Expert Testimony: Groundwater Modeling Reliability

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Law, Science, Policy and Scientific Evidence

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INTRODUCTION

A presumption of helpfulness surrounds the term “expert”.¹ For this reason, courts grant testimonial latitude to expert testimony that is normally unavailable to other witnesses. This is justified on the presumption that the expert's opinion rests upon a reliable basis in the knowledge and experience of his discipline.²

An expert’s opinion consists of three components: the bases, methodology, and conclusion.³ The bases of the opinion are the raw facts and data from which the opinion originally derives.⁴ These function much like the building materials of a bridge. The expert then applies the facts and data into the methodologies of the research design he utilizes within his opinion. This application is similar to the actual construction of a bridge. From these two steps, the expert forms his conclusion. If either the bases or methodologies are incorrectly applied or invalid, the bridge fails and the conclusion is considered unreliable.⁵

The scientific method rests upon the falsification of a given hypothesis.⁶ It also requires the existence of a logical, step-by-step connection that forms a bridge between the bases.

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⁵ Imwinkelried, supra note 3.
⁶ Daubert, 509 U.S. at 593.
methodology, and conclusion that the expert uses to testify. This creates a level of reliability that distinguishes it from other fields of human inquiry.  

The application of the scientific method in computerized groundwater modeling produces a simplified image of what many describe to be a subsurface phenomenon. (See Figure A) One court categorizes such groundwater models as “an array of figures conveying a delusive impression of exactness in an area where a jury's common sense is less available than usual to protect it.”  

However, without the use of such models, the testimony of scientists and engineers would constitute nothing more than speculation as to the sources and flow characteristics of an aquifer with limited well data. Therefore, understanding the limits that courts impose on speculative evidence is essential to ensure that groundwater models are reliable in their use within the courtroom. This paper will describe how the problem of speculative evidence has found its way into groundwater modeling and illustrate the common methods used in excluding them from court.

I. ADMISSIBILITY OF EXPERT TESTIMONY

In the admissibility of expert testimony, Federal court rulings have created a labyrinth of procedures.  

Prior to Daubert, the analysis of scientific expert

7 Id.
8 Schwabe v. United Shoe Machinery Corp., 297 F.2d 906, 912 (2d Cir. 1962).
10 Id.
testimony was straightforward and simple. From 1923 until 1993, the so-called Frye test was the dominant standard for determining the admissibility of scientific expert evidence at trial.11

In *Frye v. United States*, the United States District Court for the District of Columbia established the “general acceptance” test for the admissibility of expert testimony.12 The Frye case concerned the use of expert testimony involving an early version of the polygraph technique, which the court found inadmissible because polygraph testing had not achieved general acceptance in the relevant scientific community. Frye found that testimony "must be sufficiently established to have gained general acceptance in the particular field in which it belongs."13 Although disliked by many, the majority of courts used this test to determine the admissibility of scientific evidence at trial.14

The *Daubert* standard later emerged within a period of controversy over the perceived flood of “junk science” that Frye presumably allowed.15 In *Daubert*, the U.S. Supreme Court unanimously held that the general acceptance test was superseded by the adoption of the Federal Rules of Evidence in 1975.16 More specifically, the Court held that nothing in the text of FRE 702 requires "general acceptance as an absolute prerequisite to admissibility".17 In the Court’s view, the general acceptance approach failed to clarify which facets of the testimony or

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12 *Frye v. United States*, 293 F. 1013, 1014 (D.C. Cir. 1923).
13 *Id.*
15 *Junk Science: The Criminal Cases*, 84 JCRLC at 128.
16 *Daubert*, 509 U.S. at 589.
17 *Id.*
underlying rationale must be generally accepted. The Frye standard also did not account for the fact that much knowledge inevitably evolves into generally accepted conclusions without careful examination, especially where that knowledge has been accepted for a long period. Most importantly however, the Daubert court noted that such a broad standard negated the court’s active role as gatekeeper. Instead of assessing the evidence in the light of the law, the Frye standard merely relied upon third party peer review and publication. The Court in Daubert noted that this in turn permitted non-judicial actors to make what is essentially a judicial policy decision and deflected the existing duty away from the judge.

II. THE GATEKEEPER

Unlike the permissive role within the standard of Frye, Daubert’s interpretation of FRE 702 creates an active judicial role by serving as its gatekeeper. This judicial role requires an objective, independent validation of the expert's methodology and a demonstration that the methodology can properly be applied to the facts of the issue. Resolution of these issues will necessarily involve an assessment of the proffered testimony pursuant to Rules 702, 703, and 403 of the Federal Rules of Evidence.

To conduct a pretrial assessment of the proffered testimony, a party may raise a motion in limine pursuant to FRE 104(a). This is a request for a hearing on the qualifications of a proffered expert and the admissibility of his or her testimony. It is normally short and concise and follows
Rule 104(a) and (c) of the Federal Rules of Evidence. \(^{24}\) Prior to its expressed endorsement by the United States Supreme Court in *Daubert*, the motion was rarely utilized in pretrial litigation. \(^{25}\) With the continuing growth of expert evidence, it has become a very powerful tool in pretrial litigation. It provides the parties, the proffered experts, and the responding experts the benefit of the court's ruling before the trial starts.\(^{26}\) A preliminary Rule 104(a) exclusion can dramatically increase the probability of early case resolution when the plaintiff’s case hinges upon the admittance of the proffered expert’s testimony. \(^{27}\)

