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POLICY ISSUES ASSOCIATED WITH USING SIMULATION TO ASSESS ENVIRONMENTAL IMPACTS

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Policy Issues Associated with Using Simulation to Assess Environmental Impacts

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Abstract

This report examines the relationship between simulation-based science and judicial assessments of simulations or models supporting evaluations of environmental harms or risks, considering both how it exists currently and how it might be shaped in the future. This report considers the legal standards relevant to judicial assessments of simulation-based science and provides examples of the judicial application of those legal standards. Next, this report discusses the factors that inform whether there is a correlation between the sophistication of a challenged simulation and judicial support for that simulation. Finally, this report examines legal analysis of the broader issues that must be addressed for simulation-based science to be better understood and utilized in the context of judicial challenge and evaluation.

Executive Summary

Simulation-based science has become an essential tool across virtually all societal sectors, including environmental policymaking. Federal and state agencies routinely employ models in order to make science-based decisions, and, in fact, some modern day agency decision-making would be virtually impossible without reliance on the breadth of analytic capacity made possible by advanced computing power. Despite the policymaking value of simulation-based analyses, not all simulations are created equal, nor are all simulations equally susceptible to external critique and evaluation. Thus, a significant problem arises when a particular model or simulation is challenged in a judicial proceeding, and a scientific non-expert, such as a judge or juror, is asked to assign evidentiary weight to that model or simulation.

Legal precedent has developed various standards and tests to guide judicial consideration of simulation-based evidence. Courts are expected to consider whether the techniques at issue have a known error rate, are subject to empirical standards, and are widely accepted. The trial court is expected to guard against speculation and unreliable opinions by determining that simulations or models submitted as evidence are scientifically valid and appropriate for the facts giving rise to the instant case.

Generally speaking, judges exhibit deference to simulation-based evidence, not so much on the basis of the quality of the evidence, but more often due to a lack of scientific familiarity or comfort with assessing the 'goodness' of the challenged simulation-based analysis. Thus, even though there is legal precedent to inform judicial determinations of the appropriate value or weight of a given simulation-based analysis, significant deficiencies persist in the effective application of this precedent. Numerous disconnects between science and law continue to

diminish the depth and thoroughness of judicial evaluations of simulation-based analyses, limiting the utility of simulation tools in environmental policymaking. This report examines the policy issues relevant to maximizing the utility of simulation-based evidence, including the current judicial approach as well as proposed changes to the evaluative process.

Although the divides between scientific, lay and judicial perspectives cannot be eliminated, supplementary evaluative tools for assessing the appropriate evidentiary weight of simulation-based analyses could be developed. Adopting legal criteria that could provide a consistent means of measuring the 'goodness' of such analyses, *i.e.*, modeler expertise, model transparency, scope of model application, governmental evaluations of recently used models, a well-defined 'best available' standard, and a standardized framework for communicating the inputs and assumptions to a lay or judicial stakeholder, would greatly enhance the utility of simulation in environmental policymaking.

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List of Acronyms

CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FWS	U.S. Fish and Wildlife Service
NAAQS	National Ambient Air Quality Standards
NRC	National Research Council
OMB	White House Office of Management and Budget
USFS	U.S. Department of Agriculture Forest Service

I. Introduction

Reliance on modeling and simulation has become ubiquitous across virtually all sectors of society. From airplane design and safety, to nuclear arsenal integrity, to the scale of global warming impacts, modeling and simulation are used to set parameters for product development and risk management across the industrial and scientific spectrum. Despite this prevalence, familiarity and comfort with the mechanics of simulation-based science remains significantly more the province of academics and other professionals directly engaged with modeling than the province of either the general public or the non-scientific professional community.

A fundamental challenge for full utilization of simulation-based science is enhancing the comfort of non-scientists and laypeople with respect to the value of modeling in accurately assessing risk and effecting sound policymaking. A related challenge looms, albeit on a more limited scale, in maximizing the utility of simulation-based science in the interconnected policymaking and judicial realms.

This report seeks to examine the policy issues that inform judicial assessments of simulations or models used as evidence of environmental harms or risks, considering both how that dynamic works currently and how it might be shaped in the future. First, this report examines the legal standards relevant to judicial assessments of simulation-based science and then broadly reviews the judicial application of the legal standards in the case law. Next, this report explores whether there is a correlation between the technical superiority or sophistication of a challenged simulation and judicial support for that simulation and considers the factors that inform that correlation. Lastly, in light of the relative paucity of on point case law addressing cutting-edge simulation based science, this report concludes by discussing the broader issues that must be addressed for simulation-based science to be better understood and utilized in the context of judicial challenge and evaluation.

II. Analysis

A. Simulation-Based Science as Evidence: The Relevant Legal Standards

Stated simply, a model is a tool "used to simulate some aspect of the real world."[1] From a legal policy perspective, simulation-based analyses of potential risks or interactions between multiple elements holds the promise of more accurately predicting, planning for, and avoiding environmental and ecological harms.

> Policymakers often must predict outcomes of complicated processes, and making those predictions would be all but impossible without models. Complex environmental systems often involve more variables, data, and interdependent feedback processes than people reasonably can organize in their minds, and interactions within these systems may create counterintuitive, nonlinear responses that are impossible to understand without models. Models can organize, manipulate, and process vast quantities of data and can simulate complex multivariable processes, and these capacities allow them to predict the future, compare alternative possible futures, test the ramifications of assumptions, and contribute to improved understanding of system interactions. These powers are invaluable in planning efforts.[2]

Unsurprisingly, models have become increasingly relevant to legally mandated assessments of environmental risks. Many agency regulations depend on models to make science-based

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[1] Robert L. Glicksman, *Bridging Data Gaps Through modeling and Evaluation of Surrogates: Use of the Best Available Science to Protect Biological Diversity Under the National Forest Management Act* 13 (2008) (*quoting* James D. Fine & Dave Owen, *Technocracy and Democracy: Conflicts Between Models and Participation in Environmental Law and Planning*, 56 Hastings L.J. 901, 903 (2005)).

