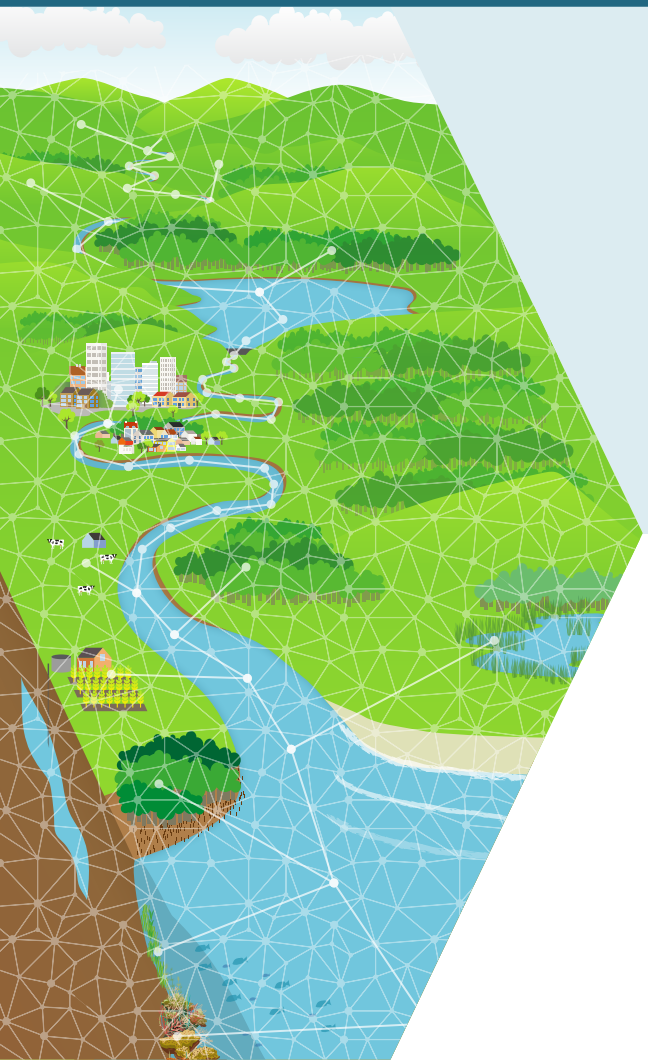
QUEENSLAND WATER
MODELLING NETWORK



Strategic Review of Models

MODEL CLASSIFICATION

Report prepared by
BMT, The University of Queensland and
The University of Western Australia
For Queensland Water Modelling Network

Queensland Government

The Queensland Water Modelling Network (QWMN) is an initiative of the Queensland Government that aims to improve the state's capacity to model its surface water and groundwater resources and their quality. The QWMN is led by the Department of Environment and Science with key links across industry, research and government.

Prepared by: BMT, The University of Queensland and The University of Western Australia

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Introduction

Water modelling helps us better understand our environment and plan for the future. Water models help inform how we manage landscapes and catchments as well as design and manage water for our cities (QWMN, 2019). Computer-based models present real-world interactions and explore how they operate under different conditions, such as learning how pollutants will disperse in coastal areas (QWMN, 2021).

A range of different water modelling tools are used in Queensland to inform critical decision-making related to the management of natural resources. Modelling makes an important contribution to policy development, regulatory compliance, development approvals, risk assessments, planning scenarios and management.

The Queensland Water Modelling Network (QWMN) was established in 2017 to help improve the state's capacity to model its surface water and groundwater resources and their quality. The QWMN provides tools, information and collaborative platforms to support best-practice use of water models, and the uptake of their results by policy makers and natural resource managers.

In particular, the QWMN advocates for water models to be 'fit for purpose' including how they can be effectively maintained and improved. A range of projects are working to address weaknesses and gaps in water modelling to more effectively support urgent and significant decision-making processes.

The QWMN's 2018-2020 Research, Development and Innovation Strategy raised the need to conduct a strategic review of water models to help identify, substantiate and prioritise investment in water modelling over the next five years (2020-2025). The Strategy noted that investment in water modelling would benefit from an objective, transparent and adaptive process for evaluating water models and identifying key challenges, opportunities and risks for future model development and application.