### III. RULE 702 ANALYSIS

Rules 702 and 703 of the Federal Rules of Evidence serve as the basis of *Daubert’s* standard of admissibility. \(^{28}\) To warrant the use of expert testimony, the proponent must 1) establish that the witness is qualified as an expert in the relevant field, 2) prove that the testimony derives from the scientific method, and 3) ensure that such conclusions “fit” the legal requirements for establishing cause-in-fact.\(^{29}\) However, testimonial evidence that conforms to these standards may still be inadmissible under FRE 403 if the court finds that allowing it will result in undue prejudice, confusion, or waste of time. \(^{30}\)

\(^{25}\) *Daubert*, 509 U.S. at 579.
\(^{27}\) Fed. R. Evid. 401(a), (c).
\(^{29}\) Fed. R. Evid. 702.
When an objection to an expert's testimony is raised, the court must perform gatekeeper duties in applying the *Daubert* standard before the jury is permitted to hear the evidence. A trial court's gatekeeper duty requires the following assessments.

**A. Qualifications of Expert**

In order to testify to specialized knowledge, FRE 702 first requires that the witness be qualified as an expert in that specific field. In order to be qualified, he or she must possess sufficient knowledge, skill, experience, training, or education within the relevant field. Even though trial courts generally interpret this requirement liberally, the knowledge that an expert testifies upon must be specific to the facts of the case. Testimony from an expert who possesses a general knowledge of the subject matter before the court may still not be admissible if he or she lacks experience or the relevant knowledge with regard to the specific subject matter. However, *Daubert* provides much discretion for judicial gatekeepers and ultimately leaves the admission or exclusion of expert testimony to the discretion of the trial judge. Only when the decision is “manifestly erroneous” will appellate courts overturn the exclusion or admission of expert testimony.

In *Perkins v. Volkswagen*, the Fifth Circuit Court of Appeals affirmed a trial court decision finding a specialist in mechanical engineering was not qualified for expert testimony.

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32 See Fed. R. Evid. 702.
33 *Perkins v. Volkswagen of Am., Inc.*, 596 F.2d 681, 682 (5th Cir. 1979).
34 *Wright v. Hartford Accident & Indemnity Co.*, 580 F.2d 809, 810 (5th Cir. 1978); *Wallace v. Ener*, 521 F.2d 215, 222 (5th Cir. 1975); Fed. R. Evid. 401, 402.
within vehicle design.  36 Although he may have expertise in certain mechanics of vehicle engineering, he lacked the relevant knowledge designing automobiles in their entirety.  37 The Court also noted that as long as a witness can demonstrate proficiency in the use of complimentary disciplines that, by itself, should not disqualify him. Yet, even a qualified expert may be barred from testifying if the basis of his opinion is flawed, thereby resulting in unreliable conclusions. 38

B. Reliability of Testimony

To ensure that the qualified expert’s testimony is reliable, FRE 702 requires that it derive from scientific, technical or other specialized knowledge that will assist the trier of fact. 39 Reliability and relevancy are the touchstones in determining the admissibility of expert scientific evidence. To ensure this standard exists, the trial judge must conduct an initial assessment to ensure that “any and all scientific testimony or evidence admitted is not only relevant, but reliable”. 40

The Daubert Hearing

These evidentiary goals are not passive in nature. Instead, they create an active judicial role as gatekeeper to ensure the reliability of evidence. The “Daubert Hearing” is the implementation of FRE 104(a) regarding the admissibility of expert witnesses’ testimony during

36 Perkins, 596 F.2d at 682; but see Garrett v. Desa Industries, Inc., 705 F.2d 721, 724 (4th Cir. 1983) (disagreeing with the result in the Perkins case, qualified a mechanical engineer as an expert despite lack of prior experience with stud drivers).
39 Fed. R. Evid. 702.
40 Daubert, 509 U.S. at 589.
United States federal legal proceedings. Pursuant to rule FRE 104, a party may raise a motion in limine. This is usually conducted before trial to exclude the presentation of unqualified evidence to the jury. Prohibiting opposing counsel the use of certain expert testimony can dramatically increase the probability of early case resolution when the plaintiff’s probability of success hinges upon the admittance of the proffered expert’s testimony.

**The Daubert Standard**

*Daubert*'s standard of evidentiary reliability under FRE 702 requires that the expert's opinion be based on the "methods and procedures of science," rather than on "subjective belief or unsupported speculation".

The *Daubert* Court requires that experts follow this "scientific method" even before it turns to the subsequent factors that lower courts have fixed upon.\(^{41}\) Therefore, the assessment of the reliability of scientific evidence under Rule 702 first requires a determination as to its scientific validity.\(^ {42}\) Since the basis of the Court’s reasoning lies within the scientific standards of reliable evidence, comprehending its requirements it essential.\(^ {43}\)

In *Daubert*, the Court finds scientific evidence to be reliable when it possesses “scientific validity”.\(^ {44}\) Establishing scientific validity is dependent on the expert’s adherence to the scientific method.\(^ {45}\) To determine this, a trial judge must ultimately conclude that the expert’s testimony derives from the scientific method.\(^ {46}\) When properly adhering to the scientific method,\(^ {47}\)

\(^{41}\) *Id.*
\(^{42}\) *Id.*
\(^{43}\) *Id.* at 590.
\(^{44}\) *Id.* at 596-97.
\(^{45}\) *Id.* at 590.
\(^{46}\) *Id.*
evidentiary results will be both “scientifically valid” and “scientifically reliable”.\footnote{Id. at 592-93.} If either is absent, the conclusion cannot possess scientific validity.\footnote{Id. at 590.9.}

