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Comparative Analysis of Groundwater Simulation Models: MODFLOW vs. FEFLOW

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ABSTRACT

Aquifer analysis and management tools have become common; these are groundwater modelling tools like MODFLOW and FEFLOW. This paper sought to compare the perceptions of the experts regarding their usability, learning curve, suitability and effectiveness. The qualitative approach was used, and a secondary sources literature review was implemented alongside the semi-structured interviews of six experienced practitioners conducted and thematic analysis was a method of their analysis. Findings indicate that MODFLOW is more approachable, generally accepted by governments, and more efficient in situations where a large geologic regional coverage with a homogeneous type is involved, and FEFLOW is more efficient in cases where complex heterogeneous systems and coupled processes are involved. The research has concluded that one model is not by any means superior to the other, and selection depends on the situation. It suggests flexibility in being able to use both tools as a dual capability. An example of practical implications is informing model selection, training design and policy guidelines. The weaknesses are small purposive sampling and the use of self-reported experiences.

Keywords: MODFLOW, FEFLOW, Groundwater Modelling, Thematic Analysis, Hydrogeological Applications.

INTRODUCTION

Groundwater modelling is a vital aspect within hydrogeology as practitioners' equipment, allowing them to simulate flow systems within the ground, assess how aquifers react to stresses and assist in making sound decisions in sustainably managing water resources. Renowned examples of modelling platforms include the MODFLOW, which has been developed and maintained by the United States Geological Survey (USGS) and the FEFLOW commercial developed by the DHI Group Inc. Although the organisation of the set of equations in MODFLOW has become, by convention, the global standard of well-organised finite-difference modelling of groundwater flow, the finite-element framework of FEFLOW has the added benefit of flexibility in modelling complex geometry and coupled phenomena. Although they are considered roles established within the sphere, there is still a lack of qualitative studies in the view of learning how such expert users perceive and implement these models in the real world. The current study fills that gap by presenting expert hydrogeologists' opinions on the usefulness and applicability of MODFLOW and FEFLOW through a thematic study on in-depth interviews.

In the last 20 years, numerical groundwater models have been increasingly used to quantifiably estimate the potential of an aquifer, assess pollution of groundwater, and plan how to use water as a resource. Initially available in the 1980s, MODFLOW has emerged into a full-featured modular block that can incorporate surface-sinter-groundwater interactions, the transport of solutes, and variable-density flows using extensions (Guleria et al., 2023). With the publication of MODFLOW 6, new powerful simulation features were added to it, such as better integration of the hydrological system and model discretisation (Zhao et al., 2024). Simultaneously, FEFLOW has also become an effective code platform that facilitates multi-physics simulations that integrate flow, solutes, and heat transport simulation in an unstructured mesh-based form (Koskinen et al., 2025). This qualification of distorted boundaries and heterogeneous formations has made it enticing to any site-specific exploration with complicated hydrogeology (Lozano Hernández et al., 2024). Recent works emphasise the increase in demand to consider the use of numerical tools in decision-support structures of sustainable groundwater management (Kumar et al., 2025; Hoglund et al., 2025). MODFLOW as well as FEFLOW have been shown to be quite worthy of both academic studies and real-world projects, but most of the literature has focused on the technical capabilities with little attention to the user-feature point of view.

Problem Statement

Despite the wide application of both tools, a comparative assessment of MODFLOW and FEFLOW has been carried out mainly with mass measurement performance indicators, including accuracy in calibration, computational time, and reliability in the forecasts (Sharma et al., 2020). Although such measures are valuable, their inability to measure experiential value, such as the learning curve, workflow efficiency, flexibility to project limitations and technical support quality, makes them less valuable in model selection. Lack of systematic qualitative knowledge hampers the possibility of forming substantial decisions by practitioners, teachers, and policy-makers when planning to use modelling tools in a certain application (Kumar et al., 2025; Haque et al., 2021). Also, with the growing complexity of the groundwater management issues, new requirements are emerging in the search for models not only technologically viable but also operationally feasible as well as convenient to use (Lozano Hernández et al., 2024; Leaf & Fienen, 2022). In the absence of a detailed study on expert perceptions, one could be faced with incorrect tool selection opportunities, and hence, groundwater modelling project efficiency and effectiveness may be undermined (Hoglund et al., 2025).

