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Title: Technology and Meaning in Natural Resource Management: The Story-Making Role of GIS in the CLAMS Project

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The working hypothesis for this study is that the introduction of GIS technology into the ancient procedures of map-making has changed the map-making context sufficiently to require a revision of the way we think about, learn from, and use maps, specifically in the public involvement process in natural resource management. The assumption that we jointly know what maps mean, and how to use them, has been carried unchallenged into the vastly changed arena of digital, information-dense, and highly technical map-making, courtesy of Geographic Information Systems (GIS). It has remained unchallenged even as the social context for environmental policy-making is undergoing historic upheaval.

GIS fundamentally changes how information is viewed, literally, by many different groups, for its maps and databases contain varying levels of uncertainty, multiple embedded assumptions, potentially privileged knowledge, and considerable power as story-makers, along with unintended and unexplored social consequences. GIS maps/databases are used here as the central refractor of ideas about relationships

between scientists and lay audiences; between the post-modern understanding of privilege and social change; and ultimately between technology and meaning, where changing expectations about the role of science in natural resource management resonate most profoundly.

Key research questions are: (1) How can GIS maps contribute to mutual learning in the natural resource management arena?, and (2) Which consequences of GIS development could change approaches to natural resource management? The exploratory case study used to address these questions examines GIS maps from the Coastal Landscape Analysis and Modeling Study (CLAMS), a landscape-scale bioregional assessment in western Oregon that draws heavily on GIS technology to illustrate ecological and socioeconomic dynamics and interactions.

Findings suggest that use of GIS through time may change the realm of designing and structuring decision problems, adjusting it from a largely science-driven exercise in natural resource management to a more collaborative story-making one. While epistemological differences between scientists and lay audiences remain, they can be offset through such collaboration, with concomitant shifts in power structures that could affect a range of conditions including rates of technology diffusion, and management of a broad transition in how natural resources are perceived and utilized.

Technology and Meaning
in Natural Resource Management:
The Story-making Role of GIS in the CLAMS Project

by

Sally L. Duncan

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Sally L. Duncan, Author

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 1
Of Meaning and Maps 2
CHAPTER 2: LITERATURE REVIEW 6
Introduction 6
Considering Theoretical Frameworks 7
Revolutions in Science and Environmental Thought 10
Logical Positivism and the Quest for Truth 15
Images of Science and Scientists 19
Unfolding Scientific Controversy 22
Changing Acceptance of Science Findings 24
Cultural and Institutional Barriers 25
Across the Language Barrier 28
How do we Process Information? 31
Across the Larger Landscape 34
Whose Truth Prevails? 39
GIS as Communication Device: Peril and Promise 42
Technology on the Move 46
Mapmaker, Mapmaker, Make me a Map 49
Natural Resource Decisions at a Crossroads? 53
The Rest of the Story 55
CHAPTER 3: METHODOLOGY 57
RESEARCH DESIGN 57
- Qualitative versus Quantitative 59
- Case studies 61
- Surveys 64
- Mental Mapping 66
- Focus Groups 69
- Content Analysis 71
- Research Design Steps: 73

TABLE OF CONTENTS (Continued)

1. Web-site Survey 73

2. 2002 Workshop 75

3. Mental Mapping 76

4. Focus Groups 79

5. Pre-test, Post-test, with Control 80

CHAPTER 4: RESULTS 83

I. WEB-SITE SURVEY 83

II. 2002 WORKSHOP 89

Confidence Levels: questions of validation and reality 91

Tool of Inquiry: the science 93

Decision-making: the potential policy tools 95

Public Education: the spread of ideas 97

III. MENTAL MAPS 100

Composite Map #1: Scientists 101

Composite Map #2: Non-scientists. 108

Map #3: Manager/agency 113

Map #4: Economist/social researcher 117

All maps: summary 120

IV. 2004 WORKSHOP: FOCUS GROUPS 121

The Clash of Epistemologies 126

Effects of Alternate Story-Making 135

Shifting Learning Goals 140

Process as a Tool of Change 146

System Adjustment: Facing the Consequences 149

V. PRE-TEST/POST-TEST SURVEY 152

Control Group 153

Workshop group 155

CHAPTER 5: DISCUSSION 163

I. WEB-SITE SURVEY 163

TABLE OF CONTENTS (Continued)

II. 2002 WORKSHOP 166
III. MENTAL MAPS 169
IV. 2004 WORKSHOP: FOCUS GROUPS 172
V. PRE-TEST/POST-TEST SURVEY 175
VI. PATTERNS 178
i. Trajectories of change 178
ii. Story-making 181
iii. Clashing epistemologies 181
iv. Learning about learning 182
v. Responsibility and knowledge 183
vi. Balance points 184
vii. Interrupting the scientific method 185
viii. Unintended consequences 186
CHAPTER 6: CONCLUSIONS 188
1. Fading of espistemological problem. 188
2. New knowledge communities. 188
3. Potential system adjustments. 189
4. A new phasing stage in technology diffusion. 190
5. Retrieving the power of story-making. 190
6. Implications for studying science and society 191
7. The movement from structure to meaning. 191
BIBLIOGRAPHY 193
APPENDIX A: CLAMS WEB-SITE SURVEY 202
APPENDIX B: PRE-TEST, POST-TEST SURVEY 207

LIST OF FIGURES

Figure | Page

1. Research design for CLAMS/GIS case study 58
2. Composite map/map makers. 102
3. Composite map/map users.. 109
4. Manager map. 114
5. Economist/social scientist map.. 118
6. Preliminary coding. 123
7. Themes in Content Analysis.. 125

LIST OF TABLES

Table Page

1. Responses to web-site survey Question 4. 84
2. Responses to web-site survey Question 5. 85
3. Responses to web-site survey Question 6. 85
4. Responses to web-site survey Question 8. 86
5. Responses to web-site survey Question 9. 87
6. Responses to web-site survey Question 10. 87
7. Responses to web-site survey Question 11. 88
8. Summary of node clusters and key questions from 2002 workshop. 90
9. Potentials for change, 2002 workshop 99
10. Content analysis codes, 2004 workshop 127
11. Interaction between consequence clusters and content analysis themes. 151
12. Control group responses pre- and post-test, questions 5-7. 154
13. Question 5, pre-test/post-test comparison. 156
14. Question 6, pre-test/post-test comparison. 158
15. Question 7, pre-test, post-test comparison. 160
16. Question 8, Pre-test, post-test comparison 162
17. Database characteristics 180

TECHNOLOGY AND MEANING IN NATURAL RESOURCE MANAGEMENT: THE STORY-MAKING ROLE OF GIS IN THE CLAMS PROJECT

CHAPTER 1: INTRODUCTION

Picture a small meeting room in a rural town in western Oregon. Two scientists, one from Oregon State University, one from the USDA Forest Service Pacific Northwest Research Station, are presenting ecological findings about the Oregon Coast Range in a project called CLAMS to a group of local people. Some of these people have had sawdust on their boots since they could stumble on short legs into the woods with their grandfathers. Others are local administrators, forest industry activists, or well-read homemakers. Only one in the small audience is a trained scientist.

The CLAMS scientists offer their preliminary conclusions. Their medium is GIS maps, some of which project ecosystem processes and their effects across the next one hundred years. In question time, it starts.

Why do you base your science on falsehoods? Who's paying for this project? Why do you try to force us to accept your values? Why doesn't your science reflect our reality? Why can't you agree among yourselves on the right answer? And concerning the science findings themselves: So what?

Embedded in the list of questions, compiled almost verbatim from an actual meeting in Philomath, Oregon, in the late 1990s, is all the stuff of the well-known but not well-understood communication gap between scientists and practically everyone else.

There is the tension between professional expertise and democratic governance, between the well-established technocracy and the rudimentary power and appeal of "civic science." There is the specter of that terribly messy requirement of most environmental legislation: public involvement and collaborative decision-making. There is the challenge to several centuries of logical positivism and its strict tenets of investigative method, by postmodern ideas proposing the validity of multiple ways of knowing. There is nose-thumbing at long-established authority structures, tied directly to a long-festering failure of trust between technical experts and the public.

And hovering over it all, something much simpler and yet more overwhelming: the invisible problem posed by a common language. When you say "ecosystem" do you mean what I mean? When I say "sustainable" what do you hear? And, startlingly, when we each say "map," could we possibly be at cross-purposes?

Of Meaning and Maps

> "Like the universal fascination with moving water, or the dance of a fire's flame, maps hold some primal attraction for the human animal." (Aberley 1993)

> "Maps break down our inhibitions, stimulate our glands, stir our imagination, loosen our tongues. The map speaks across the barriers of language..." (Robinson and Petchenik 1976)

Primal attraction and stimulated glands aside, the assumption that maps cross the barriers of language is deep-seated. When The Nature of Maps (Robinson and Petchenik 1976) was published, mapping had not yet been assailed by the techniques of Geographic Information Science (GIS). It was still a supportable argument that maps were indeed so broadly understood that they breached linguistic barriers, that they were effectively universal social icons.

But is this still the case? In the current study the working hypothesis is that the introduction of GIS technology into the ancient procedures of map-making has changed the map-making context sufficiently to require a revision of the way we think about, learn from, and use maps, specifically in the public involvement process in natural resource management. It is apparent, not least in exchanges such as those quoted here, that we all still assume we jointly know what maps mean, and what they do, and how to use them. This assumption has been carried unchallenged into the vastly changed arena of digital, stunningly information-dense, and highly technical map-making, replete with new levels of uncertainty and assumption. And it has remained unchallenged even as the social context for environmental policy-making is undergoing historic upheaval.

Given that much is coming to be expected of GIS maps—as flexible displays of huge natural resource databases, as purveyors of technical information to non-technical audiences, as untried bridges between rival epistemologies, as proxy storytellers—they represent a useful focal point for considering matters of science, natural resource management, and public involvement. In that capacity, they have been used as the central refractor of ideas for this study, in the full knowledge that other technologies could be just as important. GIS, however, brings with it a clear change in how information is viewed, literally, by many different groups.

Until we can be comfortable with the levels of uncertainty and the multiple assumptions embedded in these maps, from the production technology itself to the range of indices selected for any given layer, they could continue to obscure as much as they illuminate. Until we comprehend their unintended social consequences and gauge their unexplored social potentials, we cannot know whether they are more likely to become political tools or a liberating technology.

Key research questions, therefore, are:

- How can GIS maps contribute to mutual learning in the natural resource management arena?
- Which consequences of GIS development could change approaches to natural resource management?

Arrayed around these two questions are others that will help uncover the relevant issues: What does "understanding" and "using" these maps mean to mapmakers (typically scientists) and map users (typically, but not always, non-scientists)? How does this relate to mutual learning? What role does technology and its diffusion play in changing communications between scientists and non-scientists in natural resource management? What role do the emerging properties of public interaction—power relations, trust, epistemological barriers, social change issues—play between these two groups? Does the power of personal meaning ultimately trump the power of social structure?

