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Decision Analysis and Joint Fact Finding
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The United States Geological Survey (USGS) has invested resources in investigating a number of different decision-making processes and decision support systems both through its Science Impact program and through individual research projects. The purpose of this memo is to explore and compare the two processes of decision analysis (DA) and joint fact finding (JFF) in terms of their origins; main assumptions and theoretical parameters; and current forms and uses. In so doing, it becomes evident that DA and JFF have distinct, though potentially complementary, approaches to problem solving. The most notable distinction between the two is that DA is designed as a rational model to support a unitary decision-maker while JFF recognizes decisions as being constantly negotiated and challenged, even in situations of clear authority. DA involves modeling probabilities of expected outcomes in a linear fashion while JFF involves organizing a multiparty negotiation over disputed scientific and technical information. Therefore, DA and JFF are not interchangeable processes; they serve distinct functions, involve different audiences, and produce distinct outcomes. There are, however, potential vehicles for the integration of DA within a JFF process or a JFF process within a DA model that should be further explored.

Origins of the fields

Decision Analysis is a field that emerged from the diverse disciplines of mathematics, statistics, economics, business, and psychology. The term was coined in 1964 by Stanford University professor Ronald Howard. It builds from the logic of game theory and relies heavily on probability to explain, predict, and weight decisions on complex problems. It also has antecedents in military operations research, which involves making decisions under situations of great complexity or incomplete information (Raiffa 2002). One could characterize decision theory or decision analysis as having three main sub-fields: multiattribute utility analysis, cost benefit analysis, and social choice theory. In each of these, a rational analyst attempts to take into account all relevant information, build it into a model, and determine the best decision. Utility analysis compares expected utility of different outcomes for different stakeholders, whereas cost benefit analysis expresses the different outcomes in terms of money, and social choice theory ranks but does not give integer values to preferences (Susskind, personal communication). But this is just one way of dividing the broad intellectual terrain of DA. One can also see discreet differences in the fields of probability assessment, utility assessment, and game theory/competitive decision-making (von Winterfeld and Smith 2004).

Bell et al (1988) categorized decision analysis research as being either normative (like the work of Neumann and Morgenstern on game theory and economic behavior), descriptive (such as the psychological work of Kahneman and Tversky on heuristics), or prescriptive. Smith and von Winterfeld expand upon Bell's classification in their 2004 review of DA publications in the journal *Management Science*.[1] Normative research builds from certain axioms to provide logical

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[1] This review provides an excellent introduction to the history of DA publications in a particular journal. The authors recommend that for further current and historical research on DA, one should consult the following journals: *Management Science, Operations Research, Decision Analysis, Organizational Behavior and Human Decision*

guidance in decisionmaking. Descriptive work lies largely in the realm of psychological theory and experimentation, building from the empirical observation of how humans actually behave and make choices. Prescriptive decision analysis work is that which implements DA and recommends a particular course of action. It is normative but also recognizes the limitations and realities of human judgment in real time. Logically this is the strain of work that is most relevant to public policy writ large and environmental management specifically and is the branch of DA being most closely explored by USGS.

Like all fields, DA has evolved in many ways. As noted above it has developed discreet sub-disciplines of scholarly research, but it has also deepened over time. DA contains underlying principles dating back to the 18th century in the work of Bernouilli and Bayes as well as to the writings of Kant and Bentham (Smith and von Winterfeldt 2004; Susskind, personal communication). Despite these deep roots, DA emerged as a field for the most part in the 1940s and burgeoned throughout the 1960s. The seminal text of its time was Howard Raiffa's *Decision Analysis: Introductory Lectures* (1968). The field tapered off somewhat in the 1980s and 1990s in terms of research written on DA. This tapering off, however, may simply be a function of the diversification of the field. DA has also been incorporated into practice in a number of unique ways and continues to be a vibrant field of research.