Aims and Objectives

The main research idea of using the current study is reflected in the perception of expert hydrogeologists on usability and the level of a match of the specifications of MODFLOW and FEFLOW in diverse hydrogeology circumstances. The research is guided by two objectives:

To explore experts' perceptions of the usability and learning curve of MODFLOW and FEFLOW in practical groundwater modelling applications.

To examine experts' views on the suitability and effectiveness of MODFLOW and FEFLOW for different hydrogeological scenarios.

All the objectives would be backed by specific interview questions that would give a detailed experience-based opinion and would be thematically analysed to determine common patterns and themes.

Significance of the Study

The study contributes significantly to the methods and practical work in the field of groundwater modelling. Its methodological context is a qualitative one, conducting theoretical analysis of the expert interviews as a thematically analysed qualitative approach to develop a contextually in-depth insight into the study that would have been lost had it made a quantitative comparison. In practice, the conclusion would offer a guide on how to choose modelling tools taking into consideration operational issues like user friendliness, flexibility to a particular hydrogeological environment and possible long-term applicability. The approach to the analysis of user experiences would help researchers, consultants, and water managers to meet the project requirements, training strategies, and institutional capacities in the choice of the model. In addition, it is likely to draw out possible future areas of enhancement in the design of software and user support and eventually improve the practical handy-ness of both MODFLOW and FEFLOW as they apply in the field of groundwater management.

LITERATURE REVIEW

Hydrological science involves the behaviour of groundwater dynamics, which is measurable and plausible by groundwater simulation models considering multiple stressors responses, and this also helps the researchers and practitioners in the management of the available resources in a sustainable manner. The two prevailing groundwater modelling methods are MODFLOW and FEFLOW, but there is an inadequacy of empirical perceptions through the examination of these two methods. In order to correct this imbalance, the current literature review synthesises the recent studies to analyse the way in which expert practitioners view the topics of usability, learning curves and model applicability in the light of hydrogeological settings. The two research objectives form the structure of the review and thus the theoretical framework, and the identification of literature gaps forms the discussion.

Perceptions of Usability and Learning Curve in MODFLOW and FEFLOW

To develop an adequate understanding regarding the usability and learning curves of groundwater modelling tools, it is crucial to understand how such tools can be effectively utilised and how this may be achieved in the long run. Usability is about the interface design, ease of workflow, as well as intuitiveness of parameterisation processes, whilst the learning curve is how long the person takes to gain proficiency and the cost incurred or resources consumed.

Usability of MODFLOW

In recent literature, the widespread popularity of MODFLOW as a flexible, documented, and transparent modelling tool that already has a large user base and a multitude of extensions has been highlighted (El-Rawy et al., 2022; Janipella & Pujari et al., 2022). Its modular design, based on packages, allows users to tailor simulations to both individual hydrogeological processes and makes the configuration steep, which is further possible (Mohamed et al., 2024). The base USGS distribution is text-file driven, but GUIs like Model Muse and Groundwater Vistas have considerably enhanced accessibility, and that can lessen the demands of coding by hand (Lotteraner et al., 2023). However, pragmatic testing has shown that even non-expert users are likely to have trouble with parameter linking, stress period configuration and convergence troubleshooting, leading to the conclusion that the practical usability remains significantly experience-dependent (Gregory et al., 2024).