These questions, taken together, suggest a re-examination of GIS maps, their meanings, and their effect on the people who produce them and use them. With clear intentions and the right support, GIS maps might become a productive medium for mutual learning, for combining and reconsidering multiple ways of knowing about landscapes and ecosystems. Further, they may move into the realm of designing and structuring decision problems; to date their utility is largely founded on visualizing evaluation results, typically a science-driven exercise (Jankowski, Andrienko, and Andrienko 2001; Casner 1991).

The exploratory case study used to address these questions examines GIS maps from the Coastal Landscape Analysis and Modeling Study (CLAMS), a landscape-scale bioregional assessment that draws heavily on GIS technology to illustrate ecological and socioeconomic dynamics and interactions. CLAMS encompasses the Oregon Coast Range Province, a 5-million acre area stretching from the northern border of Oregon, almost to its southern border with California, and west from the crest of the Coast Range to the Pacific Ocean. Combining data collection from remote sensing and field plots, the CLAMS science team has developed multiple models, and displays much of its data in the form of GIS maps.

As an anticipatory bioregional assessment (projecting potential outcomes of various management policies out as far as 100 years), the CLAMS project provides a unique opportunity to examine the utility of an emerging technology as it is coupled to an emerging resource management philosophy. A CLAMS principal investigator has noted, "We have hit the wall in terms of pushing our spatial analysis into the public policy arena until we work out the understandability and usability issues surrounding our maps and tools."

The case study is designed to illuminate potential mis/understandings and mis/uses of GIS maps as presentation devices and communication tools in public settings. For the purposes of the study, "scientists" are defined broadly as those who actively engage in ecological or social research, advise resource managers on the interpretation of science, or have appropriate scientific qualifications (Lach et al. 2003). In the case of CLAMS, scientists, exclusively, are the map makers. "Non-scientists" are also broadly defined, as those who either do not have such scientific qualifications, or are not routinely pursuing scientific inquiry, but are attentive to natural resource issues, whether in a professional or lay capacity. For CLAMS, these are the map users. This division of labor, a component of the movement towards public interaction in natural resource decision-making, offers a simplified gauge of the social assumptions that have until recently informed both map-making and natural resource management.

For the purposes of this study, the references will predominantly be to "map makers" (generally the CLAMS scientists), and "map users" (generally non-CLAMS people, most of whom are non-scientists by the definition given). Where scientists and non-scientists are otherwise mentioned, it is in a more general sense, not specifically referring to CLAMS.

"Public interaction" here covers the range of formats in which scientists and non-scientists converse about the scientific issues in natural resource management: formal or informal meetings, presentations or conversations, one-on-one to much larger groups. "Mutual learning" here refers to the multi-directional exchange of ideas and interpretations of scientific information, ideally with the outcome of developing further inquiry in a collegial atmosphere.

CHAPTER 2: LITERATURE REVIEW

Introduction

In undertaking this study, a number of fields of literature offer productive insights. First, social studies of science help explain the journey science and scientists have taken to arrive at today's changing roles in policy-making and the public interaction that often precedes it. It will be argued that the nature of scientific controversy in history teaches us something about the power of the scientific method through the ages, and how its imposed rules of investigation have shaped the way we think and our notions of what is truth in nature. However, as it has crossed from the worlds of art and architecture to the study of the social and natural sciences, postmodern thinking has turned much traditional thinking on its end, and contributed to the shifting status of the scientist. For example, are the questions and inquiries of scientists more, or less, valid than those of the people who live, work, or play on the resource lands they study?

The fundamental question of whether scientific information actually improves the quality of complex natural resource decisions has been raised (Lach et al. 2003; Mazur 1981). This study reviews the nature of learning exchange and potential for improved or impaired interactions, when GIS maps are the medium of communication.

Part of what both scientists and non-scientists today find themselves required to do is to communicate effectively with each other, a task once conceived as simple and linear, but increasingly recognized as a complex challenge of many parts. Communication theory, then, is a second area of the literature that helps define the structural and societal barriers between scientists and their multiple new audiences. By addressing a range of issues from the difficulties of cross-cultural communication to the way we each structure our own knowledge, it will be argued that the processing of information is not unlike map-making in that it is fraught with invisible assumptions. Thus the much-used term "effective use of science" becomes a concept in search of a precise definition.

A third field of study encourages us to ask, How do we think about large landscapes, such as those most often portrayed by GIS maps? What are the tools and assumptions of ecology as investigated at the landscape level? How has ramping up to the scale of whole watersheds, and so-called megasheds, affected the way scientists think about and execute their crucial experimental work? What do we each see when we look across large landscapes, either in reality or via the representation of maps? And how does sense of place play into these considerations? Social studies of landscape ecology will here inform our questions about how humans are changing their comprehension of their environments, and of the resources they must manage within complex environmental constraints.

Building logically from considering large landscapes, the terrain of cartography and studies of GIS provide a fourth constellation of ideas. Theories about the nature of maps, the problems of reality versus representation, the role of mapmaker, and the understanding and use of GIS maps as presentation medium, will lead into the heart of considering maps as powerful tools of communication. But is their destiny to continue evolving as universal social icons, or to become scientific stumbling blocks?

To understand more clearly how GIS technology itself plays a role in communication around the sciences, technology diffusion theory will help illuminate the process of integrating new technology into society, and how this relates to the highly technical side of the CLAMS project. Finally, the emerging theory of transition management will provide a framework for placing the CLAMS endeavor in its social and historical context, and understanding the extent of its capacity for improving our approaches to natural resource management.

Considering Theoretical Frameworks

The production of highly technical GIS maps that could be used in policy decisions carries different meanings and therefore different implications for map makers and map users, which in CLAMS has typically meant scientists and non-scientists respectively. Indeed the very knowledge used to create such maps carries different meanings for the two groups. Only by continuous interaction can these meanings be mutually understood and thus brought via public interaction into the realm of policy-making in a useful form.

The breakdown of environmental policy implementation often comes about because of differences and misunderstanding between stakeholders, scientists and policy-makers in the region being assessed. Scientific knowledge is only a fixed entity at a given point in time, so its use as the sole basis for policy-informing GIS maps ignores the possibility that other definitions of knowledge will inevitably be present at the policy table.

How do people understand other people's knowledge? How do they see it in relation to their own knowledge? As noted, in the context of creating GIS maps, knowledge is defined and perceived in very different ways. To a scientist, knowledge can only be arrived at by a rigorous process built upon the scientific method; all other forms of knowledge are "anecdotal," and open to question, if not ridicule. To a policy-maker, conflicting interpretations of scientific data are exasperatingly common, but are typically preferred to including "untested" theory from non-experts. To a non-scientist, who may be relying on ancient tradition, or a lifetime of working the land, such narrowness is absurd, and proof only that scientists and policy-makers do not "understand" the land except in the most impersonal and inexperienced of ways.

The challenge of combining these types of knowledge to form new knowledge is implied in the research questions. The questions examine meanings and symbols, investigate the invisible assumptions of human interaction, and also explore the fundamental differences between scientific and non-scientific epistemologies. Therefore the overall theoretical approach to synthesizing and analyzing the literature, and then collecting and analyzing new data for this study, will predominantly come from the symbolic interactionist (SI) tradition, although structural functionalist thought will inform some observations and analysis.

SI takes a social-psychological perspective, with the focus on the individual and his or her social behavior. Individuals are perceived to be active in the creation of meanings for all events, objects, and decisions, rather than as passive creatures upon whom outside forces act and meaning is imposed (Wallace and Wolf 1995; Perinbanayagam 1985; Griffin 2003). Meaning is what social reality is constructed upon, and it is negotiated through the use of language. That is, it is not pre-existent in a state of nature, or inherent in objects. Symbolic naming is the basis for human society, symbolic interaction is the way we learn to interpret the world.

To some theorists, SI represents the perfect fit with social trends of the late twentieth century: "The pragmatic, humanistic theory of symbolic interactionism has been, quietly, one of the most enduring social theories of the twentieth century...it is the harbinger of postmodern social theory" (Plummer 2000). Plummer further enumerates the four central themes of the SI tradition: an elaborate system of symbols (semiotics); change, flux, emergence, and process; interaction; and engagement with the empirical world. Thus, methodologically, the investigator works largely at the micro-level of individuals and their changing, even rapidly changing, conceptions of meaning, rather than acknowledging predetermined social rules and external forces (Wallace and Wolf 1995).

The current study will operate largely at the level of the individual. However, because all the subjects of the study, both scientists and non-scientists, are inevitably part of, or interacting with, various social and institutional structures, aspects of the structural functionalist perspective are also of value here.

The structural functionalist view of society is of a stable, well-integrated entity, where people are socialized to perform their social functions, and cooperation and consensus about social structures tends to reinforce views of predictable functioning. This view holds that social systems tend to perform the tasks necessary to their survival and the preservation of the status quo; no part can be understood in isolation from the whole (Wallace and Wolf 1995). The focus on the individual required by SI operates at too fine a scale for structural functionalists; indeed the macro versus micro debate between the two theories continues to thrive (Lazega 1992; Plummer 2000).

Perhaps of greatest import in this debate is the work of scholars who have explored ways of integrating the two grand theories. Such scholars raise the question of structure in terms of the institutional constraints influencing the actors' negotiation of identities. In other words, what is there about the social setting—the relative power a community might confer on a research institution or its individual scientists, for example—that might affect the way people think about it, and create meaning for it?

This negotiation of identity is theorized as the link between the structure of the social setting and the interactive, highly individual processes that take place within them (Lazega 1992). Plummer in particular theorizes that the larger world structures on which structural functionalists base their theories of external forces are simply larger versions of the microsociological worlds studied under SI. He further insists that SI itself has no one single definition, surely a required comment from a committed symbolic interactionist (Plummer 2000)!

Revolutions in Science and Environmental Thought

Outside of the scale of "grand theory" as represented by SI and structural functionalism, other theoretical developments in the social sciences provide guidance to the current study. Primary amongst these are the social condition of postmodernism; a sociocultural phenomenon known as the New Environmental Paradigm; and the nascent idea of transnational development and its attendant ecological risks.

Postmodernism defies simple description. As an influence on modern thought about society and social structures, however, it is pervasive and persistent. Generally agreed to have emerged around the middle of the twentieth century, postmodernism by the 1970s was recognized by one of its major proponents as more than a new body of theory in the social sciences, or a new creative style in art and architecture (Lyotard 1979). While Lyotard did not claim a very broad meaning for the term, he initiated the idea that it was already a generic social condition by the late 1960s.

Central to his overall thesis on postmodernism is the notion that scientific knowledge is a form of discourse that will be rapidly changed by technological advances, and that access to knowledge will affect power relations. By challenging the ideas of science as liberator and truth, Lyotard synthesized some of the thoughts of contemporary historians and philosophers of science, and paved the way for ongoing debates about the nature of scientific knowledge and the legitimacy of other ways of knowing that have continued to this day.