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Negotiation is as old as human interaction itself, though the contemporary study and scholarly research on the subject has emerged in a similar timeframe to that of decision analysis. Ancient Greeks discussed the relationship between government, science, knowledge and decisionmaking (Rich and Oh 2000). That relationship has undergone massive changes, particularly in the last fifty years in the United States; there has been an upsurge in public desire for participation in decision-making, including scientific decision-making (Sarewitz, 1997). There are both pragmatic and rights-based reasons for expanding the sphere of decisionmaking to include citizen stakeholders and not just agency "technocrats." Demands for participation and due process grew from disparate movements including the civil rights movement and the environmental movement, coalescing in the 1960s and 70s. Not coincidentally, it was during this time of strong social movements and heightened public awareness that most of the country's core federal environmental regulations and regulations affecting participation, like the Federal Advisory Committee Act and the Freedom of Information Act, were created. Laws like the National Environmental Protection Act (NEPA), "never intended to be the overarching structure for public involvement, [have] become the basic template for agency actions in many cases" and frame the way in which agencies and citizens interact, forcing federal agencies to adapt (Wollondeck and Yaffee, 2000: 243).

The limitations of NEPA, particularly in its ability to manage complex and controversial projects, have become apparent and have raised the issue of what constitutes meaningful involvement in environmental decisionmaking. Public input in NEPA generally consists of a scoping phase and a later public comment period on the Environmental Impact Statement that the managing agency can either choose to take into account or not; which can hardly be considered more than token involvement and is not a means for fostering democracy (Arnstein 1969; Peyser, 2003; Jasanoff, 1996). Critics state that the current approach to meeting the letter of the NEPA

Processes, the Journal of Behavioral Decision Making, The Journal of Risk and Uncertainty, Theory and Decision, and the Journal of Multi-Criteria Decision Analysis.

law is not well suited to manage and promote citizen involvement, particularly given the length and technical complexity of EISs. Furthermore, legal tactics are a costly response to some of the most high profile and contentious cases, although these comprise just .2% of all the 50,000 filed EISs. The Task force on Improving NEPA of the Committee on Resources of the House of Representatives found that "litigation has shaped the meaning and applicability of NEPA" through the ripple effect of making agencies "more cautions, but not necessarily more deliberative, in issuing NEPA documents" (2005, 11-12). Without denying the instrumental role of (and the right to) legal action, groups of stakeholders and agencies are realizing that the adversarial science involved in a lengthy court case is a drain on resources and may have unintended consequences (Wollondeck and Yaffee, 2000). Furthermore, even in undisputed cases, the costs of NEPA compliance are rising and the timelines are lengthening (HOR NEPA Task Force 2005, 18, 21).[2]

The need for functional public participation in environmental issues spans all scales, from regions and water basins to municipal and even site-specific concerns. Yet, agencies are still struggling with the challenges of successfully managing scoping and public comment, let alone more innovative collaborative practices. The House NEPA Task Force found,

> "In fact, public participation reduces the amount of controversy associated with Federal projects….When stakeholders, including project proponents, may be excluded from deliberations during the NEPA process, the result is inevitably more appeals and litigation…. [A]gencies must be responsive to public comments in some meaningful way. If they are not, it will erode confidence in NEPA's public comment requirement and thus degrade the importance of the Act" (2005, 22-23).

A second wave of change that goes beyond one-way communication towards real collaborative decision-making has been taking place. Consensus building and collaborative decision-making has been introduced in response to crises that necessitate change in the status quo and through the creation of innovative new institutions that bring stakeholders to a common table (see, for example, the Northwest Power Planning Council case in Lee 1993).

Different forms of collaboration are appropriate to disputes over management and disputes over science, though these two issues are often largely intertwined. In terms of addressing the later, agencies recognize the need for credible science that is reputable by the highest standard, salient science that is policy-relevant, and legitimate science that is trusted and generated in a transparent manner to support participation and inform decision-making (Cash et al., 2003). Sheila Jasanoff notes that information exchange alone will not generate solutions to complex

[2] A number of distinct efforts have attempted to evaluate and improve upon NEPA mandated processes, including the Council on Environmental Quality's NEPA Modernization Task Force, which issued its final report in September 2003, and the aforementioned House of Representatives Task Force, which issued a draft report in December 2005. Given that NEPA has only been amended twice in its 35 year history and there is a great degree of institutional inertia to changing the law, these efforts cover a broad spectrum of issues related to NEPA, with interagency collaboration and public participation featured prominently (HOR NEPA Task Force 2005). A full review of the work and publications of these groups is beyond the scope of this report. It is taken simply as an indicator of the non-consensus on the sufficiency of existing regulatory frameworks in complex problems of ecosystem management.