[2] James D. Fine & Dave Owen, *Technocracy and Democracy: Conflicts Between Models and Participation in Environmental Law and Planning*, 56 Hastings L.J. 901, 912-13 (2005).

decisions, and agencies are encouraged to be forthcoming about their models' assumptions and limitations in order to enhance the transparency and utility of the regulations themselves.[3] For example, the U.S. Environmental Protection Agency (EPA) has issued policy guidelines intended to inform model usage for environmental rulemaking within its purview.[4] However, despite EPA's guidelines and internal agency comfort with developing and utilizing simulations, the judiciary remains a frequent arbiter of EPA decision-making, and courts are frequently called upon to make independent determinations of whether EPA's use of models and simulations are appropriate, required, or properly done in particular cases.[5] Courts are similarly called upon to evaluate models from agencies other than EPA tasked with managing environmental resources, such as the U.S.D.A. Forest Service (USFS), which has employed differing approaches to the use of modeling in its decision-making.[6]

Prevalent agency reliance on modeling in decision-making is all but inevitable, given the uncertainty that pervades environmental decision-making and trade-offs coupled with the vastness of the landscape of potentially relevant data. As noted by Glicksman, "Congress has directed the agencies responsible for administering the environmental statutes to ground their

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[3] Wendy Wagner, Elizabeth Fisher & Pasky Pascual, *Misunderstanding Models in Environmental and Public Health Regulation*, 18 N.Y.U. Envtl. L.J. 293, 305-06 (2010).

[4] Susan R. Poulter, *Environmental Risk Assessment – Science, Policy, and Legal Issues,* 9 Risk: Health, Safety & Environment 7, 18 (Winter 1998); John W. Hayse, *Using Monte Carlo Analysis in Ecological Risk Assessments* 10 (Oct. 2000) (noting that EPA supports the use of probabilistic analysis techniques); Wagner, Fisher & Pascual, *supra* note 3, at 304 (discussing the EPA's Council for Regulatory Environmental Modeling, which provides oversight for models).

[5] *See* Glicksman, *supra* note 1 (discussing procedural requirements for model use, such as notice and comment).

[6] *See id.*

policy decisions in science. . . . Agencies sometimes cope with the responsibility of making science-based decisions despite the presence of uncertainty by relying on scientific models, or otherwise using the limited information available to them, to make predictions about the impacts of agency decisions on the environment."[7] However, "competing models or differential applications of a single model may yield starkly divergent predictions about the effects of an agency's decision on the environment. As a result, litigation concerning the use of simulation models and surrogate parameters by environmental and resource management agencies has been plentiful."[8] Despite the ascendance of simulation-based analyses in the policy-making and judicial realms, legal critics note shortcomings in the legal approach to "spatial tools and models."[9]

> [L]egal thinkers have devoted little attention to spatial analysis…very few legal authors have considered whether emerging spatial analysis techniques hold transformative potential for either the practice or theory of environmental law. Nor do legal researchers typically use spatial analysis tools. Even as other research

[7] *Id*. at 2. *See also* Matthew W. Swinehart, *Remedying Daubert's Inadequacy in Evaluating the Admissibility of Scientific Models Used in Environmental-Tort Litigation*, 86 Tex. L. Rev. 1281, 1284 (2008) ("Models have long been a part of the scientific community's methodological arsenal. However, in recent decades, their influence in science and policy has dramatically increased, due largely to the confluence of two distinct phenomena: the advent of computers and the rise of intricate and demanding environmental regulatory regimes.").

[8] *Id.* at 3.

[9] Dave Owen, *Mapping, Modeling, and the Fragmentation of Environmental Law,* 1 Utah Law Review 219, 223 (2013). Owen notes that, "Over the past four decades, increased data availability, new software systems, and exponentially greater computing power have combined to turn spatial analysis— that is, quantitative analysis of data coded to specific geographic coordinates—into the coin of the environmental realm. At federal, state, and local government offices, in the private sector, and throughout nonlegal academia, thousands of analysts in dozens of fields now spend their days gathering and crunching spatial data. Their efforts serve a wide variety of purposes and, more fundamentally, are leading to new ways of conceptualizing ecological systems and environmental change. (internal citations omitted)." *Id.* at 222-23.

> fields move toward quantitative analysis based on spatial data, environmental law research remains largely the domain of qualitative argument, often grounded in intuition and anecdote and delivered exclusively in prose.[10]

While there are clear exceptions to this criticism, *e.g.* simulation-based analysis in the area of climate change and evidence of specific demonstrated modeling utility under the Clean Air Act (CAA), the Clean Water Act, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Safe Drinking Water Act, the broader disconnect between the legal and scientific comfort with simulation-based analyses remains a challenge.[11]

From a legal perspective, the admissibility of models and simulations is subject to the following legal tests: *Frye*,[12] *Daubert*,[13] and Federal Rules of Evidence 702 (or its state equivalent). The 1923 *Frye* test focuses on "general acceptance in the relevant scientific community."[14] "The *Daubert* criteria, adopted seventy years later, expanded upon *Frye* to include, among other things, whether the techniques have a known error rate, are subject to standards governing their application and enjoy widespread acceptance."[15] Additionally, *Daubert* instructs the trial court to act as a gatekeeper to keep out speculative and unreliable

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[10] Owen, *supra* note 9, at 223-24.

[11] *See id.*; *see also* Wagner, Fisher & Pascual, *supra* note 3, at 304 (2010); Daniel A. Farber, *Modeling Climate Change and its Impacts: Law, Policy, and Science*, 86 Tex. L. Rev. 1655 (2008); Fine & Owen, *supra* note 2; Thomas O. McGarity & Wendy E. Wagner, *Legal Aspects of the Regulatory Use of Environmental Modeling*, 10 Envtl. L. Rep. 10,751 (2003).