In retrospect, for example, what Thomas Kuhn bequeathed most productively to the dialogue, apart from the beleaguered term 'paradigm shift,' was the idea that scientific investigation and its concomitant output was tactically and strategically fallible (Kuhn 1962). Paradigms, he claimed, help scientific communities bound their discipline, formulate questions, select methods, define areas of relevance. So discovery begins with the awareness of anomaly, the recognition that nature has violated the paradigm-induced expectations that govern so-called "normal" science. And normal science is a pursuit not directed to novelties, tending at first to suppress them.

However, normal science is in fact well-suited to detecting novelties: the tighter the paradigm fit, the narrower the focus, the more room there is for exceptions to arise in the empirical arena. Kuhn elegantly argued the case for paradigm shifts based on the constricting format of positivist science, but should not be interpreted as foretelling its doom.

What, though, is to become of the pursuit of science if it is discovered to be too narrowly defined? Toulmin optimistically sees the postmodern period as a return to the humanism flourishing at the end of the Renaissance (Toulmin 1990). The free-ranging intellectual style and skepticism typical of the humanists to Toulmin represents an openness to ambiguity, uncertainty, and toleration, that disappeared rapidly in the early decades of the seventeenth century, as Rene Descartes' ideas rose to influence.

Toulmin, like Kuhn, insists his theory is not a rejection of all that has been accomplished under 300 years of logical positivism, or rationalism. Instead, the news for the sciences is good. He believes that natural sciences in particular can now flourish under the multiple sources of light shed by multiple, equally-respected methods of inquiry, of which empiricism is but one.

A more radical, but also more succinct, version of relativist, postmodern thinking comes through the lively essays of Feyerabend, who sees science as essentially an "anarchic enterprise;" indeed, he posits anarchy as excellent medicine for epistemology in general (Feyerabend 1988). From among the descriptions in his analytical index may be gleaned the following description of his postmodern views:

> "The only principle that does not inhibit progress is: anything goes...The consistency condition which demands that new hypotheses agree with accepted theories is unreasonable because it preserves the older theory, and not the better theory. Hypotheses contradicting well-confirmed theories give us evidence that cannot be obtained in any other way. Proliferation of theories is beneficial for science, while uniformity impairs its critical power. Uniformity also endangers the free

> development of the individual...There is no idea, however ancient and absurd, that is not capable of improving our knowledge. The whole history of thought is absorbed into science and is used for improving every single theory. Nor is political interference rejected. It may be needed to overcome the chauvinism of science that resists alternatives to the status quo" (Feyerabend 1988).

With just as much revolutionary fervor, the Brazilian Freire wants to see local knowledge brought to the very forefront of civic decision-making (Freire 1998). Science, in his lexicon, is accorded no special position as producer or purveyor of truth. He frames local knowledge not as the "problem", but as part of the solution, the only intelligent solution, to the overwhelming problem of social oppression. His intellectual work can be characterized as an effort to rebuild solidarity in an anonymous, fragmented society, and by doing so, to bring the oppressed—and their valuable knowledge—to the table where futures are framed.

Freire's viewpoint is unabashedly Marxist in orientation, and shares with Lyotard the idea of knowledge as the new commodity of exchange, therefore the fulcrum on which social equality can conceivably be balanced.

Knowledge, then, by postmodern standards, is no longer the exclusive domain of the experts, an idea which underscores the question of whether one of their increasingly common presentation media in the natural resource management realm—GIS maps—can meet the twin communication and learning challenges posed by the research questions guiding the current study.

Arising from just this dilemma in redefining learning and the role of science, the concept of "post-normal" science suggests that we clearly need to move beyond the "masters and possessors of Nature" approach to science that Descartes and his followers once espoused (Funtowicz and Ravetz 2001). Noting that the scientific mindset fosters expectations of regularity, simplicity, and certainty in both phenomena and our interventions, Funtowicz and Ravetz perceive that such expectations get in the way of broader understanding of our problems and of appropriate solutions. Carefully emphasizing that their conception of "post-normal science" does not by definition imply an attack on the accredited experts, they propose it as an assistant approach:

> "The management of complex natural systems as if they were simple scientific exercises has brought us to our present mixture of triumph and

> peril. We are now witnessing the emergence of a new approach to problem-solving strategies in which the role of science, still essential, is now appreciated in its full context of the uncertainties of natural systems and the relevance of human values" (Funtowicz and Ravetz 2001, p.24).

Not surprisingly, postmodern thought has given rise to several other social movements signifying changes that impinge upon the current investigation. These include the New Environmental Paradigm, "post-normal" science, and the transnational development of "risk societies."

Widely although not universally accepted as the emerging paradigm describing changing social attitudes and values relating to the natural environment (Steel, Clinton, and Lovrich jr. 2003; Switzer 2001), the New Environmental Paradigm (NEP) places humans firmly within the larger ecosystem, linked to all other creatures through the earth system by which jointly they are nourished. Proponents of NEP are concerned with population growth and the type of economic expansion that depends for its fuel on rapid rates of natural resource consumption, both of which they view as unsustainable from a planetary health perspective.

What NEP is purported to replace is the so-called Dominant Social Paradigm (DSP), which contends that the central purpose of nature is to produce goods and services primarily for human use, emphasizing commodity production over environmental protection (Brown and Harris 1992). NEP is generally perceived to have arisen in the second half of the twentieth century, particularly in postindustrial nations such as the United States, Japan, and Western Europe. The paradigm has taken shape at least in part because of the growing postmodern awareness that science and technology—hailed as the savior of humanity under the DSP—have caused as many problems as they have solved. Steel and his colleagues (2003) point out, however, that despite the increasingly widespread adoption of NEP ideals, the consumptive lifestyles and behaviors of most people in those countries still conform more closely to those of DSP.

It is this broadly spreading, widely documented (Milbrath 1993; Dunlap and van Liere 1978; Brown and Harris 1992) change in attitude towards the status of science and technology, no matter whether it is acted upon, that bears upon the current study. For until a scant few decades ago, the ability of science and technology to meet environmental challenges was rarely questioned. The technical expert with the answers, typified in the United States after the Second World War by dam builders, chemical companies, and the U.S. Forest Service, was the cornerstone of the elite-based technocracy that underpinned technological advance (Fischer 2000; Switzer 2001). The CLAMS scientists and their maps might in earlier days have left the meeting in Philomath after a few polite questions, secure in the knowledge that their research results were accepted and respected.

No more. Insofar as postmodern reflections and NEP can be "blamed" for such a change, they belong on the list of culprits. More salient to the argument here, however, is the fact that the social changes they represent have pitched scientists, unprepared, into the lion's den that is the public arena, starting at the end of the twentieth century.

The concept of "post-normal" science again provides a compelling framework for considering the outcome:

> "The insight leading to Post-Normal Science is that in the sorts of issue-driven problems characteristic of policy-related research, typically facts are uncertain, values in dispute, stakes high, and decisions urgent. Some might say that such problems should not be called 'science'; but the answer could be that such problems are everywhere, and when science is (as it must be) applied to them, the conditions are anything but 'normal.' For the previous distinction between 'hard,' objective scientific facts and 'soft,' subjective value-judgments is now inverted. All too often, we must make hard policy decision where our only scientific inputs are irremediably soft" (Funtowicz and Ravetz 2001, p.19).

The social systems in which the hard decision must be made, Funtowicz and Ravetz note, are not only complex, but often reflexively complex. A new role for science is inferred, and it can no longer rely exclusively on the academic learning and experimentation of what was once considered "normal" science: "When the assumptions of simplicity and certainty are totally inappropriate, the goal of achievement of factual knowledge must be substantially modified" (Funtowicz and Ravetz 2001, p.20).

A third category of theoretical interest here, also arguably an offshoot of postmodernism, is the idea of transnational development, most cogently articulated by Ulrich Beck. Beck's "risk society" (Beck 1992) is a pervasive new condition in which no human is exempt from the "bads" to be shared by the industrial society which previously produced "goods" limited only by their distribution. Beck argues that the newness of the global context sets up conditions for entirely new responses.

Plagues of almost global proportions are not new to our planet: whole civilizations have fallen into decay as a result of various natural disasters, such as the eruption of Mt Vesuvius and the spread of bubonic plague. The difference now is that there is no denying the hands of humans in the creation of the disasters. Beck refers to mega-technological catastrophes that grow from institutions primed purely by economic gain. It's no longer the gods causing the disasters, or even the rats.

Beck's ideas, of course, dovetail absolutely with the postmodern breakdown of faith in science and technology, and also with the enhanced environmental awareness proposed by the New Environmental Paradigm. While transnational development and its political implications do not loom specifically over the particular regional maps under study here, the specters of globalization and of Beck's "risk society" are undeniably adding to the concerns of non-scientists with matters of resource extraction and management (Fischer 2000; Steel, Clinton, and Lovrich Jr. 2003; Switzer 2001).

It is with these theoretical frameworks as context that the current study undertakes to consider how GIS maps might contribute to, or detract from, the necessary bridge between worldviews so often lacking in environmental policy discussions.

Logical Positivism and the Quest for Truth

It is too easy to dismiss logical positivism and its very focused quest for what it wants to call "truth," and thereby to dismiss a set of standards which despite our current disdain has for three centuries represented a thriving enterprise close to the backbone of our civilization. A closer look at what postmodernism might mean in practical terms is warranted.

Post-positivist beliefs have moved us from a system of axioms believed to be of universal and timeless validity, to a more fluid world of dynamic paradigms that are creations of a given age or phase of science (Toulmin 1990; Fischer 2000; Woolgar 1988). From the latter perspective, we have begun to notice, appreciate, and analyze dynamic systems. The natural sciences are now seen as a collection of dynamic, rather than pre-ordained enterprises. The revolutionary idea of no longer separating observer from observed opens the way for a return to oral and written, to local and general, to timely and timeless studies. Taking this view, Toulmin contends, means "no obstacle remains to studying Nature however our experience requires."

Post-positivist, or postmodern, science will also demand more adaptive institutions than currently exist for its pursuits. Fischer's view of the postpositivist approach to knowledge is in some accord with that of Toulmin. Contemporary postpositivism, Fischer claims, is rooted in both the natural sciences and the history and sociology of science—the static view of the universe is rejected in favor of one in flux (Fischer 2000). Science itself is now seen as a form of human action, thus vulnerable to biases, subjectivity, and social and practical judgments. Empiricism, framed this way, loses its claim to privilege, and takes its place alongside the historical, comparative, philosophical, and phenomenological perspectives. Thus the crucial debate is seldom over data per se, but rather over the underlying assumptions that organize it—the surrounding social context.

Clarke and Fujimura ask what needs to be taken into account in order to understand the context in which science is being conducted:

> "Everything in the situation, broadly conceived: who is doing it and how is the work organized; what is construed as necessary to do the work; who cares about the work (in the pragmatist philosophical sense); sources of sponsorship and support both locally and elsewhere; what are the intended products, and for which consumers or users; what happens to products after they are sent out the door into user workplaces; and last, but far from least, what interpretations do participating actors construct over the course of the work" (Clarke and Fujimura 1992, p.5).