The QWMN commissioned BMT, The University of Queensland and The University of Western Australia to undertake a strategic review of Queensland water models including developing an approach to classify models and a framework for assessment. Case studies were performed to test the applicability of the framework. This report provides a summary of the model classification approach that seeks to:

- expand the information available for models in the QWMN Model Catalogue
- guide assessment of models, with emphasis on the underlying science, use and functionality
- explore model limitations and adaptation.

The Strategic Review of Models – Model Assessment Framework report provides more information about the assessment methodology and is recommended reading to obtain a holistic understanding of how the approach works in practice. A worked example of the application of the model assessment framework can be found in the 'Strategic Review of Models – Great Barrier Reef eWater SOURCE case study.

Model classification approach

The QWMN Water Model Catalogue (Carroll, C and Yu, B, 2018, QWMN Water Model Catalogue, Department of Environment and Science, Queensland Government) collates and provides a concise overview of 18 of the major water models currently used by the Queensland Government (see below). While the catalogue provides comprehensive information for the specified models, the Strategic Review proposed a broader classification methodology to enable improved understanding and comparison of models. The expanded classification was organised into different themes that helped to guide community engagement activities and informed the development of the Model Assessment Framework. It is intended that this be a living document, recognising how existing models develop and new models emerge. Future iterations of this work will reflect and incorporate models beyond those used by the Queensland Government.

Major water models in use by the Queensland Government

1. 2CSALT
2. APSIM
3. Aussie GRASS
4. BC2C
5. eWater SOURCE – water quantity
6. eWater SOURCE – water quality
7. GRASP
8. HEC-RAS
9. HowLeaky
10. IQQM
11. MEDLI
12. MIKE
13. MODFLOW
14. Sacramento
15. SIMHYD
16. SoilWater App (SwaApp)
17. TUFLOW
18. WATHNET

Classification themes

A series of classification themes were developed to support assessment of current model uses and their corresponding functionality. Collectively, the themes would enable an assessor to map the current capabilities of a model and to subsequently identify any areas requiring improvement and investment.

The themes are presented in the tables below.

Model classification themes

Theme	Classifier
Key area of model use	▶ Farming and agricultural systems assessment ▶ Water planning and supply ▶ Catchment policy ▶ Groundwater policy ▶ Receiving and coastal water quality reporting ▶ Flooding ▶ Aquaculture ▶ Mine decommissioning and discharges ▶ Other
Model type	▶ Deterministic v stochastic v mixed ▶ Static v dynamic ▶ Discrete v continuous*
Model licensing	▶ Open source ▶ Proprietary ▶ Public ▶ Not specified
Spatial and temporal scales	Models are often able to operate over a relatively wide range of spatial and temporal scales. This means that there could potentially be multiple models that can be used to answer the same question. This component aims to identify any overlaps that there might be between models and help with the selection of potential model platforms for a given key area of model use. This information is provided in graphic form to facilitate identification of models and scales.
Process understanding and expertise required for effective model use	▶ Comprehensive ▶ Partial ▶ Conceptual ▶ Very little (black box) ▶ None
Type of interface	▶ GUI ▶ Text-based ▶ Mixed
Set-up and post-processing effort	▶ Extensive ▶ Medium ▶ Little ▶ None

* Discrete in this context means models that are run on a grid or mesh and on a specified time step. Continuous are models that can produce a response at any location and time that are not defined on a grid or mesh or a specified time step.

Theme	Classifier
Calibration requirements	▶ Extensive ▶ Moderate ▶ Little ▶ None
Level of support	▶ Well supported ▶ Moderately supported ▶ Poorly supported ▶ Not supported
Stakeholder communication and knowledge transfer	▶ Easy and readily achievable ▶ Easy but not readily achievable ▶ Moderate ▶ Difficult ▶ Not required
Governance/quality control of modelling process	▶ Extensive ▶ Reasonable ▶ Limited
Model usage context	▶ Policy formulation ▶ Regulatory/permitting ▶ Planning ▶ Impact assessments ▶ Other
Uncertainty handling	▶ Comprehensive ▶ Partial ▶ Non-existent

Model classification

Models were classified according to each theme. The classification was determined using an online community engagement survey, modellers' feedback and a model end-users' workshop. Where the information was not directly available, information was obtained from the public domain (i.e. internet search and model web pages). An additional five models not in the QWMN Model Catalogue were included in the model classification approach: AEM3D, eReefs, FABM, GLM and SWAT. Inclusion of these models in the classification provided greater diversity of models addressing pollutant fate and transport and lake and reservoir modeling.