environmental problems, rather institutions of community and trust are also required to move towards collective action (1996). Joint fact finding is a subset of collaborative decision making processes. It responds to the classic conundrum of *dueling scientists* or *adversary science* and "is particularly useful in disputes in which parties interpret data and information differently, or where there is a great deal of scientific uncertainty" (Ehrmann and Stinson 1999, 383). While DA struggles over how to weight and take into account the opinions of experts that disagree, JFF provides a forum for those experts to negotiate and expose their work to public scrutiny.

Main assumptions and theoretical parameters

According to USGS scientist Jim Coleman, DA is a process that enables the end user of data to ask questions of a model and give a scenario where the questions and conditions translate to a result that is bounded by probabilities or uncertainties of each input. This essentially describes the way in which DA is intended to work; as a support device for the decisionmaking process of a rational and unitary actor. Differing opinions can be brought into the model, but they are filtered through the weighting process of the creator of the model. The success of a model is dependent upon the accuracy of the information and the probabilities being put into the model, and that in and of itself is a judgment. Other limitations include the real cost and time cost of including every larger amounts of information in a model. So, while DA makes strides towards incorporating all available information into a decisionmaking process, there are still a number of tacit subjective judgments that go into the creation of any model.

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JFF assumes that in science-intensive policy disputes, contending interests seek to manipulate scientific advice to provide a rationale for the decision they prefer. This most frequently occurs when scientists disagree. In their analysis of mediation in science-based policy disputes, Ozawa and Susskind (1984) found that disagreement among scientists generally arises at two key points in a policy debate: scientists may disagree on the significance or implications of available evidence; or they may disagree on the scientific evidence itself. The act of exploring many possible options in a systematic way helps diverse factions develop a shared understanding of the underlying assumptions, methods for analysis and scope of scientific uncertainty (Andrews 2002.) JFF represents a collaborative decision-making process[3] that is designed to deal with science-intensive policy disputes and is distinguished from other

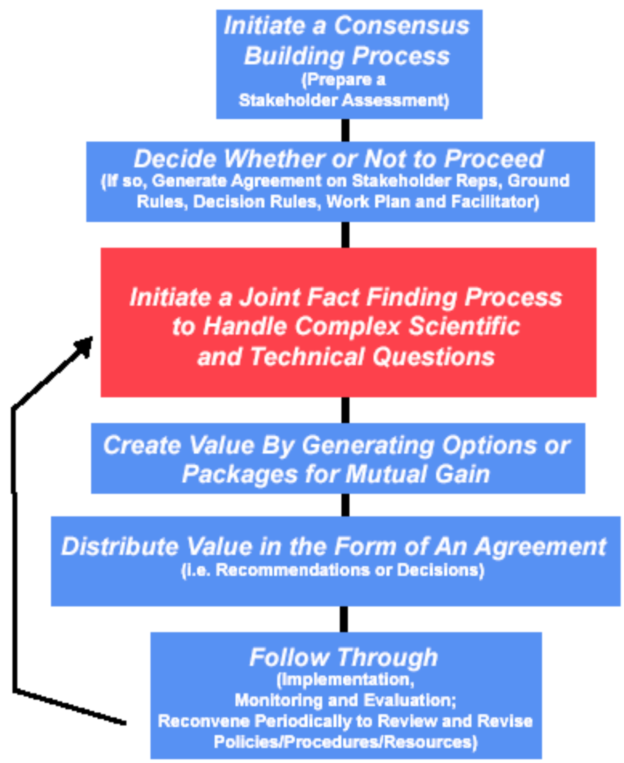

Figure 1: Joint Fact Finding in the Consensus Building Process
Source: Consensus Building Institute, 2002

[3] For more background on the spectrum of strategies encompassed under collaborative decisionmaking, refer to the MIT-USGS Science Impact Collaborative Open File report of May 2005, which provides both description and cases.

collaborative processes by a few, simple criteria. The process: 1. is neutrally facilitated; 2. uses consensus for decision-making; and 3. has a goal of creating a single text that is ratified by participant's constituencies. It is important to note that JFF is seen as one step of technical negotiation in a multi-step negotiation process that also deals explicitly with values, interests, and has a goal of building consensus (see figure 1, right).