Their alarmingly comprehensive answer echoes the postmodern quest for coverage of all the angles: science no longer just wields the microscopes, it goes under them itself.

However, a number of scholars have pointed out the considerable philosophical contradictions inherent in the postmodern dismissal of the scientific way of knowing. Why, if all ways of knowing are supposed to be legitimate in the more "humanistic" postmodern worldview, should the scientific method be singled out to be wrong in its approach (Toulmin 1990; Schweizer 1998; Fischer 2000)? It is worth noting that the perceived problem with the scientific method is more about its privileged status than about its well-tested approach.

Schweizer, an anthropologist, notes: "It is interesting that the postmodernist proposition of the historical limits of knowledge is a generalizing statement at the metalevel, that is itself a claim for a universal truth and thus contradicts its own premise" (Schweizer 1998, p.49).

In Fischer's view, science should still be taken seriously, but recognized clearly as a contextual interaction between physical and social factors. In other words, objective facts are deemed so based only on the decisions of particular communities of inquirers and the theoretical presuppositions to which they subscribe. He writes:

> "The postpositivist objective is not to reject the scientific project altogether but rather to recognize the need to understand properly what we are doing when we conduct one...Recognizing reality to be a social construction, the focus shifts to the circumstantial context and discursive processes that shape the construction" (Fischer 2000, p.75).

A quest for meaning, indeed.

At best, scientists who continue laboring faithfully under the time-honored tenets of logical positivism are left wondering what their futures hold. Are they supposed now to bend in whatever epistemological wind is blowing? Seek only meaning where previously they sought to find hard facts? Or uphold their standards of knowing against all axiological opposition?

For if we were to give up the notion of science as the quest for truth, and science were to abdicate its role as "expert" in policy-making, are we left with the specter of anarchy in decision-making? As the types of decisions to be made become more complex, just as the concept of public involvement and collaborative decision-making become more prominent, a purposeful question arises in the scholarly debate: can democracy thrive in a complex technological society (Fischer 2000; Priest 1995)?

Fischer rightly identifies the tension between professional expertise and democratic governance as an important political dimension of our time. Nowhere does he claim that professional expertise, as developed under the rubrics of a long tradition of logical positivism, ought to be put out to pasture. Instead, and honoring the postmodern, interactionist traditions he upholds, he seeks a solution that brings multiple rather than singular strengths to the table of policy debate.

In postmodern environmental politics, as the New Environmental Paradigm portends, citizens actively challenge expert theories which ignore local knowledge that might relate technical facts to social values. Fischer is one among a number of scholars proposing a new model of politics based on participatory inquiry and citizen-expert collaboration (Fischer 2000). Other scholars note that, given this trend, it is important to examine our notions of who holds the evaluative powers that most contribute to sound decision-making (Gethman 2001). Must scientists abdicate their right to evaluative thinking, merely by their assumed responsibility as value-neutral participants? Are citizens, frequently ill-informed but willing to learn in the natural sciences, somehow more endowed with that crucial evaluative ability? Gethman suggests that the idea of citizen participation enjoys a high degree of plausibility in part because of the potentially successful communicative function such participation often serves.

Indeed, under the symbolic-interactionist focus on meaning as a primary tool for understanding human interaction, the case can be made that the interactive process involved in moving stakeholders, citizens, and policy-makers toward a decision with input from scientists, may be as important as the details of the final decision itself. Funtowicz and Ravetz further propose that the two fundamental properties of human systems—radical uncertainty and the plurality of legitimate perspectives on any contentious issue—create the need for integrative thinking in dealing with complex systems such as natural resource management, replete as they are with diversity and conflict. It helps, they write, "...to understand that this diversity and possible conflict is not an unfortunate accident that could be eliminated by better natural or social science. It is inherent to the character of the complex system..." (Funtowicz and Ravetz 2001, p.18).

Freire, the Brazilian revolutionary scholar, describes "reintegrative networks" as the structures by which the participative change may become possible. These consist of critically aware citizenry who are prepared to step up and solve political problems, speaking in their own voices in their own interests; the networks pull together isolated individuals in the creation of a new collective will. In other words, they are reintegrated (Freire 1998).

The case for local knowledge and local engagement is buttressed by insights from contemporary epistemology and the sociology of science (Berkes, Colding, and Folke 2000; Lawrence, Daniels, and Stankey 1997; Blahna and Yonts-Shepard 1989); these studies tend to propose ways to facilitate epistemological integration of expert and citizen forms of knowledge. The clash is framed by Fischer explicitly as technical rationality versus sociocultural orientation, and the ensuing question posed as how can the two forms be discursively integrated, rather than mutually rejected (Fischer 2000)?

One result of the social turmoil surrounding modern science has been that as scientists rigorously trained in empirical approaches make their honest attempts to be more open to outside perspectives, they make tentative efforts to include other viewpoints in critiquing their work, and in doing so feel they have bared their souls. Their audiences of attentive publics do not perhaps appreciate the scale of their capitulation, and want more. We might ask, then, what on earth does discursive integration mean to a scientist? And can it be done with the help of a GIS map?

Images of Science and Scientists

An instructive place to start trying to address the first question may be in the arena of how scientists are perceived and how they wish to be perceived in a post-positivist world. A question that dogs scientists trying to make their work accessible to policy makers and others is whether what they are doing can be construed as advocacy. A recent examination of this question illuminates a number of important related issues (Lach et al. 2003).

Lach et al.'s regional study of selected scientists in the Pacific Northwest reports on the attitudes of scientists, resource managers, representatives of interest groups, and members of the involved and attentive public; they investigate preferred roles for research and field ecologists in natural resource management, examining the critical linked issues of advocacy and credibility.

The researchers posed their findings against the traditional role for scientists, the "ideal type" (Weber 1946), in which scientists are not supposed to cross the line between providing their findings to managers, and making management recommendations. They identified five potential roles that managers could play: reporting results; reporting then interpreting results; working with managers to integrate results into management decisions; advocating for preferred decisions; making management decisions. All groups except the scientists found the integrative role most preferable; scientists were supportive of it, but preferred the less active interpretive role.

Scientific credibility was key to which role scientists choose; in general, they actively fear their loss of credibility if advocacy is detected, as a number of scholars have noted (Rykiel 2001; Pouyat 1999; Mills and Clark 2001). Credibility is highly valued by scientists, and they believe it can only be lost once. In strong contrast, non-scientists tend to associate credibility of scientists with their ability to communicate with non-traditional audiences!

The Lach et al. (2003) study suggests that at least in the Pacific Northwest, both scientists and non-scientists are open to a more active and integrative role for scientists in resource management, in tune with recommendations from other scholars (Lee 1993; Fischer 2000).

To some scholars, there is a continuum, not a selection of discrete positions, between data and advocacy (Blockstein 2002). All scientific reporting, Blockstein claims, involves interpretation or contextualization, but much confusion remains over the relationship between data, scientists, and advocacy. He offers a number of tenets useful for advocating without undermining credibility: follow the facts, tell the truth, obey the "rules" of science, present caveats, identify uncertainty, distinguish between uncertainty and guesswork, and avoid hyperbole.

Regardless of their approach, the challenge for scientists will be to become more effective communicators with non-traditional audiences, in order that science findings can be integrated in “meaningful and scientifically respectable ways” (Lach et al. 2003). Non-scientists, for their part, will have to learn to accept uncertainties, and recognize the limits of what ecology and ecologists can teach us.

This study defers to the theoretical constructs of both institutional structure and communicated meaning in modern society. Scientific institutions have “functions” both to produce information and to participate in its dissemination in order to maintain their status, and their explicit beliefs in balanced environmental decision-making. At the same time, legislative requirements push citizens to the forefront of decision-making, and they bring different expectations and understandings of the roles of current science and their own epistemologies in formulating policy. Unless decision-making processes and tools change or adapt, these two forces will likely remain at odds.

Several other scholars implicitly suggest the turmoil we face in environmental policymaking has both structural and interactionist components (Pouyat 1999; Van der Vink 1997). Van der Vink's essay in *Science* in particular takes the scientific community to task over its failure to engage with the political community in the ways demanded by today's environmental policy context. Noting the tendency of scientists to speak of the public's "scientific illiteracy," and their continuing quest for scientific answers that last, he writes,

> "As scientists, we are called upon to find the best solution that fits within political, social, and economic boundary conditions. As the boundary conditions inevitably change, scientists appear to disagree, the media reports on the controversy, and the public watches in frustration" (Van der Vink 1997, p.1175).

He justly concludes that the greatest threat to current scientific institutions may in fact be the political illiteracy of scientists, not vice-versa.

Pouyat (1999) concurs that scientists have failed to comprehend that so-called solutions from the biological sciences have confused the public, or been ignored by the political process. In the increasingly technical needs of problem-solving, the sophistication of various advocates has led to new approaches to influencing policy, such as hiring scientists and funding environmental research by interest groups, which he recognizes as a guarantee for yet greater controversy. Pouyat identifies seven "problem areas" that include the cultural and structural barriers between scientists and non-scientists, although his analysis does not explicitly confront the structural issues as foci of potential change.

In tune with the idea that lack of understanding between scientists and non-scientists is eroding public confidence in the environmental policy-making process, another approach suggests that the problem may lie less with alienation from science itself than with alienation from certain of its sociopolitical aspects (Priest 1995). This conclusion strongly endorses Fischer's call for deliberative institutions to engage in policy-making, institutions that can embrace the vigorous debate and heated differences of opinion that are already at play in both scientific and public arenas.

Unfolding Scientific Controversy

Disputes between technical experts, of course, are defining characteristics of scientific controversy. At a deeper level, they represent struggles over meaning and morality, over the distribution of resources, and over issues of power and control. But clashing methodologies and opposing theoretical bases appear to be sufficient for historians of science to apply the official label of scientific controversy (McMullin 1987). Indeed in McMullin's case, a seminal typology of scientific controversy and its resolution has been developed. The question needs to be asked: are clashing epistemologies—disputes between experts and non-experts—also valid cause for such study? The question is apt considering the postmodern tendency to accord equal status to many kinds and bodies of knowledge.

Taking a historical perspective, Westrum considers the practices of science from the eighteenth century when the idea of meteorites was in its infancy, outlining the already-established idea of tight control of scientific knowledge that most natural scientists continue to espouse (Westrum 1978). He underscores one of the mutual misconceptions that stymie the communication process between scientists and non-scientists: finding methods for accepting and rejecting data is traditionally uppermost in scientists' minds. The scientific enterprise is built on the belief that control of data quality by verification is the only path to truth.

However, from the point of view of the non-scientist, this can look all too easily like politically-motivated "control" of data, refusal to consider alternatives, and blindness to all but the existing knowledge of science. That Westrum was considering these ideas in the context of recognizing the reality of meteorites in the eighteenth century, suggests how deeply ingrained through time are the features of the one-way communication model to which so many modern scientists subscribe.