[12] *Frye v. United States*, 293 F. 1013 (1923).

[13] *Daubert v. Merrill Dow Pharms, Inc.,* 509 U.S. 579 (1993).

[14] The National Judicial College, *Hydrologic Modeling Benchbook: Dividing the Waters,* 52 (2010).

[15] *Daubert*, 509 U.S. at 593. *See also* Swinehart, *supra* note 7, at 1301-11 (discussing the *Daubert* criteria).

opinions by performing "a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue."[16] The Federal Rule of Evidence 702 states:

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.[17]

Generally speaking, a strong presumption of validity exists in regards to agency regulations relating to technical subjects, including modeling.[18] The rationale for this deference is that judges often "lack the competence to evaluate modeling evidence satisfactorily. The limited scientific expertise, training, and education of judges make it difficult to determine an appropriate level of review at the evidentiary screening state… [and] drawing a line between good and bad models is often not an easy task, even for those with the relevant scientific expertise operating outside the adversarial context of litigation."[19] Deference can also be

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[16] *Daubert*, 509 U.S. at 593-94.

[17] Fed. Rules Evid. Rule 702, 28 U.S.C.A. Examples of federal and states cases citing Rule 702 (or the state law equivalent) in the context of simulation-based evidence analyses are; *Abarca v. Franklin County Water Dist*., 2011 WL 140371 (E.D.Cal. 2011); *In re Static Random Access memory (SRAM) Antitrust Litigation*, 264 F.R.D. 603 (N.D.Cal. 2009); *In re Flood Litigation Coal River Watershed*, 668 S.E.2d 203 (W.Va. 2008); *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie*, 508 F. Supp.2d 295 (D.Vt. 2007). *Liquid Dynamics Corp. v. Vaughan Co., Inc*., 449 F.3d 1209 (C.A.Fed.Ill. 2006); *Eclipse Electronics v. Chubb Corp*., 176 F. Supp.2d 406 (E.D.Pa.2001); *Ruff v. Ensign-Bickford Industries, Inc*., 171 F. Supp.2d 1226 (D.Utah.C.Div. 2001).

[18] *Lourdes Med. Ctr. of Burlington Country v. Bd. of Review,* 197 N.J. 339, 376 (2009).

[19] Swinehart, *supra* note 7, at 1299.

attributed to judicial discomfort or erroneous assumptions. Many courts "perpetuate the pervasive misunderstanding and assume that since the model is mathematical, it is correct. As a result, they pass the model through the system without much, if any, scrutiny…even in cases when there are reasons to suspect that the model may have significant problems."[20]

Notwithstanding the above, there is judicial precedent for rejecting models based on assumptions not supported by, or at odds with, ascertainable facts.[21] Courts have invalidated agency decisions that relied on modeling or simulation exercises where "they have found that a particular model was ill-suited to the activities to which it was applied or that the agency was unable to justify building the model on apparently arbitrary assumptions."[22] Challengers have also been successful when an agency declines to explain its decision or revise a supporting model after receiving comments attacking the model's methodology, as well as situations when the model was not applicable to a particular subset of industries, activities, or locations.[23] Lastly, faced with legal challenges to "embedded policy judgments, such as the risk adversity of

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[20] Wendy, Fisher & Pascual, *supra* note 3, at 320. *See Sierra Club v. U.S. Forest Serv.*, 878 F. Supp. 1295, 1310 (D.S.D. 1993) ("As long as an agency reveals the data and assumptions upon which a computer model is based, allows and considers public comment on the use or results of the model, and ensures that the ultimate decision rests with the agency, not the computer model, then the agency use of a computer model to assist in decision making is not arbitrary and capricious.").

[21] *Leather Indus. Am., Inc. v. EPA*, 40 F.3d 392 (1994).

[22] Glicksman, *supra* note 1, at 20-21. *See Ctr. for Biological Diversity v. BLM*, 422 F. Supp.2d 1115 (N.D. Cal. 2006) (reversing the FWS' reliance on modeling or simulation techniques on these grounds).

[23] National Research Council of the National Academies, *Models in Environmental Regulatory Decision Making* 77 (2007). *See State of Ohio v. EPA*, 784 F.2d 224 (6th Cir. 1986).

assumptions built into a risk assessment, courts will sometimes invalidate a model and not defer to the agency."[24]

B. Judicial Analyses of Simulation-Based Science: Applying the Legal Standard

This section of the report presents excerpts of the specific language and reasoning of several courts, both state and federal, faced with the judicial task of deciding a challenge to simulation-based scientific evidence. The several cases are presented in chronological order. While the facts of each case are presented very briefly for context, the procedural histories of the cases are omitted. This overview is not intended to be exhaustive but rather to illustrate a range of judicial analyses applying the legal evidentiary standards described in the previous section of this report.

Cleveland Elec. Illuminating Co. v. EPA, 572 F.2d 1150 (6th Cir. 1978), arose from a lawsuit filed by various companies and the State of Ohio petitioning for judicial review of EPA's sulfur dioxide pollution control plan. In upholding EPA's model, the Court stated: "It is, of course, no part of the responsibility of this court to determine whether the RAM model represents the best possible approach to determining standards for the control of sulfur dioxide emissions. Our standard of review of the actions of United States EPA is whether or not the action of the agency is 'arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law.'"[25] The Court found that EPA's use of the RAM model was supported by sufficient evidence since (1) EPA's initial use of a "rollback" model was strenuously objected to

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[24] National Research Council of the National Academies, *Models in Environmental Regulatory Decision Making* 77 (2007). *See State of Ohio v. EPA*, 784 F.2d 224 (6th Cir. 1986). *See Gulf South Insulation v. Consumer Product Safety Commission*, 701 F.2d 1137 (5th Cir. 1983).