Current forms and uses
Decision analysis has been broadly applied in diverse sectors, including the military, business/management, health care[4], and natural resource management (Raiffa 2002). DA can take multiple forms, but one useful division is between decisions under certainty and decisions under uncertainty. In the former situation, Raiffa et al recommend the following steps for good decisionmaking, "specifying the problem or opportunity; examining objectives (interests); formulating creative alternatives; conditionally evaluating consequences on some evaluative objectives; and grappling with tradeoffs." In the latter situation of uncertainty, one must compare the expected monetary value, expected desirability value, and expected utility value to choose among competing risk profiles (Raiffa et al 2002).

For the purposes of narrowing the scope of examination in this memo, I focus here on how DA has been described and tested within the USGS. Currently, Coleman is conducting research on the use of DA with respect to the release of Selenium into the environment due to Mountaintop Removal Mining in West Virginia. This multiyear project is ongoing and slated to complete in mid-2006, with dual goals of both understanding the flow of Selenium in stream valleys and of understanding DA as a process for decisionmaking. The team believes that if accurate information is put into the model, it will be able to assist decisionmakers in choosing whether or not to mine in a particular stream basin based on all of the aggregate potential costs and benefits. Thus it is a tool to be used in natural resource management and scenario planning.

Coleman's team has mapped the flow of Selenium "from rocks to water to birds to people" and is including all of the social, economic, human and environmental health impacts of the mining practice into their model. Jaye Lunsford of the USGS Environmental Affairs Program argues that an inherent strength of DA lies in its ability to assimilate different kinds of costs and benefits. Whereas a typical EIS process describes environmental, social, and economic costs and benefits separately and then chooses an alternative based on some opaque tradeoff, DA makes those tradeoffs explicit and transparent. Coleman's team constructed a linear model that contains geologic, hydrologic, biologic, and toxicologic data; to achieve this they have partnered with a number of scientists from different disciplines with USGS as well as partners in the West Virginia DEP and are working with the GIS and visualization firm Geomatrix. There has been some level of stakeholder and proxy stakeholder participation in the development of the preliminary and final models. Diverse scientists, end users, and one USGS scientists acting as a mining company proxy were asked to give input on the model which was then adjusted and refined. This is an important step that goes beyond the bare minimum of DA-model building to include the expertise of multiple stakeholders, thereby bringing DA into the realm of negotiation.

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[4] Indeed, upon conducting generalized searches for "decision analysis" in online databases like ProQuest, a majority of the listings were medical or health related.

Coleman noted that he has not thought about how DA would work "in a nonlinear fashion" if all experts and stakeholders converged in one place. Although his team did invite some consultation on the model, participation was restricted to scientific experts. Coleman was not certain of how a DA process could work with the inputs of laypeople. He believed, however, that there was a benefit simply in making this information available and transparent, so that stakeholders can see the data and the relationships that went into the model. In theory, complex models can be built that include the input of multiple stakeholders. William Kendall explains,

> "When more than one model of system dynamics is considered, management will be based on an average of dynamics predicted by each of the competing models. This averaging process requires some weighting factor or measure of relative model credibility….By updating these model weights based on how well each model predicts the impact of an implemented decision on the system, these model weights provide a metric for learning which model has the best predictive ability as the decision process iterates....[and] knowledge of the system will increase" (20001, 162).

While a useful process of learning for seeing which stakeholder held the best model of reality, the iterative process described by Kendall does not address how the initial weighting would be conducted. Likely, it would either be a unilateral decision (made by the head of the study) or would be a negotiated process (or a form of JFF). .