Technical controversies, from meteorites to old-growth, have the typical round of hypothetical experiments, discrediting, and selective use of data. The myriad forms of disagreement between scientists in the course of a scientific controversy are a major source of frustration for public and policymakers. Scholars of scientific controversy concede that the political, non-scientific content of a scientific dispute is often at the heart of its resolution (McMullin 1987; Mazur 1981; Priest 1995).

Indeed, a cursory look at the nature of scientific controversy uncovers both the positivist view of how knowledge "should" come into being, and solid grounds for expanding the definition of scientific controversy to include other ways of knowing. Ambiguities invariably play a central role in scientific disputes: when to make simplifying assumptions, which one to use, when to use data from other sources, how trustworthy a set of empirical observations might be. Often one side will accept as firm conclusion what the other side regards as mere tentative hypothesis; the entire enterprise is stymied by the fact that scientific hypotheses are never proven but only gain increasing acceptance (Mazur 1981).

What we can discern from the history of scientific controversies is that to date, not surprisingly, they have been strongly imprinted with the logical positivist framework. Their resolution has depended on accepting its rules of investigation, but their history has also recognized the role of uncertainty and ambiguity. In time the purview of historians of scientific controversies may expand to include epistemological controversies between rationalists and constructivists, between scientists and non-scientists, rather than leaving those exclusively to sociological or philosophical theorists. For it is most often general worldviews, not the details of the science, that fuel the conflicts surrounding natural resource policy-making (Priest 1995).

The example of environmental conflict in forest resources in the Pacific Northwest in the 1990s provides a clear example of worldviews at odds. But it also provides insight into what happens when a social imbalance is created by the rise to power of two separate but ultimately related strands of society—environmentalists, and natural resource scientists (Duncan and Thompson, in preparation). Such an imbalance, given other circumstances, can contribute to a rapid change to the rules of engagement or the way of doing business. That the CLAMS project was born out of this fiery period suggests its place in a phase of rapid transition and change. It is therefore conceivable that bridging tools between espistemologies, such as GIS maps could become, may emerge in newly-framed histories of controversy as useful foci of studies in social change.

Changing Acceptance of Science Findings

Embedded in much of our understanding of the changes occurring in how science and scientists are viewed in today's society, is something of a revolution in society's notion of the acceptability of scientific findings. We are at a crossroads, in the sense that a different choice must be made about how environmental decision-making is done (Rykiel 2001). The question is now more frequently raised about how science can best make its contribution to technical and scientific policy decisions; many believe a core part of the answer lies in interdisciplinarity (Gethman 2001).

A number of factors have been suggested as responsible for changing levels of faith in scientific research (Yosie 2001). They include a discernable lack of public trust in decisions of major institutions, higher expectations for improved environmental quality, expanded capabilities for participating in environmental decision-making, and attempts by government and industry to include stakeholders in decisions in order to build credibility. Yosie cites recent public opinion research that found 40% of the polled public believes industry-only research is rigged; 63% believe there are political agendas behind government-only research; and 79% have a favorable or very favorable view of industry, government, and environmental groups working together.

The latter data point rescues this potentially grim set of findings; it suggests the public perceives that a better way of developing, managing and communicating scientific research already exists, and thus that a high price will be paid if science-based and stakeholder-based decision-making are not reconciled. This study found that the public does still trust scientists, to whom they give a 73% trust rating, but they want to be assured of independence of research, a confirmable track record, and confirmation of sources.

Yosie's position on the value and values of science, like those of many commentators on science, does not question the primacy of scientific information. This position assumes that objective/subjective, value-free/value-laden, and neutral/advocatory continue to be natural divisions between scientific information and all other kinds. However, there are scholars who disagree. For example, Rykiel sees these opposing aspects of science as artificially dichotomous (Rykiel 2001). He notes, for example, that scientific procedures are aimed at minimizing subjectivity, not at the unattainable goal of eliminating it.

Relating to the question of trust, Lazega frames the social conflicts over environmental policy as the aforementioned struggles for control of knowledge (Lazega 1992; Lyotard 1979; Freire 1998). Both scientists and non-scientists, he notes, have multiple identities, none of which is objective or neutral, and any one of which may be called upon in a given setting. In the negotiation of identities, what is at stake is authority and accountability; in general, informed and active members of the public are no longer likely to accept without question the bold or bald statements of scientists on any given subject.

With polarized views, controversy, and overt conflict becoming pervasive, the frustration runs strongly both ways (Slovic 1993). Frustrated scientists and industrialists perceive the public to be irrational or ignorant. Members of the public are likewise antagonistic toward the arrogance of industry and government. Central to Slovic's argument is the notion that distrust becomes the agent of regime change—the motivator—when it finally surmounts the perceived lack of control over social and political circumstances, and in this case, over information. The implications for productive evolution of environmental policy include the possibility of significant system adjustment.

Cultural and Institutional Barriers

Both cultural and institutional issues play a role in raising barriers between scientists and non-scientists. Thus another field of study that offers useful analogies here is that of cross-cultural communications. Defining culture broadly (DuPraw and Axner 1997; Carr 2002) as a group or community with which we share common experiences that shape the way we understand the world, we can frame scientists and non-scientists, again broadly, as having separate cultures. DuPraw and Axner (1997) note that our cultural identity is central to what we see, how we make sense of it, and how we express ourselves.

One of the best known writers on the subject of the cultural divide between scientists and non-scientists is also arguably the most controversial. C.P. Snow's entry in the fray came with a lecture at Cambridge in 1959, titled The Two Cultures and the Scientific Revolution, in which he insisted there was a "gulf of mutual incomprehension" between scientists and literary intellectuals (Snow 1962). While the gulf is more clearly than ever a serious impediment to their communication, Snow developed his arguments in a rather wild manner, ranging from anecdotal to apocalyptic, mixing his terminology ("literary intellectual" and "traditional culture" become interchangeable), and his metaphors, to make his point. The resulting furor in the lay and professional literature brought bright attention to his argument, but little to the resolution of its central challenge.

He wrote of the cultural divide as "one of the situations where the worst crime is innocence" (Snow 1962), implying with many of the scholars referenced here that the very invisibility of the communication gap is perhaps its greatest threat. He aptly produced a caricature of scientists and non-scientists blithely speaking past each other without hearing a thing the others are saying, forcing us to consider the possibility that his caricature remains entirely applicable (Benda et al. 2002; Weber and Word 2001; Pouyat 1999; Van der Vink 1997).

What has changed since C.P. Snow echoed the ideas that had in fact been expressed in earlier centuries, by no lesser intellectuals than Sir Francis Bacon and Matthew Arnold? Are we destined merely to repeat our concern about the different worlds and worldviews of scientists and non-scientists, in our own twenty-first century words?

The ideas of postmodern thinking had not yet taken root at the time Snow set the stage for the intellectual melee surrounding his supposed "two cultures." Science, it was still assumed, held the superior position. Furthermore, the emerging tenets of the New Environmental Paradigm now display the seeds of such compelling environmental legislation as the National Environmental Policy Act (1969), the Endangered Species Act (1973), and the National Forest Management Act (1976).

Since the passage of these acts, the conversation between scientists and non-scientists is no longer just wishful thinking on the part of a physicist/novelist: it is a legally-required component of environmental policy-making involving federal lands and resources, and is increasingly called upon for other public and even some private lands. And it is one fraught with all the difficulties to which Snow alluded, from non-scientists' understanding of the second law of thermodynamics to scientists' familiarity with the works of Shakespeare (Snow 1962). Not only has the problem not gone away, it has stolen inexorably towards center stage.

Among the most predominant cultural boundaries DuPraw and Axner (1997) identify in cross-cultural communications at large are communication style, attitudes toward conflict, attitudes toward disclosure, and approaches to knowing. Communication style, for example, includes non-verbal communication, such as seating arrangements, personal distance, and sense of time, all of which come into play in a meeting between scientists and non-scientists. With regard to attitudes to conflict, some people regard open meetings as the ideal place to deal with differences; scientists, however, are accustomed to working differences out via the written word in the academic literature. Disclosure to a scientist may mean making his/her statistical approach available for critique; to a non-scientist it may mean telling an audience how their findings derive from their personal values.

Carr's qualitative study adapted a cultural framework to conflicting interdepartmental cultures at a small university, where he compared approaches of undergraduate science and education majors to an assigned teaching task. He found that often we are not aware that culture is acting upon us, nor even that we have different cultures from other people in the room (Carr 2002). Like others, Carr also found numerous instances of the two groups using the same word to mean different things. Epistemological differences engendered different expectations about communication outcomes, as well. Scientists assume communication is easy and one-way. Non-scientists tend to expect a longer and more complex dialogue to develop; a role for feedback is assumed.

What is at play here is a set of different ideas about espistemology. For example, science is perceived by scientists as coming up with results through hard individual work and discipline, thereby developing the "authority of knowledge." Non-scientists tend to be looser in their definitions of the foundations of knowledge, and what power it confers. They tend instead to see it as a community-based body of information, not necessarily the exclusive realm of a single group.

In a similarly cross-cultural vein, a survey of international literature found the role of traditional ecological knowledge to be far more "social" than that of scientific knowledge (Berkes, Colding, and Folke 2000). The social mechanisms behind traditional practices reveal a variety of methods for generating, accumulating, and transmitting knowledge: the use of local institutions; mechanisms for cultural internalization; and development of appropriate world views.

Habermas's idea of "pre-linguistic" development of people along different pathways (Habermas 1970) in this case offers an analogy for professional training, and suggests one of the organizational arrangements that tend to keep scientists and non-scientists culturally separated. And finally, it is well established that power relationships within organizations also affect methods and styles of communication (Waldron 1991).

Despite the potential depth and breadth of cultural and institutional separation between scientists and non-scientists, however, technology itself has been perceived as an instrument for crossing boundaries. This line of thought relates directly to the effectiveness of GIS maps in conveying technical information from scientists to non-scientists and encouraging mutual learning (Sieber 2000).

Across the Language Barrier

But first, how do scientists try to bridge this famously obstructive gap between themselves and the larger world of non-scientists? Of most interest to the current study is the intriguing truth that when biophysical scientists "take on" the subject of communication with "other" audiences, it is most frequently with their deeply entrenched assumptions of epistemological superiority fully intact: rallying calls for change (Lubchenco 1998), detailed recommendations for planning and approach (Mills and Clark 2001), lists of the virtues of scientific knowledge, including wisdom (Blockstein 2002), and the standard call for the best available science to inform policy (Johnson et al. 1999) all of which rest on the positivist view of scientific knowledge.

While these calls to action are heartening and bring attention to the fact that a communication problem exists, they run the risk of exacerbating it by contributing their assumption that scientists just need to communicate more of their science to more different kinds of people (Lubchenco 1998; Mills and Clark 2001) and the problem will be solved. The one-way communication model with scientist as sender, peer-reviewed science findings as message, and non-scientists en masse as passive receivers, needs to be quietly laid to rest.