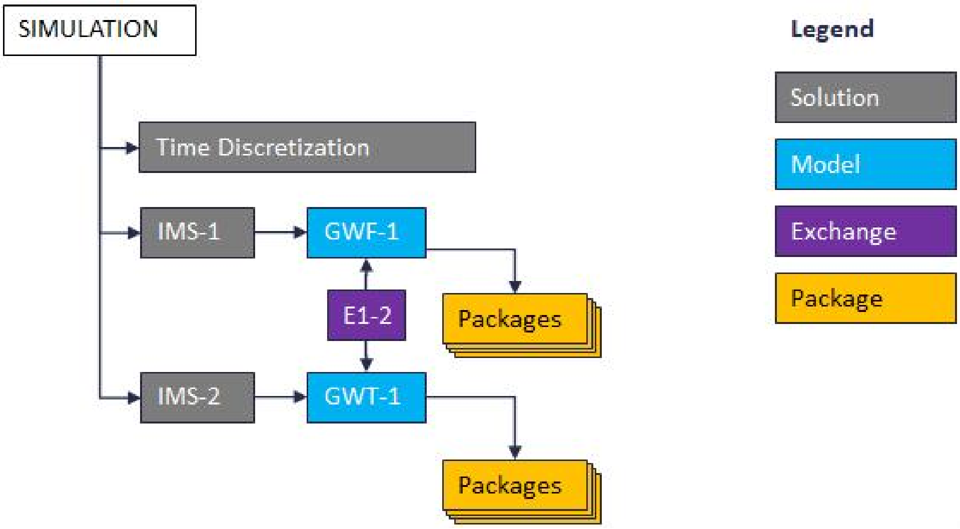

Figure 1. Simulation Framework of MODFLOW

Figure 1 shows the simulation framework which underlies the structure of the MODFLOW-6 input file. This enables the capability to develop simulations with one or more models of either the same or different types into separate or combined solution categories. Today, MODFLOW-6 supports groundwater flow (GWF) and transport (GWT) models; the framework is strongly generalised; thus, other models can be added later (e.g. connected linear network flow and transport and/or surface water flow and transport). It is written in the main simulation file (MFSIM.NAM) that involves the links to the model(s) and solution group(s). Linked to the file is a time discretisation that is processed by the time discretisation (TDIS) package for all models within the simulation. This contrasts slightly with the style in earlier versions of MODFLOW and MT3D-MS (and variants) in which stress periods and transport steps were treated differently. The Models are solved as a solution group in the Iterative Model solution package (IMS), which is nearly identical to the solver used in MODFLOW-USG, the sparse matrix solver (SMS) package, which consists of both nonlinear and linear solvers, and exchange packages connect the models.

Usability of FEFLOW

It has been reported that FEFLOW has a very integrated GUI, allowing users to create and set boundaries on the model and run simulations in one place (Zhou et al., 2020; Koskinen et al., 2025). Finite-element meshing of the irregular representation of a boundary and the local discretisation are possible, which MODFLOW does not provide in its structured grids (Zhou et al., 2020). Moreover, the tools incorporated into the package, including an automated calibration tool, FePEST and many add-on transport and density-dependent flow options provided in the core package, improve the functionality of the package (Mishra et al., 2025). Moreover, being a commercial tool, free access to FEFLOW is partly limited by the price of licenses and US-based free learning materials that can potentially exclude small organisations or novice professionals in the field (Narayanamurthi & Ramasamy, 2023).

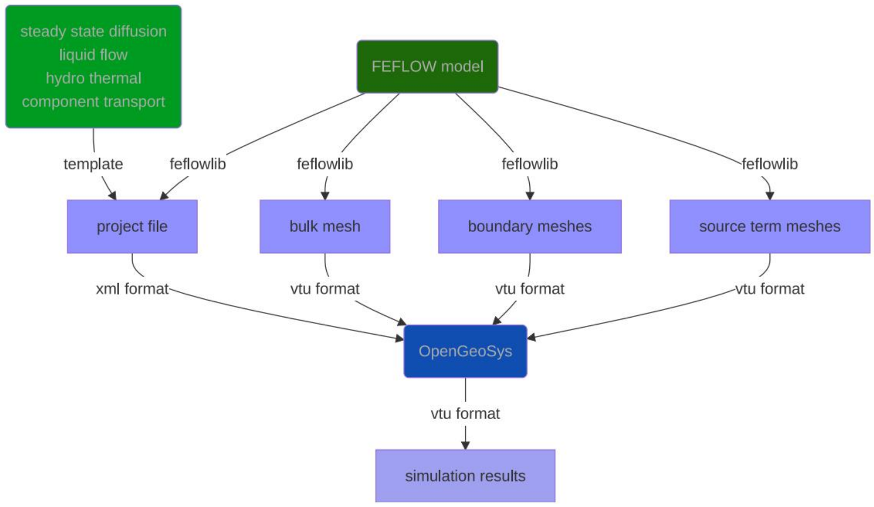

Figure 2. Simulation Framework of FEFLOW

Figure 2 shows the simulation framework of FEFLOW, in which the Data flow chart of the converter is shown. The lilac boxes within the middle row indicate what the converter may yield from a FEFLOW model. Files are generated when there is a need to produce such of file and the model involved needs it.