Evidence is “scientifically valid” when every premise underlying an expert’s conclusion is capable of being authenticated and must lead as a matter of logic to the proffered conclusion.\footnote{Id. at 594.} This ensures that the reasoning or methodology underlying the testimony is valid. Scientific reliability occurs when consistent results derive from valid principles of science. In other words, it is the existence of a valid connection to the pertinent inquiry before the court.\footnote{Id. at 592-93.}

Whether or not evidence is “scientifically reliable” depends on whether or not the methodology is capable of producing consistent results by means of a valid scientific method. This is known as the “testability” factor.\footnote{Green, Expert Witnesses and Sufficiency of Evidence in Toxic Substances Litigation: The Legacy of Agent Orange and Bendectin Litigation, 86 Nw. U. L. Rev. 643 (1992).} Testability serves as a control variable that ensures a hypothesis can be verified or falsified by observation and experiment.\footnote{Supra. at 645.} Not only must the result be clearly determined, it must also ensure that the hypothesis has precise logical consequences that are incompatible with any other alternative hypotheses.\footnote{Supra.} In other words, testability allows the researcher to consistently determine if a certain result exists, and why such a result occurred. This elevated level of reliability is what “distinguishes science from other fields of human inquiry”.\footnote{Supra.}
The Daubert Trilogy

The Daubert trilogy consists of three United States Supreme Court cases that shaped the Daubert standard to its current form:

*Daubert v. Merrell Dow Pharmaceuticals*, which held that Rule 702 did not incorporate the Frye "general acceptance" test as a basis for assessing the admissibility of scientific expert testimony;\(^{55}\)

*General Electric Co. v. Joiner*, which held that an abuse-of-discretion standard of review was the proper standard for appellate courts to use in reviewing a trial court's decision of whether expert testimony should be admitted;\(^{56}\)

*Kumho Tire Co. v. Carmichael*, where the Supreme Court expanded the judge’s gate-keeping function identified in *Daubert* by applying it to all expert testimony, including that which is non-scientific.\(^{57}\) It found that the attributes of reliability are not limited to testimony that is based on scientific knowledge, but also to testimony deriving from technical and other specialized knowledge.\(^{58}\) The Court reasoned that the language of Rule 702 makes no distinction between "scientific" knowledge and "technical" or "other specialized" knowledge. It does however separate evidence that is reliable from that which is not.\(^{59}\)

\(^{55}\) *Daubert*, 509 U.S. at 579.
\(^{57}\) *Kumho Tire*, 526 U.S. at 137.
\(^{58}\) *Id.* at 147.
\(^{59}\) *Id.* at 138.
The Original Daubert Factors

In assessing the reliability of an expert opinion, the Daubert Court outlined four non-definitive factors. The Court explicitly warns that its discussion of these factors is only to be interpreted as "general observations", and that the factors listed are not exhaustive and do not constitute "a definitive checklist or test". The Court also emphasizes that testimony may be admissible even where one or more of the factors are unsatisfied. To illustrate, the Daubert Court stated that publication, "is not a sine qua non of admissibility and does not necessarily correlate with reliability". Rather, proper applicability of factors should turn on the precise issue of each case.

1. Hypothesis Testing: Even though it is not one of the four originally stated factors listed within Daubert, the basic technique of hypothesis testing has been well settled for decades and is simple to analyze. It is the process of deriving some hypothesis about an observable group of events from accepted scientific principles, and then investigating whether, upon observation of data regarding that group of events, the hypothesis seems true. Because hypothesis testing distinguishes the scientific method of inquiry from other non-scientific methods not admissible as expert testimony, a close analysis is warranted.

2. The Known or Potential Rate of Error: The second parameter that Daubert suggests in evaluating the evidentiary reliability of purported scientific testimony is the "known or potential

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60 Daubert, 509 U.S. at 593.
61 Id. at 597.
62 Id. at 592.
63 Id.
65 Id.
66 Id.
rate of error" that is associated with using the particular scientific technique. This measures the technique’s scientific validity, which inevitably determines the evidentiary reliability. In plain language, this is the likelihood of being incorrect that scientists associate with the assertion that an alleged cause has a particular effect. Most scientists routinely require that this error rate be very small, usually below five percent.67

3. Peer Review and Publication: The third criteria that the Supreme Court suggested for use by trial courts in determining whether expert testimony reaches the trier of fact is "whether the theory or technique has been subjected to peer review and publication." Publication is typically the purpose for which research is offered up for peer review and passing the peer review is required for publication. "Peer review and publication" of a scientist’s work is largely a term of art that means that the scientist’s peers have sanctioned the work as credible and accepted it for publication. Publication then exposes the work to further review by other scientists whose responses to the research indicate their agreement or disagreement with the methods and results of the work. Scientist’s peers often express agreement with the work of a particular scientist by citing the work with approval or as authority, or by extending the work. Properly executed hypothesis tests with their attendant error rates are the essence of scientific method and are very nearly necessary conditions for peer review to result in publication.68

4. General Acceptance: Like the Court’s third criterion, general acceptance weighs the particular degree of acceptance in the particular field in which it belongs.69 Scientific methods begin the process of becoming generally accepted in the scientific community by bringing appropriate hypothesis testing techniques to bear on questions of interest to the scientific

67 Id.
68 Id.
69 Daubert, 509 U.S. at 586.
community in a fashion that results in the peer approval required for publication. \(^\text{70}\) They move toward general acceptance by then withstanding the scrutiny of the broader scientific community to which publication exposes the methods. \(^\text{71}\)