[25] 572 F.2d at1161.

at public hearings, (2) EPA responded by devising and adopting the RAM model, and (3) the RAM model could be applied to many individual sources of pollution and employed a wider, more complete and accurate data base than any prior model.[26]

Alabama Power Co. v. Costle, 636 F.2d 323 (D.C. Cir. 1979), involved a challenge to EPA modeling regulations under the CAA. In upholding the regulations, the Court opined, "[o]f great importance is a reasoned agency response to substantial questions of fact, policy or science raised in comments on recommended models or in proposals to employ new techniques."[27] The Court found that modeling "is on 'the frontiers of scientific knowledge,' but the lack of scientific certitude about modeling techniques increases rather than reduces the need for the agency to critically examine all substantial questions of fact and science emerging from the commenting process."[28]

State of Conn. v. EPA, 696 F.2d 147 (2d Cir. 1982), arose when the State of Connecticut sought review of EPA's final rule permitting a New York electric company's continued burning of fuel with 2.8% sulfur content until Sept. 24, 1984. The Court rejected challenges to the statistical modeling used by EPA in assessing the impact of the plant's emissions upon Connecticut's air. The State of Connecticut alleged that EPA contravened its own Guidelines on Air Quality models when it decided to rely on the CRSTER model at issue in the case.[29] However, the Court found in favor of EPA, noting that (1) EPA's guidelines recommended that

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[26] 572 F.2d at 1162-63.

[27] 636 F.2d at 387.

[28] 636 F.2d at 387-88.

[29] 696 F.2d at 158.

"each complex situation be treated on a case by case basis with the assistance of expert advice," (2) EPA had adopted this case-by-case approach, adjusting the model to account for terrain complexities in Connecticut, and (3) EPA had provided a detailed technical rationale for the inadequacy of other proposed models.[30]

Natural Resources Defense Council v. Herrington, 768 F.2d 1355 (D.C. Cir. 1985), stemmed from a challenge to final rules promulgated by the Department of Energy (DOE) determining that mandatory energy-efficiency standards were not justified for eight types of household appliances. At issue in the case was DOE's use of an econometric computer model to project future energy consumption of household appliances. Although the Court found that DOE's choice of model was neither arbitrary nor irrational, as the agency provided a reasoned basis for use of its model, the Court also found that the use of statistics for annual hours of operation of central air conditioners, in an econometric model designed to project energy savings from standards, was not supported by substantial evidence. "An agency may utilize a predictive model so long as it explains the assumptions and methodology it used in preparing the model. If the model is challenged, the agency must provide a full analytical defense. However, we will defer to an agency's judgment to use a particular model if the agency examines the relevant data and articulates a reasoned basis for its decision. (internal citations omitted)."[31]

In discussing the flaws of DOE's underlying algorithm, and rejecting DOE's defense of its chosen model, the Court stated: "The safety valves in the use of such sophisticated methodology are the requirement of public exposure of the assumptions and data incorporated

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[30] 696 F.2d at 159.

[31] 768 F.2d at 1385.

into the analysis and the acceptance and consideration of public comment, the admission of uncertainties where they exist, and the insistence that ultimate responsibility for the policy decision remains with the agency rather than the computer. With these precautions the tools of econometric computer analysis can intelligently broaden rather than constrain the policymaker's options and avoid the 'artificial narrowing of options that [can be] arbitrary and capricious.' (internal citation omitted)."[32]

Commercial Union Insurance Co. v. Boston Edison Company, 412 Mass. 545 (Mass. 1992), resulted from a lawsuit brought against the utility company by customers seeking compensation for overcharges resulting from a faulty steam meter. The Court held that the utility's computer-generated model for estimating energy usage was admissible, although the utility's customers were not required to accept the utility's estimate of energy usage. The Court reasoned that the admissibility of computer-generated models or simulations, like other scientific tests, is conditioned upon sufficient showing that: "(1) the computer is functioning properly; (2) the input and underlying equations are sufficiently complete and accurate (and disclosed to opposing party, so they may be challenged); and (3) the program is generally accepted by appropriate community of scientists."[33] The Court further found that the utility's computer-generated model of steam usage in buildings was admissible due to its general acceptance in the relevant community of scientists and its use by engineers and other professionals to model energy consumption. The Court stated that judicial obligation in evaluating a model extended only to determining "(1) the completeness and accuracy of the data and underlying equations,

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[32] 768 F.2d at 1391.

[33] 412 Mass. at 549.

and (2) whether program was generally accepted by appropriate community of scientists," not determining whether all the complex, underlying coding was complete and accurate.[34]

Novartis Corp. v. Ben Venue Laboratories, Inc., 271 F.3d 1043 (2001), arose when a patentee brought legal action against an alleged infringer relating to patent on forms of crystalline pamidronate disodium. The court held that the model and associated expert testimony submitted by the patentee was presented without any factual foundation and was thus irreparably deficient from an evidentiary standpoint: "There is nothing inherently unreliable or suspect about computer simulations as evidence, but every simulation of a physical process embodies at least some simplifying assumptions, and requires both a solid theoretical foundation and realistic input parameters to yield meaningful results. Without knowing these foundations, a court cannot evaluate whether the simulation is probative, and it would be unfair to render an expert's opinion immune to challenge because its methodology is hidden in an uncommented computer model."[35]

Natural Resources Defense Council v. U.S. Army Corp. of Engineers, 2001 WL 1491580 (S.D.Fla. June 28, 2001), arose from a challenge to the implementation of a hydrological model in accordance with the Endangered Species Act (ESA). The Corps' Hydraulic Engineer had opted to use the South Florida Water Management Model (SFWMM) rather than the MODBRANCH model recommended by the Fish and Wildlife Service (FWS), a decision subsequently upheld by the Court.