Model users self-reported via the online community engagement survey and the following classifications are informed by survey feedback and workshop results. It should be noted that some models may have more than one classification within a theme as a single model can be used for several applications. It is also important to recognise the classification represents a synthesis of water modelling community feedback and that some of the responses were necessarily subjective to the respondents. It is anticipated that some of the assigned model classifications may evolve over time in response to additional feedback and/or technology advances.

Using the key area of model use as the foundation, the following pages map each model to the remaining themes, characterising each model by its performance against objective measures. This is based on results from various surveys and workshop consultations.

Key area of model use

Each model was classified for each key area of model use. The results were as follows:

Model use	Model/s
Paddock scale processes	HowLeaky, GRASP, Aussie Grass, APSIM, MEDLI
Catchment/basin scale hydrology	Mike 11, IQQM, Sacramento, eWater SOURCE, HowLeaky, MUSIC, SIMHYD, SWAT, WATHNET, HEC-RAS, Aussie Grass, APSIM, MODFLOW, TUFLOW
Groundwater related investigations	APSIM, MODFLOW
Flooding	Mike 11, HEC-RAS, TUFLOW
Pollutant fate and transport	eWater SOURCE, HowLeaky, MUSIC, SWAT, GLM, AEM3D, FABM,GRASP, Aussie Grass, APSIM, MEDLI, MODFLOW, e-Reefs, TUFLOW
Water Balance	HEC-RAS, WATHNET, TUFLOW
Regional Water Security and Drought Respond Planning	IQQM, WATHNET
Lake and reservoir modelling	GLM, AEM3D, FABM, TUFLOW
Hydraulic Modelling	HEC-RAS, TUFLOW
Water Delivery to Customers	IQQM
Customised SEQ Stream Health Model	eWater Source, TUFLOW

Remaining themes

Paddock scale processes

Theme	Classifier	HowLeaky	GRASP	Aussie Grass	APSIM	MEDLI
Model type	Deterministic v stochastic v mixed	Deterministic	Deterministic	Deterministic	Deterministic	Mixed
	Static v dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Continuous	Discrete	Continuous	Continuous	Discrete
Model licensing	Open source		■	■		
	Proprietary	■			■	■
	Public					
	Not specified					
Process understanding and expertise required for effective model use	Comprehensive	■	■	■	■	■
	Partial					
	Conceptual					
	Very little (black box)					
	None					
Type of interface	GUI	■	■			■
	Text-based			■	■	
	Mixed					
Set-up and post processing effort	Extensive		■	■	■	■
	Medium	■				
	Little					
	None					
Calibration requirements	Extensive					
	Moderate	■	■	■	■	■
	Little					
	None					
Level of support	Well supported				■	
	Moderately supported	■				■
	Poorly supported		■	■		
	None					
Stakeholder communication and knowledge transfer	Easy and readily achievable	■				
	Easy but not readily achievable					
	Moderate					
	Difficult		■	■	■	■
	Not required					
Quality control of modelling process	Extensive					
	Reasonable	■	■	■	■	■
	Limited					
Model usage context	Policy formulation	■	■	■	■	■
	Regulatory/ permitting	■				■
	Planning	■	■	■	■	■
	Water management	■	■	■		
	Other		■	■		■
Uncertainty handling	Comprehensive					
	Partial	■	■	■	■	■
	Non-existent					

Remaining themes

Catchment/basin scale hydrology

Theme	Classifier	Mike 11	IQQM	Sacramento	e-Water SOURCE	HowLeaky	MUSIC	SIMHYD
Model type	Deterministic v stochastic v mixed	Determ.	Determ.	Determ.	Determ.	Determ.	Determ.	Determ.
	Static v dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Cont.	Discrete	Discrete	Discrete	Cont.	Cont.	Discrete
Model licensing	Open source							
	Proprietary	■			■	■	■	■
	Public		■	■				
	Not specified							
Process understanding and expertise required for effective model use	Comprehensive	■	■	■	■	■	■	■
	Partial							
	Conceptual							
	Very little (black box)							
	None							
Type of interface	GUI	■			■	■	■	■
	Text-based							
	Mixed		■	■				
Set-up and post processing effort	Extensive	■			■			
	Medium		■	■		■	■	■
	Little							
	None							
Calibration requirements	Extensive	■	■	■	■			
	Moderate				■	■	■	■
	Little							
	None							
Level of support	Well supported							
	Moderately supported				■	■	■	■
	Poorly supported	■	■	■				
	None							
Stakeholder communication and knowledge transfer	Easy and readily achievable	■	■	■	■	■	■	■
	Easy but not readily achievable							
	Moderate							
	Difficult							
	Not required							
Quality control of modelling process	Extensive							
	Reasonable	■	■	■	■	■	■	■
	Limited							
Model usage context	Policy formulation	■	■	■	■	■	■	■
	Regulatory/ permitting	■	■	■	■	■	■	■
	Planning	■	■	■	■	■	■	■
	Water management					■		
	Other							
Uncertainty handling	Comprehensive							
	Partial	■	■	■	■	■	■	■
	Non-existent							