Suitability and Effectiveness Across Hydrogeological Scenarios

The second research objective has to do with the conditions in which the use of the two (MODFLOW and FEFLOW) is most appropriate and effective. Among these are their capability to model hydrogeological heterogeneity, coupling and incorporation into a multidisciplinary workflow.

MODFLOW in Hydrogeological Applications

Structured finite-difference solution MODFLOW. It is also appropriate to consider the discretisation relatively uniform on large-scale regional problems (Wali et al., 2024; Izady et al., 2022). It has been suitable when used in integrated water management settings, and compliance with regulations requires transparent, reproducible modelling outputs (Curran et al., 2023). Moreover, since MODFLOW is compatible with a vast set of transport models, such as MT3DMS and SEAWAT, one can create a simulation using the tools to simulate the contaminant migration and the density-driven flow (Zhang et al., 2023). Yet the method has limitations in modelling overly irregular boundaries or thin, interbedded formations because the cost of the computation can be dramatically increased with a small grid refinement (Sbai, 2020).

FEFLOW in Hydrogeological Applications

Great flexibility of finite elements in FEFLOW enables a detailed description of geological interfaces, faults, and layers of variable thickness, so it is appropriate when the site-specific research has a complex geometry (Pathania et al., 2023; Doulgeris & Zissis, 2021). It is especially effective at tightly coupled flow-heat-transport applications, including the tracking of geothermal system behaviour and control of coastal aquifers (Ju et al., 2023). It could refine its mesh, which reduces computational loads whilst offering local accuracy (Mishra et al., 2025). However, this kind of application of FEFLOW might involve considerable experience in meshing and a good understanding of the theory of finite elements (Narayanamurthi & Ramasamy, 2023).

Theoretical Framework: Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) can serve as a useful lens supporting the knowledge that explains the embrace and continual utilisation of groundwater simulation software. TAM was originally developed by Mogaji et al. (2024), and it holds that perceived usefulness and perceived ease of use are the main drivers of technology acceptance. Newer versions have also included newer constructs like enablement conditions and self-efficacy of users (Peng et al., 2023). When applied to groundwater modelling, perceived usefulness denotes how the practitioners consider that a given model would support their efforts to improve the performance of their projects, whereas perceived ease of use reflects the ease of using the interface and how the model is easy to learn its functions. Engineering software adoption research indicates that the perceptions have a high statistical ability to predict user preference and loyalty (Jarvie-Eggart et al., 2024). Placing this study squarely in the context of TAM, one would be able to organise the analysis by means of aligning expert attitudes toward MODFLOW and FEFLOW with the professional theory of understanding technology use in the workplace.

Literature Gap

As the literature review shows, although the applications of MODFLOW and FEFLOW are abundant in various hydrogeological projects, the methods to carry out relative analyses are inclined more towards the accuracy of the computation, calibration efficiency, or process depiction. A specific lack of qualitative research which records practitioner experiences can be observed, including that on the effects of usability and learning curves on the model selected. Theorised investigations into decisions made by experts about choosing between structured and unstructured modelling frameworks are rare, with few studies at all presenting such a theorised framework to understand these choices. Furthermore, whereas technical documentation is rich with advice on operational capabilities, it is seldom helpful in displaying the perceptions of users in terms of trade-offs between the functional capacity, learning investment, and long-term effectiveness. This paper fills such gaps by taking a qualitative and theory-informed stance by specifically tapping directly into expert knowledge via a thematic analysis of expert interviews.

RESEARCH METHODOLOGY

A clear and clear procedure is the guarantee of the credibility and replicability of the research results that meet the objectives of the study. In the given study, a qualitative approach, which is facilitated by specific secondary review, is used to investigate the expert opinions about MODFLOW and FEFLOW. In the light of the methodological framework, a combination of secondary data analysis and primary data collection based on deep personal interviews is integrated, which allows gaining a multi-perspective insight into the topic.

Research Method and Design

A qualitative research approach was set up in this investigation with a qualitative study method that consisted of a secondary literature review to make the study as powerful and sound in its theoretical background. The qualitative component presupposes a semi-structured interview format that will give rich insights about specialists who implement the application of MODFLOW and FEFLOW. The style has helped the participants elaborate on their experiences, and the interviewer can follow up more on emerging themes. The secondary research component is grounded on the new academic literature on groundwater modelling tools, to ensure that the interview structure is up to date concerning the discourses and advances in the field. It is a combined source method, and, as a result, it offers a theoretical rigour that is combined with practice (Butler et al., 2021; Flick, 2019).