Even though general acceptance was overruled in not being an appropriate per se standard of evidentiary reliability, the *Daubert* court noted its usefulness when coupled with other factors of the analysis. \(^\text{72}\) The widespread acceptance or skepticism of a methodology within a scientific community can still be an important factor in ruling whether particular evidence is admissible. \(^\text{73}\)

**Expanding Daubert’s Factors**

Even though *Daubert* originally outlined only four factors that courts may include in its analysis, federal district courts regularly take into account the following eight factors in evaluating whether a particular scientific method is reliable. \(^\text{74}\)

- Whether the method consists of a testable hypothesis;
- Whether the method has been subject to peer review;
- Whether the method has a known or potential rate of error is known;
- Whether maintenance of standards exist for controlling a technique's operation;
- Whether or not the method is generally accepted;

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\(^{71}\) Daubert, 509 U.S. at 586.

\(^{72}\) Id.

\(^{73}\) Id. at 594.

Whether the relationship of technique to methods which have been established to be reliable;

Whether the qualifications of an expert witness testifying are based on a methodology; and

The non-judicial uses to which the method has been put; 75

**The “FIT” Standard**

Rule 702 also requires that the expert's testimony assist the trier of fact in a reliable manner. 76 More specifically, admissibility depends on whether the evidence is scientifically reliable by producing consistent results in the application of its scientific principles. 77 This depends in part on "the proffered connection between the scientific research or test result to be presented and particular disputed factual issues in the case." 78 This ensures that the evidence possesses scientific reliability.

*Daubert* explains that "fit" is not always obvious, and scientific validity for one purpose is not necessarily scientific validity for other, unrelated purposes. 79 In other words, a particular methodology may indeed be scientifically valid when applied to one group of facts, but fails to maintain its scientific reliability when applied to other facts with different variables. 80

Courts recognize that “invalid” scientific evidence, which is not based on the scientific method, may still be capable of producing consistent, replicable results and therefore be

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75 *Elcock*, 233 F.3d at 734.
76 *Daubert*, 509 U.S. at 580.
77 *Id.* at 590 n.9.
78 *Downing*, 753 F.2d at 1237; See *Daubert*, 509 U.S. at 590.
79 *Daubert*, 509 U.S. at 590 n.9.
80 *Id* at 592-93.
“scientifically reliable”. However, such results are neither scientifically valid nor reliable as courtroom evidence.\textsuperscript{81} Instead, scientific evidence must be both valid and reliable to be admitted.

In determining whether an experimental conclusion is valid, courts should consider:

- Whether the results demonstrate a relationship between the tested variables
- Whether there is a casual or merely fortuitous relationship
- Whether the hypothesized cause and effect relationship is logical in light of the experimental results; and
- Whether the relationship between the variables can be generalized to other situations.\textsuperscript{82}

IV. RULE 703 ANALYSIS

While FRE 702 focuses on the reliability of an expert's methodology, \textit{FRE 703} focuses on the data and facts underlying the expert's bases.\textsuperscript{83} If the underlying facts and data are not the personal knowledge of the expert and instead data-facts recorded by others outside the courtroom, they must be of a type reasonably relied upon by experts in the particular field in forming opinions or inferences upon the subject.\textsuperscript{84} However, if the underlying data are “so lacking in probative force and reliability that no reasonable expert could base an opinion on them”, an opinion which rests entirely upon them must be excluded.\textsuperscript{85}

\textsuperscript{81} \textit{Cook v. Am. S.S. Co.}, 53 F.3d 733, 737 (6th Cir. 1995).
\textsuperscript{82} \textsc{Thomas D. Cook \& Donald T. Campbell}, \textsc{Quasi-Experimentation: Design \& Analysis Issues for Field Settings}, 39 (1979).
\textsuperscript{83} \textit{In re Paoli R.R. Yard Pcb Litig.}, 35 F.3d 717, 758 (3d Cir. 1994).
\textsuperscript{84} \textit{Daubert}, 509 U.S. at 595.
\textsuperscript{85} \textit{In re Paoli}, 35 F.3d at 748.
A presumption of trustworthiness exists if the underlying data is of the kind normally employed by experts in the field. Nevertheless, courts do not “abdicate its independent responsibilities to decide if the bases meet minimum standards of reliability as a condition of admissibility.”86 Whether experts in the field rely on this type of data themselves is only but a portion of the assessment. When assessing whether certain testimony is based on a type of data on which experts reasonably rely, the judge has to make an independent evaluation of the reliability of the data, and should assess whether there are good grounds to rely on this data to draw the conclusion reached by the expert. The judge can of course take into account the particular expert's opinion that experts reasonably rely on that type of data, as well as the opinions of other experts as to its reliability, but the judge can also take into account other factors he or she deems relevant. 87

In finding that a conclusion is unreliable for admissibility, it may prove useful to resolve whether the flaw is within the methodology of the study, or the underlying data itself. It can be difficult to determine whether the putative problem with scientific evidence lies in the underlying data itself or the method by which the data is analyzed. Even though many courts view separate analyses of both the methodology and bases as redundant, other courts find it a useful tool in limiting portions of testimony.88 This may result in the court partially excluding portions of the expert’s testimony, while allowing others. 89

86 Id.
87 Id. at 758.
88 In re Paoli R.R. Yard Pcb Litig., 35 F.3d at 749 n.19.
89 Id. at 748-49.
For example, expert testimony that uses animal studies in forming conclusions about humans must first meet Rule 702’s requirement of “fit”.\textsuperscript{90} This requires the court to assess whether there are good grounds for concluding that the animal studies demonstrate causation in humans. This analysis concerns the methodology itself and the steps taken in forming the conclusion.\textsuperscript{91} However, the same animal studies must also meet the reasonable reliance standard of Rule 703 in forming the opinion’s bases. In other words, the underlying data used in the methodology must be reasonably relied on by experts in that field of study to analyze causation in humans. If the underlying data of one of the expert’s conclusions is not sufficiently reliable, that specific conclusion may be excluded from the overall opinion. Whether or not such an exclusion renders the entire testimony unreliable is a question for the court.