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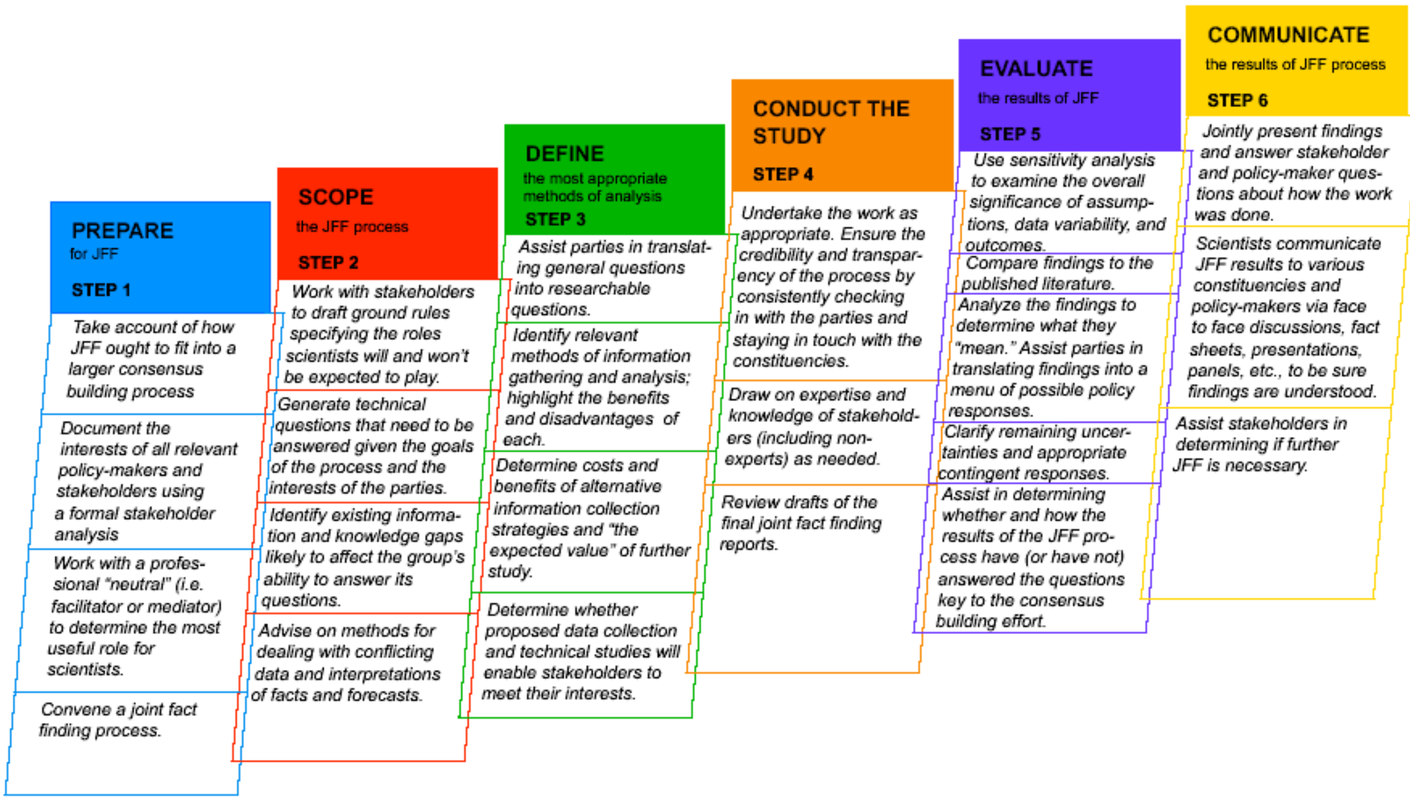
Negotiation, and specifically consensus based decisionmaking, has been applied in diverse fields from the debate over indigenous land claims, to fisheries and forest management, to energy production and NIMBY facility siting, to name a few. Consensus building is used both in diverse disciplines and at multiple scales, from the very informal grassroots scale, to citizen advisory bodies, to national and international policy fora. The Department of Interior (DOI) has placed a priority on collaboration through its "Four Cs" philosophy of "conservation through communication, consultation and cooperation" that has now spread to include other agencies as well (DOI, 2004a; Hess, 2004). Indeed, DOI has over 200 employee training courses with "collaboration" in the title (Whitley, 2004). In JFF all relevant actors—stakeholders, decision makers, and scientific and technical experts—undergo joint study and/or research to address a resource management consideration or dispute. The JFF structure allows for "space" in the process for competing scientific narratives and local knowledge, given the open exchanges of information among all stakeholders (scientific and non-scientific), and can be used as a tool to promote collective learning. The joint fact finding process is guided by a professional neutral who helps to establish a process framework and facilitates the flow of information and exchange. JFF processes tend to be sustained over time and have clear ground rules and common objectives (Ehrmann and Stinson 1999).