Data Collection Method

The data elicitation was carried out in the form of a semi-structured interview. The primary source information was gathered through the experiential interview of the selected experts who were interviewed in a semi-structured form. In terms of interview design, the questions were open-ended and could reflect the research purpose of the study, providing individuals with an opportunity to express their perception about the key themes of the study (Clark et al., 2021).

Samples

The targeted sample was composed of six professional hydrogeologists and water resource engineers who have experience in employing both the MODFLOW and FEFLOW in their occupation. The purposive sampling type was used to make sure that the participants possess any relevant research experience and can express some comparative knowledge. Such a targeted and small sample size adheres to qualitative research traditions and prioritises depth and richness of responses over numerical representation (Torabi et al., 2022).

Data Reliability and Validity

In a bid to improve the reliability, the interview guide shall be pilot tested on one professional who shall not be included in the final sample. Uniformity was addressed because the study employed the identical group of key questions throughout the interviews, and the follow-up questions were introduced only in case specific responses were necessary to be clarified or explained. Triangulation (combining the information obtained in secondary literature and the results of the interview) helped validate it. The use of member checking consisted of sitting the participants with the summaries of their responses to ensure that they are correct (Qaissi, 2024).

Data Analysis Method

Thematic Analysis was used in analysing the data in six steps, as indicated by Squires (2023). This is done through familiarity with the data, generation of preliminary codes, searching themes, reviewing themes, definition and naming of themes and preparation of the report. The reason is that Thematic Analysis is highly suitable for recording complicated perceptions and experiences, and this choice is right as the purpose of this study (Christou, 2022).

Table 1. Themes

Research Objective	Interview Question	Specific Theme
RO1: Usability & Learning Curve	From your experience, how would you describe the ease or difficulty of learning and using MODFLOW compared to FEFLOW?	Perceived Ease of Use
	What factors most influence your decision to choose one model over the other in terms of usability and workflow?	Workflow Efficiency
RO2: Suitability & Effectiveness	Which types of projects or hydrogeological settings are best suited for MODFLOW and which for FEFLOW, and why?	Contextual Suitability
	Can you share specific examples where one model significantly outperformed the other in terms of simulation results or decision-making support?	Performance Effectiveness

Table 1 shows the specific theme in each of the interview questions that was observed in the thematic analysis, and it represents fundamental values of expert perceptions. Perceived Ease of Use expresses the extent to evaluating experts evaluate on developing learning curve and the intuitiveness of the interface of each of the models. Workflow Efficiency is an expression of the operational aspects of speed, integration and adaptability that influence the model of choice. Contextual Suitability discusses the considerations of specific models of the approaches in the setting of expert observations of the model fit in specific hydrogeological and project models. Performance Effectiveness is associated with the relative quality of actions of the simulation and the decision-making influence. All these themes are directly related to the objectives of the research, so there is no diversion of the analysis in other directions, as it was structured and followed by both practical and theoretical considerations.

Ethical Consideration

Before beginning the data collection, ethical approval was gained. It was explained to all participants that their participation is voluntary, that they have the right to withdraw from the study at any point without any measure being taken against them and that they were part of a study with identifiable aims. The consent was written and informed. The anonymity was ensured by redacting any identifiers in transcripts, and all data was safely stored on password-protected devices in relation to the data protection laws (Motulsky, 2021). Recordings of the audio were destroyed upon transcription, and only aggregate findings are reported. These put measures in place to ascertain the ethical integrity of the research.

RESULTS AND DISCUSSION

Data Analysis

The research objectives informed the analysis of the collected interview data with the help of a thematic approach to analysis. Thematic analysis made it possible to identify patterns and meanings that repeated throughout the responses, which led to the formulation of four overriding themes relating to the four interview questions. The current chapter offers the interpretation of the results regarding every research objective and its respective themes based on the specific view of the respondents, refusing to quote direct words.

Perceptions of Usability and Learning Curve

This part discusses the first research objective, where the study attempted to identify the subjective insights of experts on the usability and learning curve of MODFLOW and FEFLOW based on actual groundwater modelling practices. The interview data produced two themes, which were exposure to the Perceived Ease of Use and Workflow Efficiency. Collectively, these themes indicate how the user-friendliness, accessibility, and ease of operation of the two models become operationalised in various settings in a manner that is assessed by their practitioners.