Characterizing its role in the dispute, the Court noted that, "[o]n judicial review, the role of the Court is not to attempt to become a tie-breaking technical expert. Indeed, '[b]ecause

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[34] 412 Mass. at 552.

[35] 271 F.3d at1054.

analysis of the relevant documents 'requires a high level of technical expertise,' [the Court] must defer to the 'informed discretion of the responsible federal agencies.' The fact that there is a conflict among the agencies does not lessen the deference owed to the Corps. 'When specialists express contrary views, an agency must have discretion to rely on the reasonable opinions of its own qualified experts even if, as an original matter, a court might find contrary views more persuasive' (internal citations omitted)."[36]

BCCA Appeal Group v. EPA, 355 F.3d 817 (5th Cir. 2003), arose when various industrial parties, local government, and environmental groups petitioned for review of EPA's rule approving Texas' State Implementation Plan for ozone attainment. The CAA required that Texas' demonstration of attainment be "based on photochemical grid modeling."[37] The Court upheld EPA's reliance on Texas' photochemical grid modeling, finding that while models "are imperfect tools for predicting future air quality, a modeled attainment demonstration 'provide[s] a reasonable expectation that the measures and procedures outlined will result in attainment of the NAAQS by the statutory deadline.' . . . "'a reviewing court must remember that the [agency] is making predictions, within its area of special expertise, at the frontiers of science. When examining this kind of scientific determination, as opposed to simple findings of fact, a reviewing court must generally be at its most deferential.' The court's role is to evaluate whether the EPA's projections represent arbitrary or capricious exercises of its authority, not whether they are accurate. Finally, there is a presumption of regularity to the EPA's choice of analytical

[36] 2001 WL 1491580 at *9.

[37] 42 U.S.C. § 7511a(c)(2)(A).

methodology, so challenging parties must overcome a 'considerable burden'(internal citations omitted)."[38]

The Court pointed to EPA's determination that the challenged Texas model provided reasonable predictions, as confirmed by comparisons with monitoring data, and therefore could provide an acceptable estimate of the amount of emissions relevant to attainment calculations. Further, the Texas model had been validated by various diagnostic and sensitivity analyses and graphical and statistical performance measures (*e.g*., normalized bias, gross error), leading the Court to conclude that EPA had recognized shortcomings in the model and provided plausible explanations. In sum, "[EPA's] explanation is reasonable and is supported by the record, and, therefore, EPA's determination is entitled to deference."[39]

City of Wichita v. Trustees of APCO Oil Corp., 306 F. Supp.2d 1040 (D.Kan. 2003), arose from an action brought by the City of Wichita under CERCLA. Specifically, the City of Wichita sought to secure financial contributions for incurred response costs from potentially responsible parties, as well as a declaration of responsibility for future response costs. Despite judicial reservations with the specific model used in the case, the Court noted that, "[i]f properly used, computer models appear to be an invaluable tool in approximating the complexities of underground fluid flow. Without these models, the scientists and engineers would be limited to guessing at sources and fluid flow characteristics based on the limited number of wells that penetrate the aquifer… Unfortunately, there are no true crystal balls – the models are only as good as the data placed into them. In this case, the data inputs and methods for configuring the

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[38] 355 F.3d at 832.

[39] 355 F.3d at 832.

models provided fertile ground for disagreement. Nonetheless, the court concludes that computer modeling of plume size is an appropriate basis for allocating costs. The real question is simply whose model to use."[40]

In rejecting the challenged expert testimony on computer modeling of groundwater flows as insufficiently reliable to be admissible, the Court pointed to the expert's failure to correlate model results with field data, unconfirmed assumptions as to relevant ground conditions, and design deviations from usual modeling methodology.[41] "Computer modeling is an accepted and, in appropriate circumstances, reliable method for use in determining groundwater flow and contaminant transport in an aquifer, and to evaluate the effectiveness of remedial alternatives. . . . Nevertheless, even in the best of circumstances, a model is only an estimate and the accuracy of the estimate depends to a considerable extent on the data selected for use in the computer model, the quality and reliability of that data and, of course, the skill of the modeler."[42]

West Virginia v. EPA, 362 F.3d 861 (D.C. Cir. 2004) involved two states and several businesses and energy policy entities, all of which collectively petitioned for review of EPA's rules requiring various states to revise State Implementation Plans. The Court noted that "'[a]gency determinations based upon highly complex and technical matters are entitled to great deference' . . . particularly when we review the use of computer models, because 'their scientific nature does not easily lend itself to judicial review. (internal citation omitted).'"[43] The Court

[40] 306 F. Supp.2d at 1106-1107.

[41] 306 F. Supp.2d at 1107.

[42] 306 F. Supp.2d at 1108.

[43] 362 F.3d at 802.

further observed that "EPA has 'undoubted power to use predictive models' as long as it "explain[s] the assumptions and methodology used," and held that it would "defer to the agency's decision on how to balance the cost and complexity of a more elaborate model against the oversimplification of a simper model."[44] Nonetheless, the Court noted that "[w]hile courts routinely defer to agency modeling of complex phenomena, model assumptions must have a rational relationship to the real world (internal citation omitted)," and courts will vacate an agency's conclusions if they are unreasonable.[45]

Principi v. Survivair, Inc., 2005 WL 5960352 (M.D.Fla. Oct. 18, 2005), stemmed from a action grounded in negligence and strict liability as to the design and manufacture of a breathing apparatus. The plaintiff argued that Defendant's expert witness' opinions were unreliable as they were based on a simulation that deviated from the actual occurrence in several material ways. In its opinion, the Court analyzed the reliability of the simulation conducted, holding that "the Court disagrees that the simulation must replicate exactly all of Plaintiff's activities during the CTT for it to be reliable. . . . Any differences may be addressed on cross-examination and in argument."[46]

Oceana, Inc. v. Evans, 384 F. Supp.2d 203 (D.C. Cir. 2005), arose from a challenge to the Secretary of Commerce's approval of an amendment to the Atlantic Sea Scallop Fishery Management Plan. Plaintiffs contended that "the agency's use of the SEFSC 2001 model was arbitrary, in that it constituted an 'irrational[] rel[iance] on the model to do something it is simply

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[44] 362 F.3d at 867-68.