In general, a joint fact finding process involves four primary groups of actors, though other subgroups may also play a role. First, a decision-making body serves as the "convener" of the JFF process. Second, a neutral facilitator that is not tied to any particular side helps establish a basis of trust and guides the process. Third, stakeholders, including environmental groups, industry representatives, and community organizations, provide viewpoints based on their interests and relationship to the issue. Stakeholders also often bring local knowledge and understanding to the process. In cases where decision makers, scientists, and experts have a stake in the issue, they also may be included as part of the stakeholder group. Finally, a joint fact finding process includes scientific and/ or technical experts. Although JFF is malleable and can exist in multiple forms, it is useful to think about how the process might proceed in phases. The six steps of JFF are illustrated in figure 2. Finally, it is worth reiterating that this negotiation over "the facts" must necessarily be embedded within a negotiation over management.

Figure 2: Key Steps in the JFF process
Source: Consensus Building Institute, 2002



MUSIC has distinguished between two distinct types of JFF: deliberative analysis and collaborative research. Deliberative analysis is a negotiation of experts over *existing information* whereas collaborative research involves the *co-production of new information.* In the latter, the joint body itself or a jointly selected study team collaboratively scopes, conducts, and evaluates novel research on the problem at hand. This function of producing new knowledge, rather than simply using existing knowledge to advise a management decision, is another key distinction between JFF and DA.

Integrating DA and JFF
There is an interesting convergence in the real world application of DA and JFF. DA, on its own, does an excellent job of producing recommended management steps, but does a poor job of dealing with dissention in the science. If DA is nested within a collaborative process where multiple scientists and other stakeholders give inputs to the model and the weights within the model, the process could become more robust. It appears that taking DA is being taken to this next level of collaborative process by consulting firms like Geomatrix. Raiffa himself has discussed the linkages and overlap between all different types of decisionmaking, from two

player games to multiparty negotiation, in his 2002 book *Negotiation Analysis: The Science and Art of Collaborative Decision Making*. Given that there is also a wealth of applied knowledge on collaborative decision making, it would be productive for DA consultants to bridge with experienced environmental mediators and specialists in conflict resolution (e.g the roster of mediators at the U.S. Institute for Environmental Conflict Resolution). The careful management of a contentious dispute is no less technical of a skill than the creation of a systems model. Vehicles for further exploration of this link are the USGS Science Impact program and the Department of Interior's Office of Collaboration and Alternative Dispute Resolution.

Similarly, JFF does an excellent job on its own of confronting and reconciling disagreement in the science, but does not necessarily produce management recommendations. It, too, as noted in figure 1, must be nested within a multi-stakeholder consensus-building process. This assumption is made explicit in the literature on JFF, but there is a need for further research to see if this is how JFF is being implemented in practice. MUSIC has ongoing case-based research that it is sharing publicly via the Collaborative Decision Making Inventory on its website at http://scienceimpact.mit.edu.

Given the current state of the two fields, there appear to be a few possible ways in which JFF and DA could be incorporated within as approaches to a single dispute/decision. First, one could use a DA model as a jumping-off point for discussion within a JFF process. This approach would help to initiate dialogue in a JFF and perhaps give structure to the discussion. Second, one could use the scientific outputs from a JFF to plug into a DA model, allowing for commonly agreed upon weights and probabilities to drive the model, in a refined version of the process that Kendall describes. Alternatively, if there was an opportunity for investigation of parallel but distinct JFF and DA processes on the same issue, it would point to the differences and synergies between these two approaches in terms of process, output, and outcomes.