Perceived Ease of Use

Throughout all the interviews, a common difference was presented between the very first knowledge of MODFLOW and FEFLOW. Some of the respondents stated that there are a lot of tutorials, online forums and community help within MODFLOW, which can absorb some of the basic things about it without any of the official training. Yet, due to the difficulties in setting up more complex scenarios, i.e. irregular boundaries or coupled processes, the ease of entry was partially neutralised, according to respondent 2 and respondent 4. MODFLOW bases its structure-grid design to be simple at first, but it may have limitations in certain complex situations and thus would need workarounds, which would take individuals longer to learn.

Conversely, FEFLOW was often reported to require a steeper initial entry learning curve, especially in learning to use finite-element meshing and more advanced calibration tools. Respondent 5 and respondent 6 stated that it might seem like too much initially to learn FEFLOW since the program offers a wide variety of functions and technical terms. However, being accustomed to the relevance, a wide range of respondents said that FEFLOW, with its combined graphical interface, saved a lot of effort in dealing with a multi-step workflow. This hints at the fact that although MODFLOW is a better starting point, FEFLOW might allow more usability to the advanced practitioners who frequently work with complex projects.

The other aspect that was cited by the respondents, such as respondent 1 and respondent 3, was that the ease of use also depended on the presence of institutional support. The employees of organisations where the FEFLOW licence was established and the internal training established found it less difficult to onboard than those who independently studied. Conversely, the open-source nature of MODFLOW provided easier access to it in resource-strained situations since there was no economic limit to learn and playing around with the program.

Workflow Efficiency

Workflow efficiency was also a theme that kept reappearing in the choice of model preference. Respondent 1 and respondent 5 pointed out that the modular construction of the software as a package offered a sense of division of labour that can be effective when it comes to large projects with several team members dedicated to executing certain modules. Nevertheless, this modular approach can cause inefficiency in the human interface to switch between external pre-processing, simulation, and visualisation tools, as respondent 3 points out.

Respondents 2 and 6 stressed the importance of the integrated interface of FEFLOW as an efficient tool in the workflow several times. It was perceived that having boundary condition assignment, mesh editing, calibration and visualisation of results within the same platform would eliminate unnecessary changes of context and chances of errors that may arise during exporting and importing of data between applications. Respondent 4 pointed out that this integration is particularly useful in projects that have limited deadlines since it allows for faster iteration on model adaptations and checking the outcome.

Nevertheless, the efficiency of the workflow was not equally tilted in favour of FEFLOW. Respondent 3 and respondent 5 noted that in certain large-scale, data-intensive projects, the integration of MODFLOW with scripting languages such as Python through FloPy enables automation of processes in such a way that repetitive processes can be automated, leading to more efficient systems working differently. It implies that the workflow optimisation is subject to the nature of the project and the effectiveness of the user of assisting tools.

Suitability and Effectiveness Across Hydrogeological Scenarios

The second purpose of the research was to analyse the opinions of specialists about the appropriateness and efficiency of using MODFLOW and FEFLOW in varied hydrogeological conditions. The data was found to carry two major themes, which included Contextual Suitability and Performance Effectiveness. The themes offer an understanding of the under which model to excel and what effect this produces on the project outcomes.

Contextual Suitability

The strengths of the models were often distinguished among the respondents according to the scale, complexity and geological variability of the project. Respondent 1, on the one hand and Respondent 3, on the other hand, articulated that there is indeed a good fit of MODFLOW to regional groundwater management examinations, when there is relative homogeneity in the geological strata and the administration is that of a wide-scope policy and planning. Its distinguished grid simplifies the standardisation of its models at the level of jurisdiction and provides transparency of regulatory reviews. Conversely, respondents 2 and 5 pointed out that finite-element capabilities in FEFLOW come in handy for the irregular boundaries of the project, fractured rock aquifers or highly heterogeneous geology. Respondent 6 continued that FEFLOW offers a high degree of local accuracy without unduly burdening the computer in densely modelled regions, such as the modelling of coastal aquifers, where an accurate representation of salinity intrusion is required.