By applying \textit{Daubert}’s principles of evidentiary reliability, it is clear that, under Rule 702, mere conclusory testimony by scientific experts is insufficient as a matter of law. In order to provide support for such testimonial conclusions, an expert witness must explain precisely how they went about reaching their findings. In doing so, experts must be able to point to some objective source to establish that their methodology follows the scientific method as practiced by scientists in their field of expertise.\textsuperscript{92} However, some areas of science often require a much higher level of analysis when dealing with evidentiary reliability.

\textbf{V. EXPERT TESTIMONY AND GROUNDWATER MODELING}

\textbf{A. Groundwater Modeling}

\textsuperscript{90} Id.
\textsuperscript{91} Id.
\textsuperscript{92} Daubert, 509 U.S. at 585.
Courts view groundwater computer modeling as a reliable method when applied under the appropriate circumstances and safeguards. The use of such models become especially useful when the “traditional field methods” such as geo-probing and test wells fail to clarify the relevant facts of the case. In the complex litigation surrounding groundwater resources, computer groundwater models are often involved in court litigation to evaluate the effectiveness of remedial alternatives and to fix liability and damages. Groundwater models often serve an administrative role as well in certain states in the allocation of property rights in groundwater. These property rights are normally based on the characteristics of the individual aquifer itself. Such allocations greatly depend on current water availability, sustainability, and projected availability during drought conditions. Thus, whether utilized in administering water rights to landowners or in the proving legal causation, groundwater modeling often lies at the basis of court litigation.

The usefulness of most groundwater modeling studies is usually a hypothesized recreation of past events or a prediction of future characteristics. This technological procedure often drives the allegations, discovery, and trial surrounding groundwater issues. This is due to the lack of known facts surrounding the litigated issue of groundwater. This often leaves the model itself as the foundation of evidence that surrounds the case.

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B. Groundwater Modeling Functionality

Simply stated, every computer-based model is a simulation of recorded past events. Each model consists of mathematical equations that permit experts to describe a phenomenon in nature. Groundwater models derive from mathematical computations in groundwater flow equations. Reliable groundwater models utilize data that span over many years to illustrate their behavior and predictability. Once an adequate amount of data is correctly analyzed, the behavior of a groundwater system is translated into a mathematical language. Such equations require careful attention to describing the aquifer domain, selecting boundary conditions, assigning model parameters, and calibrating the model. However, between such equations are areas of unknown variables and protocols that experts must account for in creating the groundwater model.

In constructing a groundwater model, an expert inputs multiple data fields. These inputs normally include hydrological inputs, operational inputs, initial and boundary conditions, and hydraulic parameters. However, correctly establishing the data inputs may also require

97 See Anderson & Woessner, supra end note 90, at 8 (outlining the protocol for conceptual-groundwater-model design).
99 Id.
100 Id.
consideration of various chemical components of the aquifer like water salinity, soil salinity and other quality indicators of water and soil.\textsuperscript{102}

The hydrological inputs consist of data like rainfall, evapo-transpiration and surface runoff. These factors determine the recharge of a given aquifer and indicate the underground water supply. However, this calculation varies considerably and is normally a rough estimate with a large potential rate of error.\textsuperscript{103}

The operational inputs consist of human water management and the effects it has on the aquifer.\textsuperscript{104} This would include factors like irrigation, drainage, pumping from wells, water table control, and the operation of retention or infiltration basins. This data largely depends on the hydrological inputs of a given aquifer and the time and space at which they were collected.\textsuperscript{105}

Boundary conditions relate to the subsurface interaction of an aquifer and the groundwater inflows and outflows that affect the water table. Initial conditions are the characteristics inside the underground water model and have a causal link to the boundary conditions.\textsuperscript{106}

The hydraulic parameters concern the physical domain and properties of the modeled aquifer. Parameters include the topography, thicknesses of soil layers and its permeability for water, aquifer transmissivity and resistance, aquifer porosity and storage coefficient, as well as the capillarity of the unsaturated zone.\textsuperscript{107}

After the data fields are in place, the model must then be calibrated. Model calibration is generally described as fine-tuning the groundwater model to reflect the actual data that exists in

\textsuperscript{102} Id.
\textsuperscript{103} Id.
\textsuperscript{104} Hill, Supra note 98.
\textsuperscript{105} Id.
\textsuperscript{106} Id.
\textsuperscript{107} Id.
the field. This is accomplished by repeatedly running the model and adjusting its parameters until it closely resembles the sampled field data. In other words, the model performs test runs to ensure it accurately reflects what is actually occurring.

This in turn allows for the development of a visual model that simulates its mathematical function. The model is often displayed within a three dimensional map with various colors and contour representing numerous equations and data sets that are compiled together. The result is a model to which the expert testifies to in court in order to illustrate his opinion.