Finally, it should be noted that the complexity and dynamism of ecosystems present a major challenge to any decisionmaking process that is held at a particular moment in time. Scholars and practitioners have levied criticisms about the insufficiency of our existing systems models as aids in truly practicing ecosystem management. Kai Lee stated, "models of natural systems are rarely that precise or reliable. Their usefulness comes from their ability to pursue the assumptions made by humans—assumptions with qualitative implications that human perception cannot always detect" (Lee 1993, 61). While we know how to optimize the yield of one resource (say, board feet of timber harvested or hydroelectric power from a dam) over some discreet amount of time, our western, scientific knowledge is not complete enough to manage for multiple ends over the truly long term. As such, JFF should be nested within a long-term consensus building process that is able to continue to respond to changes in the environment. And practitioners of DA must display a willingness to alter models and to recognize that the answer provided at one moment in time may not be unilaterally applicable. Ideally, one would link consensus building processes with adaptive management, which consists of interventions into the landscape that are treated as experiments to promote learning and better management. MUSIC has already begun to explore the natural links between JFF and adaptive management and it is important to understand whether and how DA professionals see a synergy with adaptive management.

Works Cited

Andrews, Clinton. *Humble Analysis: the Practice of Joint Fact Finding.* Westport: Praeger Publishers, 2002.

Arnstein, Sherry. "A Ladder of Citizen Participation." *American Institute of Planners Journal.* July 1969. 35.4:216-224.

Cash, D., Clark, W., Alcock, F., Dickson, N., Eckley, N., Guston, D., Jager, J. and Mitchel, R. in press, "Knowledge Systems for Sustainable Development" Proceedings of the National Academy of Science. 8 July 2003. 100.14:8086-8091.

Coleman, James. Phone interview, 18 Nov 2005.

Ehrmann, John and Barbara Stinson. "Joint Fact-Finding and the Use of Technical Experts." In *The Consensus Building Handbook,* Susskind, Lawrence, Sarah McKearnan, and Jennifer Thomas-Larmer, Eds, pp. 375-399, Thousand Oaks, CA: Sage Publications, 1999.

Jasanoff, Sheila. "The Dilemma of Environmental Democracy." *Issues in Science and Technology*. Fall 1996. 13.1:63-71.

Kendall, William. "Using Models to Facilitate Complex Decisions." *Modeling in Natural Resource Management*: *Development, Interpretation, and Application*, Shenk, Tanya and Alan Franklin, Eds., Washington, DC: Island Press, 2001.

Lee, Kai. *Compass and gyroscope: Integrating science and politics for the environment.* New York: Island Press, 1993.

Lunsford, Jaye. Phone interview, 10 Feb 2006.

NEPA Modernization Task Force of the Council on Environmental Quality. "Modernizing NEPA Implementation." Sept 2003. http://ceq.eh.doe.gov/ntf/report/index.html (14 Feb 2006).

Ozawa, Connie and Lawrence Susskind. "Mediating Science Intensive Policy Disputes" *Journal of Policy Analysis and Management,* 5,1, 1984.

Raiffa, Howard. "Decision Analysis: A Personal Account of How it Got Started and How it Evolved." *Operations Research*, Jan/Feb 2002, 50, 1: 179-245.

Raiffa, Howard with Richardson, John and David Metcalfe. *Negotiation Analysis: The Science and Art of Collaborative Decision Making.* Cambridge, MA: Belknap Press of Harvard University Press, 2002.

Rich, Robert and Cheol Oh. "Rationality and Use of Information in Policy Decisions." *Science Communication*, Dec 2000, 22, 2: 173-211.

Sarewitz, Daniel. “Social Change and Science Policy.” *Issues in Science and Technology.* Summer 1997. 13.4:29-33.

Smith, James and Detlof von Winterfeldt. “Decision Analysis in *Management Science*.” *Management Science*, May 2005, 50, 5: 561-574.

Susskind, Lawrence. Personal communication, 7 Jan 2006.

Task Force on Improving the National Environmental Policy Act of the Committee on Resources, United States House of Representatives. “Initial Findings and Draft Recommendations.” 21 Dec 2005. http://resourcescommittee.house.gov/nepataskforce/report/nepareport_finaldraft.pdf (14 Feb 2006).

Whitley, Rich. Lecture to “The Role of Joint Fact Finding in Environmental Decision-making”, Massachusetts Institute of Technology. Cambridge, MA. 5 Oct. 2004.

Wollondeck, J.M. and Yaffee, S.L. *Making Collaboration Work: Lessons from Innovation in Natural Resources Management.* Washington, D.C.: Island Press, 2000.