Remaining themes

Catchment/basin scale hydrology

Theme	Classifier	SWAT	WATHNET	HEC-RAS	Aussie Grass	APSIM	MODFLOW	TUFLOW
Model type	Deterministic v stochastic v mixed	Determ.	Determ.	Determ.	Determ.	Determ.	Determ.	Determ.
	Static v dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Discrete	Discrete	Discrete	Cont.	Cont.	Discrete	Discrete
Model licensing	Open source	■		■	■			
	Proprietary					■		■
	Public		■				■	
	Not specified							
Process understanding and expertise required for effective model use	Comprehensive	■	■	■	■	■	■	■
	Partial							
	Conceptual							
	Very little (black box)							
	None							
Type of interface	GUI			■				
	Text-based				■	■		
	Mixed	■	■				■	■
Set-up and post processing effort	Extensive	■	■	■	■	■	■	■
	Medium							
	Little							
	None							
Calibration requirements	Extensive	■	■	■				■
	Moderate				■	■	■	
	Little							
	None							
Level of support	Well supported	■				■	■	■
	Moderately supported			■				
	Poorly supported				■			
	None							
Stakeholder communication and knowledge transfer	Easy and readily achievable	■	■	■				■
	Easy but not readily achievable							
	Moderate							
	Difficult				■	■	■	
	Not required							
Quality control of modelling process	Extensive							
	Reasonable	■	■	■	■	■	■	■
	Limited							
Model usage context	Policy formulation	■	■	■	■	■	■	■
	Regulatory/ permitting		■				■	■
	Planning	■	■	■	■	■	■	■
	Water management	■	■	■	■		■	■
	Other		■	■	■			■
Uncertainty handling	Comprehensive							
	Partial	■	■	■	■	■	■	■
	Non-existent							

Remaining themes

Groundwater related investigations

Theme	Classifier	APSIM	MODFLOW
Model type	Deterministic v stochastic v mixed	Deterministic	Deterministic
	Static v dynamic	Dynamic	Dynamic
	Discrete v continuous	Continuous	Discrete
Model licensing	Open source		
	Proprietary		
	Public		
	Not specified		
Process understanding and expertise required for effective model use	Comprehensive		
	Partial		
	Conceptual		
	Very little (black box)		
	None		
Type of interface	GUI		
	Text-based		
	Mixed		
Set-up and post processing effort	Extensive		
	Medium		
	Little		
	None		
Calibration requirements	Extensive		
	Moderate		
	Little		
	None		
Level of support	Well supported		
	Moderately supported		
	Poorly supported		
	None		
Stakeholder communication and knowledge transfer	Easy and readily achievable		
	Easy but not readily achievable		
	Moderate		
	Difficult		
	Not required		
Quality control of modelling process	Extensive		
	Reasonable		
	Limited		
Model usage context	Policy formulation		
	Regulatory/ permitting		
	Planning		
	Water management		
	Other		
Uncertainty handling	Comprehensive		
	Partial		
	Non-existent		