C. Groundwater Modeling Susceptibility to Error

Despite the usefulness that groundwater models possess in understanding hydrogeology, each hold some amount of uncertainty. Underground water reservoir systems are so complex that it is impossible to fully substantiate each relevant process mathematically. As a result, every model contains simplifications and assumptions that will never correspond exactly with reality. Nevertheless, the complexity, or lack of data that a certain field of science may deal with is not a proper justification for unreliable evidence. In Mid-State Fertilizer Co. v. Exchange Nat'l Bank, the seventh circuit court of appeals rejected expert testimony that merely

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109 Id.
112 Id.
113 Mid-State Fertilizer Co. v. Exchange Nat'l Bank, 877 F.2d 1333 (7th Cir. Ill. 1989).
argued the difficulties involved in analyzing a certain field of science.\(^{114}\) The court stated that, judges should not be “buffaloed by unreasoned expert opinions” that merely attempt to avoid its burden by “pleading the purported difficulties of using the traditional methods of science”.\(^{115}\) It noted that in *Daubert*, the Supreme Court rejected such an argument. In the court’s discussion, it emphasized the importance of safeguarding the integrity of the judicial process by requiring the trial judge, when he believes that an expert's testimony has fallen below professional standards, to say so.\(^{116}\)

Errors in groundwater modeling most often occur within the compilation of data and are usually the result of faulty laboratory testing procedures or defective sample handling techniques.\(^{117}\) Such errors inevitably affect the methodological framework of the model itself and require experts to imply their own professional judgment in explaining the correlations of data.\(^{118}\) However, expert opinion becomes inadmissible when the model’s conclusions lie upon multiple layers of assumptions. When misapplied, the addition of assumptions “takes the expert's opinion from the realm of fact to that of mere speculation, rendering it incompetent”.\(^{119}\)

The high level of complexity within a groundwater model also increases the likelihood that it will be subject to abuse by the expert. This is due to the possibility that an expert’s unsupported assumption will go unnoticed by an overwhelmed finder of fact. This is also known as “garbage in-garbage out”.\(^{120}\) The court must therefore be vigilant against the possibility of a

\(^{114}\) *Mid-State Fertilizer Co. v. Exchange Nat'l Bank*, 877 F.2d 1333 (7th Cir. Ill. 1989).

\(^{115}\) *Id.* at 1340, *See also*, *Daubert* 43 F.3d at 1313-1314.

\(^{116}\) *Id.*


\(^{118}\) *Id.*


\(^{120}\) *Anderson v. Cryovac, Inc.*, 862 F.2d 910, 920 (1st Cir. 1988).
jury being swayed by an expert simply because of his credentials and the purported scientific nature of his opinions. By serving as a judicial gatekeeper and ensuring that only reliable evidence is presented to the jury, the court safeguards against speculative theories having an improper influence on the jury.\textsuperscript{121}

\textbf{D. Groundwater Modeling Reliability}

The reliability of such a model is highly dependent upon the basis of data it operates under, the methodology of administering the data, and the expert’s assumptions that he or she relies upon in applying the model.\textsuperscript{122}

Under the \textit{Daubert} analysis, the court is required to look behind the surface of an expert's claims of reliability in making its preliminary determination concerning admissibility under Federal Rules of Evidence 702 and 703.\textsuperscript{123} If the court determines that proffered testimony is based upon unreliable assumptions or speculative theories, the testimony must be excluded. Every premise or assumption underlying an expert's conclusion must be capable of being substantiated and must lead as a matter of logic to the proffered conclusion.\textsuperscript{124} In other words, the accuracy of these equations is measured by what actual results are produced within the groundwater system itself.\textsuperscript{125} If either the data or the operating assumptions within a groundwater model are speculative, the conclusions that are drawn from the model’s results do not possess

\begin{itemize}
  \item \textsuperscript{121} \textit{Id.}
  \item \textsuperscript{122} \textit{United States v. Hooker Chemicals & Plastics Corp.}, 607 F.Supp. 1052 (W.D.N.Y. 1985).
  \item \textsuperscript{123} \textit{Daubert}, 509 U.S. at 593.
  \item \textsuperscript{124} \textit{Hooker Chemicals & Plastics Corp.}, 607 F.Supp. 1052.
  \item \textsuperscript{125} \textit{See In re “Agent Orange” Prod. Liab. Litig.}, 597 F. Supp. 740, 781, 795 (E.D.N.Y. 1984).
\end{itemize}
sufficient reliability and is excluded as a matter of law. 126 Nevertheless, even in the best of circumstances, a model is only an estimate. The accuracy of such an estimate inevitably depends on the selection, quality, and reliability of the data to be used within the computer model, and, of course, the skill of the modeler. 127

The data and mathematical formulas used in generating the model’s projections are normally constant and drawn from generally accepted methodologies. This often results with opposing parties utilizing the same data within their own groundwater model. On the other hand, the assumptions that the expert chooses to rely upon will vary from model to model and ultimately depend upon the expert’s professional judgment. 128 Thus, the disputed issues within a case generally involve the assumptive reasoning that each expert uses within their model. As noted above, the construction of a conclusion is similar to that of the bridge. Even though two individual builders may start with the same construction materials, each bridge may result in drastically different levels of quality if the methods of construction differ. This “bridge construction” occurs when the expert rationalizes a causal link from the data to his conclusion. Various approaches exist for such a task and are ultimately dependent upon the expert’s “professional judgment”. Thus, the overriding issue in most cases is not the data, rather it is simply whose model should the court use in administering its ruling. 129 It is within such judgments that the battle is litigated. 130