Priest's challenge to the postmodern view of the conduct of scientific research being at the heart of the problem is based on a study that combines quantitative study of mass media coverage of biotechnology issues with qualitative study of processes used by people analyzing its risks (Priest 1995). Her data suggest that it is not so much alienation from the conduct of scientific research that maintains the gap between scientists and their many-faceted publics and adversaries, but alienation from the policy-making process to which their science may contribute. In other words, sociopolitical aspects of policy-making can be more adversarial than the science content itself. These aspects incorporate the apparently simple but structurally huge problem of language.

As has been established for some time (Habermas 1970), language can—albeit invisibly—create more barriers to understanding than bridges. Habermas characterizes "distorted communication" as the unequal communicative relationship between technocratic planners and members of the local community, the one employing technical and the other everyday language to describe and express their positions on policy issues. He focuses on pseudo-communication of the type that all too often occurs in the public interaction context: participants do not recognize the problem because of reciprocal misunderstandings, false assumptions of consensus which are not recognized as such. Terminology such as "random", "uncertainty", "complexity", and "significant" are words so commonly used in everyday language that their specific scientific meanings—capable of leading to quite different conclusions—are not immediately considered in policy discussions by citizen participants.

A key study in the consideration of communication barriers asks what non-scientists hear when scientists speak (Weber and Word 2001). This question lies at the very heart of the current study. Weber and Word pose the theoretical basis for understanding how communications between scientists and non-scientists can so easily fail. Information is often seen by both parties as a transmission process: one way, and finite. But communication theorists see differently, recognizing that communication—which everyone believes s/he personally grasps,

> "...refers to an ongoing process of sending messages, negotiating the meanings of terms and referents, interpreting messages, and dealing with a variety of responses. It embraces the processes of misunderstandings, automatic mental 'scripts', questioning and cognitive envisioning strategies...Public discourse particularly reveals the interplay conflict, and overlap of multiple frames of reference" (Weber and Word 2001, p.6).

Through studies of the development of meaning for the term "biodiversity," and of the variable understanding of scientific fact sheets by public audiences, Weber and Word established that scientists and non-scientists would benefit by seeing science communication as a *process* as well as a *product*. Crucially, they point out that meanings must be negotiated, that dialogue in some form is the primary trait of communication, and that different frames of reference will feed different meanings.

Furthermore, they found that scientific information is understood through both general and local contexts, and that both scientists and non-scientists fall prey to what they call the paradigm frame of reference fallacy—the belief that all who do not share your frame of reference simply share another one. Echoing Priest's findings, they point out that public concerns about science encompass not just the science itself, but also the institutional and political concerns surrounding it (Priest 1995).

The idea that research should determine policy—"speaking truth to power"—is justly criticized, according to some scholars (Kasemir et al. 2000; Norton 1998), because experts do not inherently have the capacity to frame the dimensions of an environmental problem in ways the public will understand. Their observation is in accord with the odd question of whether somehow scientists have a superior evaluative capacity (Gethman 2001). The disconnect between lay and expert language needs integrative solutions, both at the actual level of word choice, and the conceptual level of productive communication.

For Norton, the problem emerges in the contrast between the serial thinking of science, which has its own descriptive language, and the integrative thinking of environmental management, which has another language to evaluate the science's content for policy purposes. However, his suggestion of creating "normatively thick indicator terms" and "bridge concepts" to encourage more multidirectional discussion, while appropriate, belies the difficulty (though not the impossibility) of teaching old dogs new language.

An alternative approach is proposed by Benda and colleagues, who recognize the many obstacles in the necessarily interdisciplinary project that is environmental policy-making (Benda et al. 2002): finding common language, mismatches in temporal and spatial scales, and conflicting levels of precision and accuracy. Their most cogent observation, however, is that all too often it is forms of knowledge—not just language itself—that do not match, and he argues for adopting a formal methodology to consider the structure of knowledge: "The epistemological exercise of defining knowledge structures at the onset of a collaborative exercise can be used to construct solvable problems" (Benda et al. 2002, p. 1128). These scholars are strong proponents of making knowledge inadequacies explicit, thus not letting them be placed in a pivotal or referee position, where they can effectively shut down communication through the simple process of misunderstanding.

How do we Process Information?

Communication theorists have long since developed several major contributions to understanding human interaction that are of value to the aspects of this study that focus on mutual (mis)understandings. The most apposite of these are the schema concept (Bartlett 1932; Bruner 1957), and dual coding theory (Paivio 1971).

The schema concept refers to cognitive structures or organized prior knowledge, stored with specific examples and instances by abstraction from experience, and providing the means of processing new and retrieving stored information (Fiske and Linville 1980). Dual coding theory, by contrast, suggests that cognition consists of two separate but connected mental systems—a verbal and a non-verbal system (Sadoski, Paivio, and Goetz 1991; Paivio 1971).

Schema theory has been much criticized as definitionally vague, inconsistently supported empirically, and merely the reworking of old ideas (Sadoski, Paivio, and Goetz 1991; Fiske and Linville 1980; Anderson, Spiro, and Anderson 1978), but it has persisted robustly into the twenty-first century as a valuable heuristic supporting research and theory development particularly in reading and cognitive research. It is not important here to investigate the current status of the theory, nor to take a position in the debate. It is raised merely to borrow from its broadly-defined tenets, and indicate how pertinent such ideas are in the study of meanings existing at cross-purposes, particularly as the pace of technology development forces us to confront new modes of communication and presentation (Mennis, Peuquet, and Qian 2000).

Schemata (also referred to variously in the literature as frames, scripts, plans, or macrostructures) provide data structures for stereotyped situations, wherein we include information on how to use the schema, what should happen next, and what to do if cognitive expectations are not met (Minsky 1975). Collections of schemata are linked into systems, and the transformations between the systems can make certain calculations economical, or represent changes of emphasis and attention; these transformations account for the effectiveness of imagery. Minsky proposes that much of the power of this theory hinges on its inclusion of expectations and other kinds of presumptions.

The formation of schemata in individual minds develops through lifetimes, and can be seen as an efficiency measure in information storage and retrieval. But the salient point here is that individuals do not magically create the same schema for the same concept; schemata depend heavily on training, experience, education, and powers of abstraction. Hence the concept "map," for example, can be interpreted very differently by people who come to it from different professional, experiential, or technical backgrounds.

However, it is also suggested that input to schemata depends on both instances and abstraction, and that the latter are more likely to be widely shared and agreed upon (Crocker 1984). Crocker proposed that the more general the agreement on a particular schema, the harder it is to change, since it is embedded in interpersonal relations, and may also be part of cultural values and ideology. Nonetheless, there is ample evidence of change to a schema once it is embedded, and Crocker has developed a quasi-typology of schema-changing events and techniques. "Map" is surely an example of a culturally embedded schema, with multiple shared abstractions, but also one that is ripe for change as technology impinges upon it.

Drawing on her study of effects of mass media coverage on public perception of risks posed by science and technology, Priest concludes that public concerns in this arena form robust schemata (Priest 1995). Such robust schemata are of the type brought by non-scientists to the presentation (by scientists) of ecological assessments via GIS maps. The implications of inherently strong schemata extend directly into the information gap outlined above: when audiences have unmet information needs they are likely to be cautious, at best, in their acceptance of new ideas. By extension, "public support is more likely to be encouraged by public dialogue on the broadest possible range of related social issues" (Priest 1995, p50).

Dual coding theory adds to the discussion the concept of effectiveness in learning. By using separate verbal and visual pathways to store and retrieve knowledge, it is believed we create stronger schemata, thus also reducing immediate cognitive load and leaving learning channels more available for new information or higher-level analysis. Key themes of dual coding include the verbal-nonverbal distinction between language and the nonlinguistic experience to which language refers; the distinction between semantic features and the contexts which can change their meanings; and the idea that meaning/comprehension occurs in gradations from superficial impressions to deeper, more complete understandings (Sadoski and Paivio 2001). Embedded in this collection of themes is the approach preferred by symbolic interactionists in trying to understand how meaning is created. For example,

> "Current views of meaning and comprehension ...have evolved away from extracting meaning from stimuli and toward the view of an active comprehender who operates continually in both internal and external, verbal and nonverbal situational contexts. This active meaning-maker regularly infers, models, distorts, and reads more into a message than was presented" (Sadoski and Paivio 2001, p.68).

The idea of reading more into a message than was presented suggests yet another element in the scientist/non-scientist communication gap that is here explained by both schema theory and dual coding theory: if comprehension is not full and immediate, existing schemata will fill in the gaps to the best of their ability, calling upon both verbal and visual information (Crocker 1984). The result can too easily be misunderstanding that remains invisible to all parties.

As an extension to dual coding theory, it is suggested that presenting information in formats that encourage simultaneous verbal encoding, visual encoding, and building referential connections between the two processing pathways encourages improved comprehension and retention (Mayer and Sims 1994). A high degree of visual-verbal overlap in presentations, as well as simultaneous verbal-visual presentation, and use of concrete text improves comprehension and retention. Investigating applications of this idea in the realm of GIS maps as presentation devices would offer a useful continuation of the current study.

Finally, studies of graphic organizers place maps in a learning context as the ultimate example of visual aids. In a critique of this field of research, Dunston finds that most such organizers are developed according to the knowledge, understanding, language, and schemata of the teacher, in our case the map maker, and may not activate the appropriate schemata in students, our non-scientists (Dunston 1992). Additionally, she notes that graphic organizers assume the existence of useful schemata; it does not take a long leap to imagine non-scientists failing to find schemata which for them correspond to, say, nearest-neighbor pixel averaging (a CLAMS/GIS innovation), of which they have never previously heard.

Across the Larger Landscape

With the idea of pre-formed cognitive structures in our minds, potentially differing greatly from those around us, it is important here to consider an issue implicit to GIS maps of ecosystems: the landscape scale view. As introduction to the study of landscape-scale science, we can borrow specifically from landscape ecology, but only as an introduction to a field of study that might more aptly be named "landscapeology," here construed to mean the general study of large landscapes.

First, what are the tools and assumptions of landscape ecology? What do they tell us about the challenge of moving up-scale from the site level to the megashed level?

It is perhaps most fitting to begin this discussion with thoughts from one of the grandfathers of ecosystem management—the concept of managing not for single species or stands of trees, but for whole functioning ecosystems. At about the time he was asked to contribute to a science-based land management plan centered on the northern spotted owl, Jerry Franklin was recognizing what to him and others was the folly of this approach (Franklin 1993). He proposed the fundamental impossibility of dealing with more than a small fraction of diversity at the species level, because it would rapidly exhaust time, money, patience, and scientific knowledge. And he pushed the scale far beyond what scientific research had routinely embraced up to that point, noting that conservation of biological diversity critically required planning and assessing at the level of landscapes and ecosystems as well as individual species. The larger task, stewardship of all of the species on all of the landscape, is "a task without spatial and temporal boundaries" (Franklin 1993).