Remaining themes

Flooding

Theme	Classifier	Mike 11	HEC-RAS	TUFLOW
Model type	Deterministic v stochastic v mixed	Deterministic	Deterministic	Deterministic
	Static v dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Continuous	Discrete	Discrete
Model licensing	Open source		■	
	Proprietary	■		■
	Public			
	Not specified			
Process understanding and expertise required for effective model use	Comprehensive	■	■	■
	Partial			
	Conceptual			
	Very little (black box)			
	None			
Type of interface	GUI	■	■	
	Text-based			
	Mixed			■
Set-up and post processing effort	Extensive	■	■	■
	Medium			
	Little			
	None			
Calibration requirements	Extensive	■	■	■
	Moderate			
	Little			
	None			
Level of support	Well supported			■
	Moderately supported		■	
	Poorly supported	■		
	None			
Stakeholder communication and knowledge transfer	Easy and readily achievable	■	■	■
	Easy but not readily achievable			
	Moderate			
	Difficult			
	Not required			
Quality control of modelling process	Extensive			
	Reasonable	■	■	■
	Limited			
Model usage context	Policy formulation	■	■	■
	Regulatory/ permitting	■		■
	Planning	■	■	■
	Water management		■	■
	Other		■	■
Uncertainty handling	Comprehensive			
	Partial	■	■	■
	Non-existent			

Remaining themes

Pollutant fate and transport

Theme	Classifier	e-Water SOURCE	HowLeaky	MUSIC	SWAT	GLM	AEM3D	FABM
Model type	Deterministic v stochastic v mixed	Determ.	Determ.	Determ.	Determ.	Determ.	Determ.	Determ.
	Static v dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Discrete	Cont.	Cont.	Discrete	Discrete	Discrete	Discrete
Model licensing	Open source				■	■		■
	Proprietary	■	■	■			■	
	Public							
	Not specified							
Process understanding and expertise required for effective model use	Comprehensive	■	■	■	■	■	■	■
	Partial							
	Conceptual							
	Very little (black box)							
	None							
Type of interface	GUI	■	■	■				
	Text-based							
	Mixed				■	■	■	■
Set-up and post processing effort	Extensive	■			■	■	■	■
	Medium	■	■	■				
	Little							
	None							
Calibration requirements	Extensive	■			■	■	■	■
	Moderate	■	■	■				
	Little							
	None							
Level of support	Well supported				■	■	■	■
	Moderately supported	■	■	■				
	Poorly supported							
	None							
Stakeholder communication and knowledge transfer	Easy and readily achievable	■	■	■	■	■	■	■
	Easy but not readily achievable							
	Moderate							
	Difficult							
	Not required							
Quality control of modelling process	Extensive							
	Reasonable	■	■	■	■	■	■	■
	Limited							
Model usage context	Policy formulation	■	■	■	■	■	■	■
	Regulatory/ permitting	■	■	■				
	Planning	■	■	■	■	■	■	■
	Water management		■	■	■	■	■	■
	Other					■	■	■
Uncertainty handling	Comprehensive							
	Partial	■	■	■	■	■	■	■
	Non-existent							

Remaining themes

Pollutant fate and transport

Theme	Classifier	GRASP	Aussie Grass	APSIM	MEDLI	MODFLOW	e-Reefs	TUFLOW
Model type	Deterministic v stochastic v mixed	Determ.	Determ.	Determ.	Mixed	Determ.	Determ.	Determ.
	Static v dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Discrete	Cont.	Cont.	Discrete	Discrete	Discrete	Discrete
Model licensing	Open source	■	■					
	Proprietary			■	■			■
	Public					■	■	
	Not specified							
Process understanding and expertise required for effective model use	Comprehensive	■	■	■	■	■	■	■
	Partial							
	Conceptual							
	Very little (black box)							
	None							
Type of interface	GUI	■			■			
	Text-based		■	■				
	Mixed					■	■	■
Set-up and post processing effort	Extensive	■	■	■	■	■	■	■
	Medium							
	Little							
	None							
Calibration requirements	Extensive						■	■
	Moderate	■	■	■	■	■		
	Little							
	None							
Level of support	Well supported			■		■	Unclear	■
	Moderately supported				■			
	Poorly supported	■	■					
	None							
Stakeholder communication and knowledge transfer	Easy and readily achievable						■	■
	Easy but not readily achievable							
	Moderate							
	Difficult	■	■	■	■	■		
	Not required							
Quality control of modelling process	Extensive							
	Reasonable	■	■	■	■	■	■	■
	Limited							
Model usage context	Policy formulation	■	■	■	■	■	■	■
	Regulatory/ permitting				■	■		■
	Planning	■	■	■	■	■	■	■
	Water management	■	■			■		■
	Other	■	■		■			■
Uncertainty handling	Comprehensive							
	Partial	■	■	■	■	■	■	■
	Non-existent							