127 City of Wichita, 306 F. Supp. 2d at 1108.
130 Id.
In *City of Wichita v. Trs. of the Apco Oil Corp. Liquidating Trust*, the admissibility of the groundwater expert’s model was challenged before the court. In this case, the opposing party argued that the facts and data supporting the expert’s opinion were not the product of reliable principles and methods that were properly applied. \(^\text{131}\) The court disallowed the use of the expert’s groundwater model because it purported to show groundwater contamination while the field data did not. \(^\text{132}\) More specifically, the court found that the expert committed serious error when he did not complete all the necessary steps in proving a connection between the data and his conclusion and instead, relied solely on his professional judgment in establishing it. In its opinion, the court would not allow the expert to substitute his own “professional judgment” in place of existing field data for proving his conclusion. The court explained that neither Daubert, nor the Federal Rules of Evidence require trial courts to accept groundwater models that only rest upon the faith of the expert himself. \(^\text{133}\) Instead, a court may conclude that there is simply too great of an analytical gap between the data and the conclusion offered for sufficient reliability to exist. \(^\text{134}\) The court quickly disposed of the remaining Daubert factors as well because the expert did not properly abide by the methodology he purported to use within the model. In doing so, the court explained that further consideration on whether such a methodology is reliable is irrelevant when it is not properly administered to begin with. \(^\text{135}\) In summary, the court simply stated that the expert knew the rules of the game, and neglected to follow them in applying the model’s methodology. \(^\text{136}\)

\(^{131}\) *Id.*

\(^{132}\) *Id.*

\(^{133}\) *Id.*

\(^{134}\) *Id.*

\(^{135}\) *Id.* at 1110.

\(^{136}\) *City of Wichita*, 306 F. Supp. 2d at 1110.
Instead, the court adopted the opposing party’s groundwater model, despite the fact that both models implemented the same procedure in forming their conclusions. The court differentiated the reliability of the two models by noting that only one independently determined the proper data and parameter inputs of the given aquifer. In other words, the court found that only one of the models had been properly calibrated and appeared more consistent with the actual field data.

VI. THE DAUBERT CHALLENGE TO GROUNDWATER ADMISSIBILITY

It is important for groundwater models to have a logical connection between the bases, methodology, and conclusion. Successful challenges of testimony regarding groundwater models should focus on the materiality of the incorrect or unconsidered information and the effects on the expert’s opinion. Motions that challenge only the conclusion itself will not ordinarily result in exclusion without first establishing unreliability. The most common grounds for exclusion in groundwater modeling are:

A. **Failing to consider or explain relevant groundwater sampling data that contradicts the expert’s conclusion:**

   The failure of an expert to use or consider certain information or data may be serious enough to undermine the reliability of his or her opinion. Reliable groundwater models must account for existing data that contradicts or does not exist. For such data not to be considered relevant in producing a reliable opinion, the expert and sponsoring party must convince the court that an adequate scientific basis exists for not using or considering the data at issue.

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137 Id. at 1110
In *Anderson v. Cryovac*, the District Court of Massachusetts considered a groundwater model that plaintiffs' proof of causation rested upon.\(^{139}\) In a post-verdict finding by the court, it found that plaintiffs had failed to produce any data to establish they had even been exposed to defendant's chemicals, thereby failing to show causation of their claim.\(^{140}\)

Upon review, the First Circuit of Appeals affirmed the lower court’s rejection of the groundwater model’s validity on the basis of the limited showing of physical, scientific, and historical data. It too found that plaintiff’s conclusions as to groundwater flow were inherently unreliable and merely a matter of “garbage in, garbage out”.\(^{141}\) The court instead credited the testimony of defendant's hydrogeology expert, who opined that several factors made it impossible to draw a firm conclusion as to whether the plaintiffs' wells drew from defendant's contaminated property.\(^{142}\)

In *Ramsey v. Conrail*, the District Court of Northern Indiana granted summary judgment in favor of the defendant because the record failed to identify any scientific data on which the expert based his conclusion.\(^{143}\) The plaintiffs alleged that they suffered from exposure of trichloroethene (TCE) from drinking water in their well, which was caused by releases of volatile compounds at the defendants’ rail yard.\(^{144}\) Plaintiff’s expert hydrologist testified that contamination migrated from the rail yard to groundwater. This migration methodology was based on well-accepted practices of groundwater flow models and was found to be admissible by the court.

\(^{139}\) *Id.* at 921.

\(^{140}\) *Id.*

\(^{141}\) *Id.* at 920.

\(^{142}\) *Id.*


\(^{144}\) *Id.* at 1032.
The court however, rejected the final step of the expert’s conclusion linking plaintiff’s exposure to TCE through their water well because it did not derive from any actual data. The necessary data linking groundwater flows with actual exposure was not present within the water well samples that would allow a reliable conclusion to find that plaintiffs had ever been exposed to TCE in their drinking water. In its exclusion of the testimony, the court observed that, “Many cases decided under Daubert have excluded opinion testimony from experts who ignored facts or considerations that must be considered under methods based on reliable principles.”

B. Failing to include a sufficient amount of groundwater data or testing in forming their expert opinion:

Lack of environmental testing or sampling may affect the reliability of an expert opinion. A groundwater model is fatally speculative in the eyes of the court if it is premised upon an insufficient number of data points. A model should likewise be ruled inadmissible if its predictions are not validated by reference to available data over a long period of time.