A few of the respondents have also brought out the kind of processes that are most efficient in each of the models. Respondent 4 and respondent 5 observed that FEFLOW is the most preferred when the study needs to rely on coupled transport and heat flow simulations, including geothermal energy projects, whereas MODFLOW is mostly used on groundwater-surface water interaction due to its connection to surface water modelling packages. Relevantly put, organisational constraints were also associated with contextual suitability. Respondent 2 and respondent 6 noted that smaller consulting firms or government entities tend to use MODFLOW because of its free licensing and its high record of recognition in formal literature, even when FEFLOW would have technical benefits on applied to a certain type of project.

Performance Effectiveness

Discussing the effectiveness in performance, the respondents, however, did not know how accurate the results of the simulation were; they discovered how useful the model was in decision-making. Respondent 3 and respondent 6 stressed that the long history of MODFLOW being used in a regulatory setting has established the likelihood of the results being more palatable by the stakeholders involved, despite possibly more sophisticated outputs being available with alternative models. This institutional confidence can also facilitate its working capacity on the policy-based projects.

Respondent 1 and respondent 5, on the contrary, gave examples in which FEFLOW generated outputs that were closer to what had been measured in the field, especially when complex transport phenomena or non-linear boundary conditions had been involved. Respondent 2 reported that in a geothermal groundwater extraction project, the fact that FEFLOW can simulate both the transport of heat and flow gave decision-makers a more complete picture of possible environmental effects.

The respondent No. 4 emphasised that computational performance may also be a source of effectiveness. In cases of exceedingly large datasets, simulation runs may be more quickly feasible in MODFLOW than in FEFLOW (particularly when parallelised, or when model discretisation is relatively coarse). Nonetheless, the respondents 5 and 6 said that when it would be necessary to conduct a comprehensive site-specific study, the adaptive mesh refinement carried out in FEFLOW could save on total simulation time by concentrating the computer power where it is most significant. The discussions showed that the effectiveness of performance is locally dependent on the physical aspects of the system being modelled and the decision-making environment in which the actions are going to be utilised.

Summary of Analysis

The thematic analysis shows that the comparative views of the experts on the elements that support the relevance of using both MODFLOW and FEFLOW cannot be simplified to a hierarchy of superiority. Rather, model choice is determined by an interaction of usability, workflow integration, contextual efficacy, and performance efficiency that is so complex that one must look at factors such as usability and workflow integration mechanically. The strengths of MODFLOW are its ease of use, availability in a community, and support of regulatory needs, whilst the strengths of FEFLOW are expressed in modelling of complex geometries, coupled processes, and integration of workflow. Such results indicate that both models of capacity-building may be required to enable organisations to tackle as many hydrogeological challenges as possible.

Discussion

The chapter reads the results of the study among the published pieces of literature by showing how and to what extent the findings can add to the perspectives of experts about MODFLOW and FEFLOW. All the research objectives are discussed individually, and the findings are interpreted in correlation with prior literature.

Perceptions of Usability and Learning Curve

These results show that MODFLOW has the general opinion of being easier for beginners to master with its large supporting communities, tutorials and the open-source nature of it. This also corresponds with the findings of the previous studies pinpointing the accessibility of MODFLOW programs and their community and resource base, which help develop the skills even in low-resource settings (El-Rawy et al., 2022; Janipella & Pujari, 2022). Nevertheless, their application is complicated when dealing with complex geometries or coupling of multiple processes, which is aligned with Mohamed et al. (2024), as they noted that the structured grid utilised by MODFLOW needs workarounds when regular boundaries overlap. On the other hand, FEFLOW was perceived to be more sophisticated to start with, especially around mesh refinement and advanced calibration. This agrees with Koskinen et al. (2025) and Mishra et al. (2025), who indicated that finite-element modelling requires first-tiering skills. However, after the undertaking of the familiarisation, the experts would value the integrated interface present in FEFLOW to align with Zhou et al. (2020), who maintained that simplified GUIs could make a big difference in achieving modelling productivity. These findings indicate that even though the initial experience with MODFLOW is more forgiving, the usage of the FEFLOW application becomes more user-friendly with experience, particularly for complex activities.