Remaining themes

Others

Theme	Classifier	IQQM	HEC-RAS	WATHNET	GLM	AEM3D	FABM	TUFLOW
Model type	Deterministic v stochastic v mixed	Determin-istic	Determin-istic	Determin-istic	Determin-istic	Determin-istic	Determin-istic	Determin-istic
	Static v dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
	Discrete v continuous	Discrete	Discrete	Discrete	Discrete	Discrete	Discrete	Discrete
Model licensing	Open source							
	Proprietary							
	Public							
	Not specified							
Process understanding and expertise required for effective model use	Comprehensive							
	Partial							
	Conceptual							
	Very little (black box)							
	None							
Type of interface	GUI							
	Text-based							
	Mixed							
Set-up and post processing effort	Extensive							
	Medium							
	Little							
	None							
Calibration requirements	Extensive							
	Moderate							
	Little							
	None							
Level of support	Well supported			Unclear				
	Moderately supported							
	Poorly supported							
	None							
Stakeholder communication and knowledge transfer	Easy and readily achievable							
	Easy but not readily achievable							
	Moderate							
	Difficult							
	Not required							
Quality control of modelling process	Extensive							
	Reasonable							
	Limited							
Model usage context	Policy formulation							
	Regulatory/ permitting							
	Planning							
	Water management							
	Other							
Uncertainty handling	Comprehensive							
	Partial							
	Non-existent							

Issues and insights

Adaptability

The authors identified a broad trend towards use of flexible/adaptable modelling platforms – i.e. surmising that future investment would incorporate aspects of the specialist models into the broader more flexible platforms. The development history of MODFLOW reflect this trend with version six now incorporating the functionality of many models that were formally considered specialist.

The classification process identified that some models are more adaptable (i.e. eWater SOURCE, SWAT, HEC-RAS, TUFLOW) than others as they span a range of uses. In particular, these models offered flexibility in their approach to dealing with both hydraulic properties and contaminant fate and transport. This does not mean the other models are inferior, rather their applicability is narrower and largely specialised for the context they were designed for (e.g. WATHNET, MEDLI, HowLeaky, APSIM, Aussie GRASS, MUSIC). MODFLOW was recognised as a versatile model and the one most widely used for groundwater investigations.

Specialist experience

The water modelling community feedback was very clear about the importance of applied expertise when interacting with models. Two themes – process understanding and expertise required for effective model use – were deemed essential requirements across all models. This feedback should not be understated, as it shows water modelling is a largely specialised field with each model requiring advanced expertise for efficient and effective application. It is corroborated by the fact that most models require significant effort in the modelling process. It is also a potential area for efficiencies to be realised, particularly for model pre-processing activities that share common inputs (i.e. rainfall data QA/QC). Efficiencies in post-processing of model outputs could also be gained such as common open source libraries for statistical analysis and plotting/visualisation of results such as the growing open source Python-based libraries. It could support a case for developing shared routines to generate information in ways that are preferred by stakeholders and regulatory agencies. Uncertainty is another area that shows current efforts are still incipient, at least in how they are applied throughout government modelling practices. Additional applied research for inclusion in more mainstream model applications is recommended.

Engagement

Model classification also highlighted differences in communication capabilities. Stakeholder communication and knowledge transfer for most models was assessed as easily and readily achievable. However, models dealing with paddock scale processes and groundwater were assessed to be difficult (e.g. MEDLI, MODFLOW, APSIM, GRASP, Aussie Grass). The feedback indicates more education and engagement with model end-users and stakeholders would result in more effective communication.

Technology

Technology support was identified as a key area to be maintained or improved. Most proprietary software was recognised as either moderately or well supported. The models that were identified as having a poor level of support included GRASP, Aussie GRASS, IQQM and Sacramento. There was not a clear distinction between the level of support offered by public and open source software.

Get involved

The model classification is designed to be a living document and is anticipated to evolve over time. The QWMN encourages modellers and end-users to consider the classifications and provide feedback to further refine and extend the analysis.

Questions to consider:

- Are there other themes that need to be included in the classification approach?
- Are there any other types of information that should be considered when making decisions about future investment in models and modelling platforms?

Send your feedback to qwmn@des.qld.gov.au

References

QWMN, (2019). Queensland Water Modelling Network Research, Development and Innovation Strategy 2018-2020. Queensland Government, Brisbane

QWMN, (2021). Queensland Water Modelling Network information accessed from https://watermodelling.org/water-modelling/what-is-water-modelling