Ecological sciences are more recently recognized by many, inside and outside the science arena, to be in transition (Holling 1998; Gunderson 1999; Tibbets 2000), being linked across scales, from the physiological to the landscape level. The transition is facilitated by a maturing body of theory, methods, and examples, and comes at a time when the policies needed to harmonize the interaction between people and nature occurs at unfamiliar scales from neighborhood to regional to global. Holling extends this point to assert that the very global culture of science can help grapple with the new scale of inquiry, since the common foundation of scientific inquiry—albeit under heavy fire in recent decades—is shared across history, language and experience between scientists (Holling 1998). Nonetheless, scholars of ecology, along with ecologists, recognize the challenges not met by the discipline: the normative basis for policy, a deterministic general theory, and of course, actual resolution of ongoing environmental problems (Shrader-Frechette and McCoy 1993; Peters 1991; Hendriks 2000).

Their concerns are reflected across the literature (Shrader-Frechette and McCoy 1993; Peters 1991; Hendriks 2000; Tibbets 2000; Gunderson 1999). Control and replication, as required by scientific method, are difficult to establish in ecological experiments across landscapes, and reproducing another ecologist's results is fraught with difficulty and rarely attempted. In fact, Peters hopes that ecology is entering a period of crisis, or transition, as posed by Kuhn (1962) as the predecessor to revolutionary change. Its ability to address ecological issues at the landscape scale is inevitably part of that revolution.

Tibbets (2000) takes particular note of the role restoration science plays, as a demanding science that also has social, economic, historical and cultural dimensions; others concur that with the new scale come new epistemologies (Gunderson 1999). Orians had earlier contributed the idea that existing legislation such as the Endangered Species Act was perhaps ill-conceived, and would benefit extensively from being revised as an Endangered Ecosystems Act (Orians 1993). While this suggestion incorporates the many conflicts within and around the sciences of ecology and ecosystems, it is difficult to imagine such legislation surviving the process of being drafted.

What Franklin and his like-minded colleagues could not foresee was that while science around the globe was developing the interpretive tools, such as GIS maps, it was not developing its interpretive skills at the same rate. The paramount social need for dialogic communication disappears below the technological radar; CLAMS is a perfect example of a technology-driven scientific enterprise in which the social aspects were tacked on after the fact.

Norton expresses this disconnect most firmly and explicitly:

> "Ecologists have not sufficiently understood the importance of scale in their own discipline and even to the extent they have recognized the importance of scalar phenomena, they have not taken policy-relevant scale considerations as compelling or even useful information in developing their topics of study and in choosing their research methodologies and the scale at which their studies are directed. Admittedly, landscape-scale ecology is very difficult and one must build such studies from analytic understanding of subsystems" (Norton 1998, p.359).

Yes, the landscape scale is difficult. In fact, it may be that few people other than the ecologists and meteorologists who routinely work at the landscape scale are ready to "see" whole landscapes at once (Shindler 2000). Context is crucial to this kind of "seeing" and certainly more complex discussions between researchers and the public might yield better understanding. Costanza adds that public opinion is notoriously fickle and inconsistent, precisely on those issues for which it has not looked at system-level, or large-scale, implications of its opinions (Costanza 2001).

To better understand how citizens view landscapes, Shindler proposes scientists go beyond attempts to "educate the public" and instead interact with citizens to promote learning, find appropriate outreach activities and simulation techniques, and directly address questions about risk and uncertainty. Easier said than done, of course, and Norton's studies suggest that both managers and scientists are predisposed to undervalue the social and technical learning that comes from policy discourse (Norton 1998).

To a significant degree in many of these studies, maps are simply implied as tools of landscape assessment. Consequently, the combination of research into ecosystem processes, with the power of GIS, has paved the way for the emergence of an evolving science of ecological forecasting such as CLAMS represents (Clark et al. 2001). The "prediction enterprise" constitutes the quest for predictions of earth systems, but it exists undeniably in a dynamic social and political milieu (Pielke jr., Sarewitz, and Byerly 2000). Pielke and his colleagues note that the participants in this enterprise necessarily represent a great diversity of interests and values: the broad public, policy makers, and scientists, the latter torn between helping to "define and resolve problems while at the same time satisfying (their) own desire to expand the frontiers of knowledge" (Pielke jr., Sarewitz, and Byerly 2000, p.362).

As clear as the implications of ecological forecasting are for ecological planning and management, however, what is perhaps of greatest importance is the need for interdisciplinary linkages that will take into consideration the societal controls on ecosystems. Without connecting to social dimensions, ecological forecasting runs the risk of being merely one more fancy technology, with narrowly-defined research uses that fail to capture its social potentials (Pielke jr., Sarewitz, and Byerly 2000).

Shindler, for example, argues that spatial scale is a nebulous term for non-scientists, that boundary designations carry a spatial meaning that people recognize and value, and that these geographic designations are too often treated by scientists as if separate from our social order, or even non-existent. Understanding, he proposes, is more likely to occur in the context of a meaningful personal relationship with the landscape than in some anonymous provision of information (Shindler 2000).

To what degree do meaningful personal relationships with the landscape—sense of place, whether we live there or not—affect our social interactions with it, and thus with the scientists who attempt to define it on their own terms?

Aldo Leopold's "ecological conscience" (Leopold 1949) has done much, directly and indirectly, to bring us to where we are today, poring over maps to determine which ethical, spiritual, physical, and ecological direction we might best take to chart the future of our natural heritage. Much of our society, particularly the technocratic segment, lives out the very attraction-repulsion conflict Euro-Americans have traditionally displayed towards wilderness (Nash 1967), and seeks, with the best ecological intentions, to control nature. Even by designating wilderness, and "leaving it alone," we leave our mark upon it, Nash argues.

Our quest to establish a sense of place takes many forms, and it draws heavily from the schemata we begin to establish from an early age:

> "The appreciation of landscape is more personal and longer lasting when it is mixed with the memory of human incidents. It also endures beyond the fleeting when aesthetic pleasure is combined with scientific curiosity" (Tuan 1974, p.95).

Tuan proposes that humans have a highly developed capacity for symbolic behavior, creating mental worlds to mediate between themselves and external reality; these mental worlds change through time, and according to our personal mythologies and taxonomies. The obvious result is that any group of people will have numerous different perceptions of a concept such as "map."

Norton and Hannon add to this discussion the idea that if devolution of responsibilities for environmental quality from the federal to state and local governments does indeed develop, it needs to be met with a process of social learning (Norton and Hannon 1998). Such processes of learning, they believe,

> "...must be iterative; they must encourage ongoing discussion of environmental goals and how those goals interact with socially and culturally expressed statements of the distinctiveness of particular places" (Norton and Hannon 1998, p.140).

The implication goes beyond the need for willingness to accept local responsibility for resources. It literally drafts maps and mapmakers into the front lines of decision-making.

The experience of CLAMS principal investigators meshes with Tuan's idea of topophilia, the affective connection between people and place or setting: when the maps of the Oregon Coast Range come out, the whole atmosphere changes, and people's attention is riveted on the area they care most about (Norm Johnson, pers.comm.).

Echoing the idea of a disconnect between the world of small-scale, descriptive ecological sciences, and the world of life-scale, landscape-level management of natural resources across large spaces and long time frames, Baskerville has suggested that the models produced by science, "with the classic contemporary focus on precision" are unlikely to be directly usable at the scale of management (Baskerville 1997). In a similar vein, others have pointed out that the usual tools of decision analysis do not apply to problems with ambiguous objectives, and multiple, contradictory approaches (Carpenter 2002).

Noting that quantitative ecological predictions are probabilistic, and cannot take into account unforeseen thresholds and surprising dynamics, Carpenter's strongest recommendation is for the use of scenarios—defined as narratives of possible futures—to help bring future considerations into present decisions when prediction is not possible. In scenarios, ecologists can play the dual roles of imagining and disciplining accounts of the future, by underscoring known uncertainties, and investigating the connections between slow and fast changes (Carpenter 2002). It is a story-making role not routinely used to date, and suggesting a return to far older and less technological methods of sharing knowledge. Scientists as map makers, then, have their work cut out for them, for they are dabbling in the palette of personal mythologies.

Whose Truth Prevails?

> "Not only is it easy to lie with maps, it's essential. To portray meaningful relationships for a complex, three-dimensional world on a flat sheet of paper or a video screen, a map must distort reality...There's no escape from the cartographic paradox: to present a useful and truthful picture, an accurate map must tell white lies" (Monmonier 1996, p.1).

Twenty years before Monmonier published his provocative How to Lie with Maps, two other cartographers, also passionate about their profession, recognized the need to review, perhaps even retrospectively to create, its theoretical foundations. The Nature of Maps (Robinson and Petchenik 1976) still stands as a seminal work in the field of cartography, asking questions of its practitioners that need continuous examination, given the simple truth that maps do indeed tell lies, and that the rapid development of GIS technology may just have made it easier.

Robinson and Petchenik follow several key themes, of which the most pertinent to the current study is that maps are tools of communication. The 'map idea' was only just beginning to be examined in the literature (Imhof 1965; Kolacny 1968; Green and Courtis 1966), and its now-obvious connection to communication theory was greatly assisted by Robinson and Petchenik's insistence upon its importance. Arguing that mapping derives from systems of assumptions, logic, human needs, and human cognitive characteristics, they deduced that as cartography increases in complexity, the analytical and intuitive effort needed to produce successful maps will increase.

Furthermore, they acknowledged that even though mapping provides an ordering and simplifying system that has great advantages over the direct experience of reality, any given arrangement of markings on a map relates to spatial 'reality' only by agreement, not by sensory testability. The corollary they suggest is that the more fluent map 'percipients' (users) become in the language and process of map-making, the more transparent map markings become. In other words, the greater the quantity of shared meaning between map maker and map user. Interestingly, however, other research confirms that there is little difference between novices and experts in terms of learning and remembering map-based information (Kulhavy, Stock, and Kealy 1993), although the more specialized the data added to the map, the more difference there is between the experienced (scientists as map makers) and the inexperienced (non-scientists as map users) in ability to acquire information from the map (Kulhavy, Pridemore, and Stock 1992).

Other studies strongly support the idea that poor design in maps, whether because of the training or inexperience of map makers, or because of the nature of the technology in use, can seriously hamper understanding by map users (Weibel and

Buttenfield 1992; Kiel and Rines 1992). One aspect of the problem, of course, is that different representations of the same data are called upon to support different tasks (Casner 1991), and can add inadvertently to confusion and mistrust. At least one study, however, found that three different representations of the same data, in this case pertaining to a forest harvest decision, had little effect on the final decision, provided the map users had enough experience to compensate for poor map design (McKendry 2000). This particular study did not control for different levels of professional experience in decisions based on map use. It did, however, reveal the importance of the act of compensation in map-reading, a mental maneuver more accessible to people experienced with GIS maps than those less experienced.