Suitability and Effectiveness Across Hydrogeological Scenarios

As the study showed, MODFLOW is a favourable tool to apply to regional-level, even Byte-based, and uniform geology initiatives and regulatory adherence models, which mirrors the previous findings of the study by Wali et al. (2024) and Izady et al. (2022) concerning the transparency and reliability of the framework in governance sessions. The fact that it can be used as it is compatible with groundwater into surface water modelling also showcases its applicability in integrated water management, as stated by Elshall et al. (2020). In its turn, FEFLOW was deemed more advisable when it comes to fractured rock, heterogeneous geology, or those processes that necessitate coupled transport and heat flow, resonating with the report by Doulgeris and Zissis (2021) and Ju et al. (2023). The ability to refine the mesh and flexibility in terms of emulating complex boundaries were perceived to be essential strengths, which is also consistent with the views of Mishra et al. (2025) and Pathania et al. (2023). The performance effectiveness turned out to be one that was context-specific: whereas MODFLOW was quicker on course-grid large-scale models (Sbai, 2020), FEFLOW fared better in site-specific, high-resolution simulations (as noticed in Lozano Hernández et al., 2024).

All in all, the findings validate the claim that the suitability of models rests upon the interaction between the scale of the project, geologic complexity, and process requirements. This confirms the approach of the Technology Acceptance Model, in which adoption depends on perceived usefulness and ease of use, which are shaped by the context, in which the modeller keeps in mind the project requirements.

CONCLUSION

This research paper investigated views of experts in respect to MODFLOW and FEFLOW, including perceived levels of usability, learning curves and applicability in varying hydrogeologic conditions. The thematic analysis unveiled that the strength of MODFLOW consists of its ease of use, community popularity, and applicability to large-scale projects and policy-based work. The fact that it is open source and already accepted into regulatory settings also makes it a trustworthy option to use among practitioners. But it cannot manage complex boundaries and complex multi-physics simulations unless supplemented with tools. However, albeit more difficult to initially use, FEFLOW performs particularly well with processes of coupled heterogeneous geology, non-smooth (due to the use of framing layers) boundaries and considering coupled phenomena, e.g. heat transport, solute transport. The interface is provided based on an integrated interface capable of efficient working cycles with experienced users and the accurate representation of complex hydrogeological systems. The effectiveness of performance was determined to be a subject of context, whereby the usage of the former (MODFLOW) was preferred in large-scale models due to speed and standardisation, whereas the latter (FEFLOW) was preferred in site-specific studies where a high accuracy and adaptability are required. The findings bring out that no measure of universality crowns one mode as excelling above the other; rather, preference is to be anchored to the requirements of the project, accessible resources, as well as the expertise of the practitioners. Combining empirical experience with existing literature, the study has added to a more detailed view of the groundwater model choice and the need to match the modelling tools and both the technological as well as operational context.

Recommendation

Organisations and practitioners are advised to build dual capability in both MODFLOW and FEFLOW to increase flexibility for a variety of projects. MODFLOW must prove to be the more appropriate choice in large-scale, uniform geology and policy-driven modelling applications, whereas FEFLOW must be applied under complex heterogeneous systems and project modelling which needs coupling of process simulations. Structured training to invest in can overcome the steep learning curve FEFLOW comes along with, and automated scripting within MODFLOW can help streamline the workflow process. The framework of decision based on geological complexity, requirement of process, and scale limitation of the resource used in cooperation projects takes place only with agreement of model selection depending on technical correctness and operational requirement in a particular project.

Practical Implication

The results of the study pointed directly to groundwater modelling practice. The clear explanation of the advantages and disadvantages of MODFLOW and FEFLOW makes them easy to use when deciding about tool selection by a practitioner. This knowledge applies to regulatory bodies to revise modelling guidelines by incorporating and harmonising technical and operational realities in the recommendations. Specific weaknesses which could be identified with each model may be addressed in the training programs to enhance the competence of the practitioners. To realise such resource allocation, consulting firms can streamline the task by allocating different projects to modellers depending on who is best suited to the most appropriate platform. In the end, these implications lead to the enhanced management of groundwater and improved modelling results.

Limitations

The study limits itself to a small and purposively chosen sample of six experts, which does not reflect the entire global groundwater modelling practice, and hence becomes a limitation to the study. The qualitative design is not focused on breadth rather than depth of the findings; therefore, results cannot be statistically generalisable. Pragmatic difference could also be affected by individual opinion, organisational culture, or experience in a particular project. Also, there was no direct performance testing of the models included, but rather relied on what people perceived. Future studies need to apply mixed methods by encompassing qualitative perspectives with quantitative benchmarking and should involve an increase in the size and range of participants, such as different sectors, geographical locations, and various degrees of modelling skills.

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