While analyzing the sufficiency of data supporting the opinion, courts frequently consider whether the accuracy of the model has been verified against one or more analytical solutions. In other words, has the data been verified by real world events? A determination of whether computer estimates are sufficiently reliable to constitute probative evidence must turn on the extent to which those estimates rely upon and are validated by real-world data. Without proper corroboration, such data degrades the groundwater model into nothing more than a demonstrative illustration of hypothetical facts and assumptions.

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145 Id. at 1037.
146 Id.
147 Id. at 1036.
148 Anderson, supra note 90, at 214.
In *Renaud v Martin Marietta Corp*, the court excluded the plaintiffs’ groundwater model from evidence because it lacked any scientific sampling in forming the conclusion.\(^{149}\) Instead of reliably establishing groundwater contamination through several distinct data points, the plaintiffs' model used a load factor calculated by reference to only a single water sample taken at one point in time.\(^{150}\) The court concluded plaintiffs' expert witnesses assumed, without verification against any other real-world data, that their single data point represented the “constant” rate of contaminant discharge to which the plaintiffs had been exposed over an eleven-year period. The court noted that such insufficient sampling constitutes a fatal threshold of data, depriving the model of any predictive value.\(^{151}\)

C. Failing to Support Testimony with Reliable Assumptions:

Experts routinely apply factual or scientific assumptions in groundwater models while rendering opinions in a litigation setting. A model is vulnerable to exclusion if it can be shown to be built on unproven assumptions regarding the hydrological issue being litigated. Expert testimony is not admissible when conclusions are based on multiple layers of assumptions that have not been confirmed or supported by other reliable groundwater experts. At some point, the addition of assumptions to the bare facts takes the expert’s opinion from the realm of fact to mere speculation, rendering the testimony unreliable.\(^{152}\)

In *Ramsey v. Conrail*, the court rejected the expert’s lack of evidence in establishing the causation of harm.\(^{153}\) The groundwater flow model that the plaintiff’s expert offered only generalized potential flow direction of the underground water beneath the Defendant’s property,


\(^{150}\) *Id.*

\(^{151}\) *Id.* 1552-53.

\(^{152}\) *Vincent*, No. 88-1006.

\(^{153}\) *Ramsey*, 111 F. Supp. 2d at 1030.
and did not possess any known rate of error that would reliably support any conclusion. The groundwater model also did not contain any data supporting the conclusion that contamination actually did occur within the relevant period of causation. Instead of the explaining why the model lacked sufficient data showing contamination in the Plaintiff’s well water, the expert’s evidence merely explained why those tests did not necessarily prove that contamination was incapable of reaching it. The court rejected this argument and found that an expert must substantiate his or her opinion, and not simply provide a presumptive conclusion without analysis. In discussing the court’s reasoning, it states that the “causal chain isn't simply that Dr. Haitjema is right and the others wrong”. The court also noted, “Nothing in either Daubert or the Federal Rules of Evidence requires a district court to admit opinion evidence which is connected to existing data only by the ipse dixit of the expert”. The defendants' motion for summary judgment was therefore granted because in the absence of the expert's testimony, plaintiffs were unable to establish a causal link between the Defendant’s property and plaintiffs’ illness.

VII. CONCLUSION

"Judges should not be buffalooed by unreasoned expert opinions". The mere fact that expert testimony derives from a computer model does not make their opinions certain or reliable for courtroom evidence. Instead, a court must initially conclude that the computer estimates

154 Id. at 1037.
155 Id.
156 Id.
157 Id.
158 Id.
159 Id.
160 Mid-State Fertilizer Co. v. Exch. Nat'l Bank, 877 F.2d 1333, 1340 (7th Cir. 1989).
161 Ramsey, 111 F. Supp. 2d at 1030.
reflect real word data and are sufficiently reliable and probative.\textsuperscript{162} Without the collaboration of some form of direct evidence, a model remains nothing more than a demonstrative illustration of hypothetical facts premised upon untested circumstantial inferences and assumptions.\textsuperscript{163} A computer-generated model is more susceptible to abuse because it is created by experts whose failure to support their assumptions and validate their methodology may be overlooked by an overawed finder of fact.\textsuperscript{164}

A groundwater model, which has not been validated by reliable evidence rests upon unreliable methodologies or data and is not evidence that is admissible in a court of law.\textsuperscript{165} Under the Federal Rules of Evidence, the data resulting from such a model cannot be reasonably relied upon by experts in the particular field”.\textsuperscript{166} Nor can it “assist the trier of fact to understand the evidence or to determine a fact in issue”.\textsuperscript{167} Instead, such models are excluded from evidence for the danger they pose in confusing the issues or misleading the jury.\textsuperscript{168} To do otherwise would permit the fact finder to indulge in unreliable speculation, resulting in bad science and bad law.\textsuperscript{169}

Successful challenges to expert testimony in groundwater modeling should focus on the expert’s failure to consider data or an expert’s use of incorrect assumptions or facts within the

\textsuperscript{162} \textit{Id.}
\textsuperscript{163} See Morgan note 106.
\textsuperscript{164} \textit{Ramsey}, 111 F. Supp. 2d at 1030.
\textsuperscript{165} \textit{Id.}
\textsuperscript{166} Fed. R. Evid. Rule 703.
\textsuperscript{167} Fed. R. Evid. Rule 702.
\textsuperscript{168} Fed. R. Evid. Rule 403.
groundwater model. Such challenges should elevate the substance of the incorrect information and the resulting effect that it produces within the opinion.  

FIGURE A
