well-informed social and environmental decisions is a global one, benefiting by involvement of diverse stakeholders, conceptual approaches, and rich local knowledge. The OMF aspires to be an environment where these can come together to improve human well-being and to envision and plan a better future.

Australian Involvement

The past two years of the OMF initiative have involved Australian researchers being engaged with the global modelling community in strategic planning workshops and one-on-one discussions to compile input and generate interest. The pandemic has stretched this out somewhat longer than initially envisioned. The OMF's early June 2021 workshops, in which Australians were directly involved, was the last of these. It is planned to finish integrating the results of this effort into a proposed governance charter, organizational structure, and work plan. It is hoped to convene an organisational meeting for the OMF before the end of 2021 and present a document for discussion, revision, and approval, formally starting the OMF. The idea is to offer an opportunity to as many potential stakeholders as possible to have a stake in the organization--get in on the ground floor so to speak. It is hoped that at least some Australian modelling organisations will join as members of the OMF.