[45] 362 F.3d at 866-68.

[46] 2005 WL 5960352 at *4.

not built to do,' while defendants countered that the model represented a reasoned methodology give the paucity of available data."[47] The Court held that the Secretary's use of the National Marine Fisheries Service model to analyze whether scallop fishing would jeopardize loggerhead sea turtles was not rendered irrational by the fact that the model was prepared to assess the impact of shrimp-trawl regulations on loggerhead populations, or that the model relied on mortality data collected in the mid 1970s and late 1980s. The model was the best available science, in-water survey data did not exist, and no expert offered any alternative for analyzing jeopardy.[48] The Court noted that although the "best available science" would not necessarily always pass muster under a rationality test, in this particular case the agency's methodological selection was not irrational given that the necessary quantitative data simply did not exist.[49]

League of Wilderness Defenders Blue Mountains Biodiversity Project v. NFS, 615 F.3d 1122 (9th Cir. 2010), resulted from a challenge brought by conservation groups to a decision by the USFS to authorize logging. In upholding the logging authorization, the Court stated that judicial deference to an agency's decision "is highest when reviewing an agency's technical analyses and judgments involving the evaluation of complex scientific data within the agency's technical expertise."[50]

San Luis & Delta-Mendota Water Authority v. Salazar, 760 F. Supp.2d 855 (E.D. Cal. 2010), involved an action brought by water districts, state water contractors, and water users

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[47] 384 F. Supp.2d at 214.

[48] 384 F. Supp.2d at 217.

[49] 384 F. Supp.2d at 220.

[50] 615 F.3d at 1130.

challenging FWS' biological opinion addressing the impact of state water projects under the ESA. In upholding the government's underlying methodology despite what it deemed valid concerns, the Court stated that, "[a]s a general rule, choices regarding modeling methods are exactly the sort of choices that … are left to the expert agency in the exercise of discretion. A court 'may reject an agency's choice of a scientific model only when the model bears no rational relationship to the characteristics of the data to which it is applied.'…a court is 'not free to impose on the agency [its] own notion of which procedures are best.' (internal citations omitted)."[51]

C. Does a 'Good' Simulation Carry More Weight in Court?

Should a technically superior simulation be afforded more deference in the context of judicial review? Or, phrased another way, does it matter to a judge how good the particular piece of simulation-based science is? The short answer is "yes, but…" The answer is 'yes' in that clearly both the judicial and simulation-based science communities value simulations of high integrity that are well-matched to the outcomes and risks being simulated. The 'but' results from differing approaches and constraints as between the scientific and judicial communities when tasked with evaluating how the 'goodness' of a particular model is established, and what those respective evaluations mean for the utility and valuation of the model.

For the scientist designing a model or simulation, 'good' could safely be assumed to denote scientific and mathematical rigor, input depth and complexity, and design sophistication, such that uncertainties in the model have been eliminated to the maximum degree feasible, model results are consistent with experimental data or physical observations, and the model has a

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[51] 760 F. Supp.2d at 908-09.

high rate of predictivity. The scientific evaluation of 'good' is measured by the standards of a professional community that is consistently working to refine and advance simulation science.[52]

For the layperson - and in the interplay between simulation science and the judiciary, laypeople would include judges and jurors who hear evidence relying on or presenting results from modeling or simulations - "good" would primarily denote accuracy, *i.e*. that the model or simulation reliably and correctly predicted outcomes to a level that resulted in a feeling of confidence or safety. However, too much faith in the inherent accuracy of scientific evidence, combined with an intellectual remove or lack of confidence as far as critically evaluating the merits of the underlying simulation analysis, presents its own legal and judicial risks.[53] As noted by Wagner, Fisher and Pascual, there is a "pervasive misperception of models as truth machines"[54] that is difficult to overcome in the absence of either professional comfort and analytic familiarity, or "a coherent, universally-shared set of guiding principles through which regulators and interested stakeholders can evaluate whether one model (or set of models) can be said to be more appropriate for a given situation than another."[55]

As with the lay perspective, the procedural (or precedent-based) judicial perspective is going to originate after the fact of the model or simulation's creation and utilization. By contrast,

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[52] *See e.g.*, Report of the National Science Foundation Blue Ribbon Panel on Simulation-Based Engineering Science, *Simulation-Based Engineering Science: Revolutionizing Engineering Science through Simulation* (May 2006) (discussing the past, present, and future application of predictive computational models).

[53] *See* Wagner, Fisher & Pascual, *supra* note 3; Edward J. Imwinkelried, *The Standard for Admitting Scientific Evidence: A Critique from the Perspective of Juror Psychology*, 28 Vill. L. Review 554 (1983).

[54] Wagner, Fisher & Pascual, *supra* note 3, at 331-32.

[55] *Id*. at 312.

the scientist's perspective will be formed over a longer arc, from design through application. For the judiciary, the determination of whether or not a simulation methodology is "good" arises in the context of a legal challenge to reliance on a given model or simulation, and thus that judicial evaluation is going to be circumscribed by the adjudicative context, *i.e.* whether the model or simulation was appropriately designed and applied to the assessment at hand. The judicial perspective is further constrained by the precedent and rules discussed above, and judicial assessment of a model or simulation must conform to the various evidentiary and discretionary review standards that apply in any given case.

While these three perspectives overlap to a degree, they also reflect significant differences in orientation, and thus the how and why of their respective evaluation of the "goodness" of a model or simulation will differ. It is easy to assume that the better the parameters and design of a model, the better the resulting modeling will be. However, in critically assessing a model, the simulation community has the expertise and inclination to focus on specific modeling inputs from a development and refinement standpoint, while judicial evaluations of modeling focus on compliance with the legal requirements, which are tied to the appropriateness of the methodology rather than whether a superior simulation alternative was available. Furthermore, in the words of one critic, "because they are contingent and technically complex, and yet at the same time enter a policymaking world that is not well prepared to use them wisely, models are fodder for abuse and manipulation."[56]

Where the simulation community is positioned to recognize and appreciate the mechanics of a given simulation, the judicial community typically does not feel comfortable assessing the

[56] *Id*. at 344.

technical or scientific underpinnings of that same simulation, nor does a court necessarily have the authority to properly make such an assessment.[57] The simulation community views modeling as an evolving and improving field, where many in the judicial community (and in the lay stakeholder community seeking recourse in judicial forums) are using or challenging modeling as the rationale or support for the more limited purpose of conclusive and deterministic evaluations - this can arise when either the model itself, or the sufficiency of public input in decision-making incorporating a model, is the subject of legal challenge. As discussed above, the judiciary is not expected to stand in the shoes of the simulation scientist, but rather to ascertain whether the methodology being challenged satisfies the legal evidentiary standards. And judicial inquiry into scientific validity and acceptance for purposes of satisfying evidentiary standards is not equivalent to determining whether the best possible simulation science was used.

Courts typically have been loathe to evaluate the appropriateness of utilizing a model, instead deferring to scientific or agency expertise.[58] From a practical perspective, it can be difficult for a court to approach a complex model or to evaluate whether the complexity of a given model precluded meaningful public participation in the eventual decision-making. In such instances, it may be easier for a court to rely on the model simply by virtue of the model's being

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[57] *See e.g.,* Poulter, *supra* note 4, at 7-8 (observing that even after EPA and the National Academy of Sciences, "recognized Monte Carlo methods as means of quantifying variability and uncertainty in risk assessments…To date, there has been little discussion of Monte Carlo simulations in court opinions – perhaps not surprising given the technical nature of this computational technique and courts' inclinations to defer to agency expertise.").

[58] *See* Wagner, Fisher & Pascual, *supra* note 3, at 320 ("In resolving challenges to models, most courts perpetuate the pervasive misunderstanding and assume that since the model is mathematical, it is correct. As a result, they pass the model through the system without much, if any, scrutiny…even in cases when there are reasons to suspect that the model may have significant problems.").

too difficult for the judge or stakeholders in the lay community to fully understand. What a court often can recognize and comfortably delve into is whether the model or simulation giving rise to a judicial challenge is a departure from past practices, is facially inappropriate for the use giving rise to judicial challenge, is widely disregarded in the relevant scientific community, or appears to have been conducted shoddily or in bad faith.

D. Bridging the Disciplinary Gap

Three broad sets of issues impede the greater utility of simulation-based science in environmental policymaking: (1) dissimilar roles and expectations as between the simulation science and judicial communities; (2) varying levels of transparency and lay accessibility as between different models and simulations; and (3) an absence of standardized cross-community criteria to facilitate critical comparisons of competing simulations and models. Given society's increasing reliance on simulation-based science - in the words of a National Science Foundation Blue Ribbon Committee report, "a host of technologies are on the horizon that we cannot hope to understand, develop, or utilize without simulation. Many of those technologies are critical to the nation's continued leadership in science and engineering. Clearly, research in [simulation-based engineering science] is quickly becoming indispensable to our country's security and well-being"[59] - identifying remedies to these existing disconnects between the scientific and judicial communities should be an interdisciplinary priority.

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[59] *Simulation-Based Engineering Science: Revolutionizing Engineering Science through Simulation, supra* note 52, at xiv. Swinehart similarly observes that, "Swinehart observes that, "Models have long been a part of the scientific community's methodological arsenal. However, in recent decades, their influence in science and policy has dramatically increased, due largely to the confluence of two distinct phenomena: the advent of computers and the rise of intricate and demanding environmental regulatory regimes." Swinehart, *supra* note 7, at 1284.

The various legal challenges presented by the increasing utilization of simulation-based analysis in policymaking, and the attendant issue of their consequent evidentiary value in related judicial proceedings, have been the subject of thoughtful analysis by legal academics. Swinehart offers a detailed exploration of how the *Daubert* standard might be reformulated to address the legal challenges presented by simulation science,[60] beginning with the premise that *Daubert* has failed to provide an adequate judicial rubric for evaluating model reliability. Swinehart asserts that the primary benefits of environmental models (which he identifies as the ability to demonstrate complex relationships, provide meaningful data frameworks, incorporate information from multiple disciplines, and explore new theories and refine existing paradigms) are offset by two fundamental flaws: uncertainty and an inherent lack of transparency.[61]

In light of the expertise- and comfort-related challenges that often limit judicial evaluation of simulation-based analyses,[62] Swinehart suggests developing an alternative framework for judicial assessments of models. Swinehart identifies two basic modes of evaluating models: first, inquire into whether the model's results are relevant to the question and compare the model results to any available empirical data for consistency; and second, examine the information that generated the model, including its theoretical underpinnings, the empirical

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[60] Swinehart, *supra* note 7.

[61] *Id.* at 1286-88, 1288-95.

[62] Judges often "lack the competence to evaluate modeling evidence satisfactorily. The limited scientific expertise, training, and education of judges make it difficult to determine an appropriate level of review at the evidentiary screening state… [and] drawing a line between good and bad models is often not an easy task, even for those with the relevant scientific expertise operating outside the adversarial context of litigation." *Id.* at 1299.

data base, and independence of the evidence supporting the model.[63] But, Swinehart notes, "while it appears that courts may be well suited to assess the qualifications of a modeling expert, it does not necessarily follow that courts are inherently adept at wading through the enormously complex – and often opaque – models themselves."[64]

Drawing on 2003 draft guidelines issued by The Council for Regulatory Environmental Modeling (subsequently finalized in 2009[65]), Swinehart proposes adopting a mandatory judicial screening checklist for evaluating simulation-based analyses: (1) is the modeler an expert in this particular methodology?; (2) was the correct model chosen?; (3) was the model applied correctly within its practical boundaries and theoretical limits?; (4) is the real-world system too complex to model?; (5) can conflicts of interest be mitigated?; (6) was the model sufficiently tailored to the model's inputs and the natural system's unique conditions?; (7) was all available empirical evidence considered?; (8) to what extent is the model meaningfully communicable to the jury?; and (9) how does the model contribute to the weight of the evidence?[66] Other proposed requirements are factual showings that the modeler considered alternative models, an explanation of why the employed model is the "best available", and consideration of governmental agencies' evaluations of models, such as EPA's ranking of certain models based on their statistical performance.[67]

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[63] *Id*. at 1299-1300.

[64] *Id*. at 1301.

[65] Council for Regulatory Envtl. Modeling, EPA, *Guidance on the Development, Evaluation, and Application of Environmental Models* (2009).

[66] Swinehart, *supra* note 7, at 1312-25.

[67] *Id*. at 1316-18. Swinehart also raises the criterion of peer review, which is recommended but not required by EPA. *Id.*

Similar legal concerns were subsequently explored by Wagner, Fisher and Pascual, who observed that, "despite their extraordinary influence on environmental policy, models are often created, refined, and deployed in the backroom, behind the curtain, only to be hauled out for critical attention when things go very wrong…confusion and even anxiety abounds within the regulatory sphere regarding the appropriate use and methods for assessing the reliability of models."[68]

Wagner, Fisher and Pascual posit that judicial evaluation of simulations would benefit from the expectation that "the documentation that accompanies a regulatory model should contain enough information about the underlying data, assumptions, and analytical approaches to allow an interested and objective stakeholder to assess the domain of the model."[69] However, Wagner, Fisher and Pascual note that "the modeling community has yet to establish a coherent, universally-shared set of guiding principles through which regulators and interested stakeholders can evaluate whether one model (or set of models) can be said to be more appropriate for a given situation than another."[70]

To improve judicial evaluation of simulation-based analyses, Wagner, Fisher and Pascual propose altering judicial review rules to ensure transparency of methods and assumptions and use of best practice guidelines, allowing agencies to revise and evaluate models in a continuous process, engaging both agencies and legislatures in the developmental phase of the modeling process, and communicating with modelers to ensure information and assumptions are shared

[68]Wagner, Fisher & Pascual, *supra* note 3, at 294-95.

[69] *Id*. at 309.

[70] *Id*. at 312.

between the two groups.[71] Under the rubric advanced by Wagner, Fisher and Pascual, "a coherent treatment of evidence in models would: (1) describe the assumptions underlying an inference; (2) justify why the assumptions apply to the circumstances on hand; and (3) explain how the inferences derive from the interplay between the assumptions and the evidence."[72]

Executive and agency have made efforts to increase the transparency and utility of simulation-based analyses, most notably by EPA in its earlier-referenced Guidance,[73] the National Research Council (NRC), and The Office of Management and Budget (OMB). A 2003 OMB circular acknowledged the growing role of simulation-based analysis and directed all executive agencies to conduct such analyses with greater transparency and to formally evaluate the techniques employed in their simulations.[74] A 2009 NRC report called for better models and better information about a model's limitations, pointing to the need for formal analyses of model uncertainties.[75] Ultimately, however, independent agency guidelines and reports will not be sufficient to provide the clarity needed. At a foundational level, interdisciplinary efforts will need to be undertaken to bridge language usage[76] and best available science and best model

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[71] *Id*. at 347-51.

[72] *Id*. at 352.

[73] *Guidance on the Development, Evaluation, and Application of Environmental Models*, *supra* note 64.

[74] Office of Mgmt. & Budget, *Circular A-4 on Regulatory Analysis* (2003).

[75] Comm. on Improving Risk Analysis Approaches Used by the EPA, Nat'l Research Council, *Science and Decisions: Advancing Risk Assessment* (2009).

[76] *See e.g.*, The National Judicial College discussing the Federal Judicial Center Reference Manual on Scientific Evidence and its consideration of "several words – evidence, theory, law, error, and mistake – that have very different meanings in law and science." *Supra* note 14, at 56.

practices across a wide range of fields, in order to fashion guidelines that have both evidentiary utility and scientific feasibility.[77]

III. Conclusion

Simulation-based science is already integrated into environmental policy formulation and decision-making across a wide range of agencies and natural resources. Regardless of the current limitations presented by the various disconnects between the scientific genesis of a simulation and the judicial treatment of that simulation in the context of a subsequent legal challenge, modeling and simulation science will only become more essential to environmental assessments, not less. It would be of evident benefit if the expectations and assessment tools for modeling currently used by the simulation-based science and judicial communities could align, such that there were clearer evaluative standards for use in judicial assessments of models, and thus greater consistency in judicial and agency decision-making. Such an enhanced alignment would not only serve to incentive more accurate and sophisticated simulation-based science, but would also aid lawmakers in maximizing the value of simulation tools in developing and administering environmental policies.

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[77] Wagner, Fisher, and Pascual propose that EPA take a lead role in such an effort: "Ideally, a comprehensive explication of uncertainties, assumptions, and model framing would be based on best model practices that apply across the scientific fields. Since this seems unlikely to occur spontaneously, however, we recommend that EPA continue to take the laboring oar – working with scientists – to develop principles for qualifying and explaining the assumptions in models; for exposing alternative scenarios and model approaches; and for clarifying whether the inferences made were consistent with the assumptions." *Supra* note 3, at 353.

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