If we accept Robinson and Petchenik's corollary about map users and their varying fluencies, we should ask whether it therefore applies to all the other assumptions embedded in maps. The problem with any map, of course, and with multi-layered GIS maps in particular, is that the list of assumptions grows longer with every production run, and is equaled only by the list of uncertainties that ought to be made explicit if we are to communicate clearly with maps (Monmonier 1996). Imhof had previously argued for the importance of good training and gifted personnel in map-making, but insisted that cartographers, whatever their gifts and tools at hand, should clearly understand their roles in the larger system of communication, in which they are but one part (Imhof 1965).

Cartographers are indeed but one part of the larger system of communication. It is not just Monmonier's flamboyant characterization of maps as lies that should be kept in mind. Tufte, the recognized guru of quantitative data display, comments on data maps in general:

> "Notice how quickly and naturally our attention has been drawn toward exploring the substantive content of the data rather than toward questions of methodology and technique" (Tufte 1983, p.20).

He also notes the increase by orders of magnitude of data density since the time early maps of earth and sky were created and agreed upon. Those who accept complex GIS maps at face value, therefore, are accepting increasingly large quantities of invisible data.

So very much is assumed, both by map makers as they select their symbols and frames of reference, and by map users as they receive, often passively, the implied messages, that lies can surely be told without anyone fully recognizing it. It has been observed that the human eye is capable of capturing information from a map that no automatic processing could hope to capture (Jankowski, Andrienko, and Andrienko 2001). But maps are not only sources of information, they catalyze preferences among spatial options; thus their construction is fraught with responsibility. Hence the current investigation.

GIS as Communication Device: Peril and Promise

GIS "can support both exploratory and confirmatory analysis, provide tools for both inductive and deductive approaches, and support both scientific research and the implementation of public policy based on GIS models" (Mark 2000, p.47). The background assumption here, as elsewhere, is that GIS has a great deal to offer and deserves full investigation, not least as a mechanism of social change. However, as noted by Sieber and others, most of the reported benefits of GIS use are based on process, and derive from a culturally-biased process orientation: efficiency gains in data handling, increases in cartographic and analytic capability, improved visualization and communication of spatial information, and enhanced decision-making (Sieber 2000).

A lucid recent history of the critique and debate within the geographic community about GIS has brought forth an integrative approach that does not favor either the social theorists who decry the positivism inherent in much of the science of GIS, nor the technologists who see no use for theorizing their emerging science, and wish only to get on with their work (Schuurman 1999).

> "Inquiries into the assumptions used in data acquisition, data organization, modeling, the generation of surfaces, and graphic display constitute just a few of the potential avenues for studying the technology along the dual axes of STS (science and technology studies) and GIS" (Schuurman 1999, p.99).

Schuurmans' synthetic monograph does much to redefine both the nature of GIS itself, and also the potentials for its research, which have been too tightly constrained to date, she believes, by disciplinary history and bias. In this viewpoint she concurs with others who have pointed out that data collection and subsequent "ownership" are hardly unproblematic matters; indeed the "ontologically shallow" analysis typical of GIS has long been decried as insufficient to the task of comprehending the many epistemological points of difference among users, students, and creators of GIS (Taylor and Johnston 1995).

In the ongoing debates within geography between social geographers and GIS researchers, GIS is postulated variously as both highly technical and therefore in need of translation, and also as a throwback to the importance of intuition and simplicity of exploration, compared with some of the quantitative methodologies available today (Schuurman 1999). Naturally these two characterizations depend on point of view, but what is important here is that the coming to fruition of GIS techniques has certainly changed the playing field, however that change is defined. A decade ago, it was noted that the tendency was to look at GIS as a technical and organizational issue, but that already the cost of its development and adoption were leading to its emergence as a "tool and product that changes the way certain groups and organizations operate" (Pickles 1995). Pickles contends that, among other things, the contingent nature of technical outcomes is overlooked, and the exploitation of some groups becomes a real possibility.

In more recent work, he emphasizes how important it is "to study maps in human terms, to unmask their hidden agendas, to describe and account for their social embeddedness and the way they function as microphysics of power" (Pickles 2004, p.181). Maps, he insists, are part of a body of social practices with ethical implications.

Following the path these scholars have laid, the current study can investigate how perceptions of maps—directly influenced by technical aspects of cartographic display in GIS, yet also by individuals' unique schemata for "seeing" maps—can affect the complex social and technical processes required for decision-making about natural resources.

Mark led a team investigating issues of scale, integration, process models, and usability, then focused on particular challenges arising in representation of geographic data in binary mode (Mark 2000). How do we summarize, model, and visualize differences between digital representation and real phenomena? In particular, Mark notes, simulation is in its infancy. Issues of usability of systems and technologies, he agrees, lack a theoretical base; he recognizes specific gaps in knowledge, such as how people respond to uncertainty, and what the scalar issues are.

Recent research points to the value of developing visualization techniques for representing uncertainty (Aerts, Clarke, and Keuper 2003). The researchers note,

> "Managing uncertainty for decision-making issues involves quantifying uncertainty, and having a thorough understanding of how uncertainty propagates through different operations in the model. Moreover, it involves learning how to make a decision when uncertainty is present and communicating uncertainty to decision-makers" (Aerts, Clarke, and Keuper 2003, p.249).

In this study experts as well as novices responded positively to various techniques for displaying uncertainty on GIS maps, and the researchers concluded that such techniques can indeed improve the efficiency of spatial decision-making for land allocation issues. The idea of revealing the questions inherent within a map has considerable power in the context of negotiating its meaning: if it is truly more than just a two-dimensional image, actors using it to make decisions need to understand its other dimensions, or their decisions, obviously, will be constrained by their knowledge limitations.

A diverse range of approaches to research around the social and technical capacities of GIS have been attempted and reported in the literature, which universally acknowledges these kinds of studies—where they exist at all—to be in their infancy. "Missing" aspects of GIS research abound:

> "...maps have been used predominantly as presentation media either to display the results of spatial decision analysis or to inform about the location of decision options. The use of maps as analytical tools in spatial decision analysis has been little explored" (Jankowski, Andrienko, and Andrienko 2001, p.102).

Jankowski and his colleagues note, for example, that for experts, the idea of a map was chiefly as a convenient tool for checking the output of their models against their expectations.

Consequently, it is generally acknowledged that accurate data on benefits generated by GIS technology are rare (Gillespie 2000). Of course the dearth of information should not be seen as a failing of the field of Geographic Information Science, merely as an indicator of its status as a relative newcomer, both as a research and analysis method and, more recently, a communication tool. Some of the more confounding questions remaining about GIS involve its design methodologies. If such barriers can be overcome, changes in the way science is performed, in the ways it is taught and learned, and even in the way we think, by diffusing ideas across disciplines, are inevitable (Gillespie 2000).

Some thinkers have decried GIS as crossing moral and ethical lines we should not trust, the "big brother" image flickering in the background. Most glaringly questionable in this context is the prevalence of monopolistic software providers with formalized rules and standards, the cost of hardware and software, and the difficulty in learning how to analyze and model complex relationships without full knowledge of how to use GIS (Curry 1998). Designed around a dominant style of thinking, such a technology inevitably discards important elements of the sense of place, reducing them to the "detritus of calculations."

In an effort reflecting the direction of recent work on the human-machine-human interface and cognitive principles, Mennis and others combine the geographic tradition for representing large-scale events with cognitive evidence from the field of psychology (Mennis, Peuquet, and Qian 2000). In other words, how might the software be better designed to match the ways the human brain stores, retrieves, and analyzes data? Their exhaustive review of cognitive storage and categorizing methods suggests patterns that might usefully be adopted in spatial databases.

The findings of these authors highlight a mode of thinking that remains grounded in the time before the rapid growth of computing power. Conventional views of database modeling take it to be the creation of a static structure with a lifetime that corresponds only to its immediate purpose. Mennis and his colleagues suggest that this provides only one view of the data, with no future development imagined or planned for. The full potential of computers as representational media can only be realized by more closely linking geographic software with the natural ordering of how humans represent and learn about geographic space.

A study of the relationship of GIS to organizational learning suggests that seeing GIS instead as GICS—Geographic Information and Communication Systems—would help in understanding that while GIS provides vast new quantities of information, it is the communication and sharing of that information that leads to yet newer information, and thus to learning (Hendriks 2000).

The point here is that GIS is an enabling technology. In other words, its importance lies in helping agencies or businesses work better, not just cheaper. Multifaceted research into its effectiveness as a communication tool is a logical next step.

Technology on the Move

The technology diffusion literature has several contributions to make to this investigation. Diffusion studies have contributed empirically and quantitatively to theories of social change, and have influenced research developments in sociology, economics, political science, and communication (Wejnert 2002).

Most researchers agree that adaptation to technology occurs in phases. One proposed path includes awareness, interest, evaluation, trial, and adoption (Brunn, Dahlman, and Taylor 1998). Another posits knowledge, persuasion, decision, implementation, confirmation, with the middle three highly dependent on potential users' being influenced by and learning from current users (Rogers 2003). What is most important to note for the current study is that along the trail from innovation, through early diffusion, to embedding, comes the need for change, at both the macro (organizational) and micro (individual) levels (Beard 2002).

It is conceivable that staging within these phases derives from a variety of sources, ranging from fear of change and new technology, to lack of resources and training, scarcity of infrastructure, or sociocultural barriers (Brunn, Dahlman, and Taylor 1998). Here questions of societal values and of dependence and dominance need consideration (Masser 1996). In turn, the stage of diffusion produces somewhat predictable responses by end users, who progress along the diffusion trail at variable rates. Beard contributes a framework by which to map the diffusion literature, in order to discern unforeseen connections between and among business, science, and engineering literatures. He proposes that such connections will grow in importance as further technological advances continue to propagate (Beard 2002).

Most useful to the consideration of the technology diffusion literature is Wejnert's integration of diffusion innovation models (Wejnert 2002). In reviewing the array of variables involved in innovation adoption, she notes the crucial need in diffusion research to incorporate more fully the interactive nature of diffusion variables; the gating or filtering function of those variables; and how the rate of diffusion over time is affected by each actor's characteristics. Examples of diffusion variables in the current study would include available time and financial resources; full access (including training) to the technology; shifting levels of trust between actors; and changing conceptions of responsibility for social action.

Wejnert observes that information moves from source to adopter depending upon the innovation's consequences. If the consequences—for example, more direct access to collaborative environmental decision-making—were to become widely institutionalized, the technology will more rapidly become adopted. If, on the other hand, the consequences appear to suggest that knowledge is becoming even more privileged as the technology becomes more complex, diffusion and adoption could be slowed. The interaction can be "potentiating or mitigating," and the relative weight of any one variable of course changes according to circumstances (Wejnert 2002).

One of the factors she notes affecting adoption is "structural equivalence." This suggestion has an intriguing resonance to the current study, given that some of the changes currently affecting environmental decision-making have to do with changing, post-modern, views of science and scientists. The relative rise in importance of other ways of knowing, and thus of non-scientists in the building of knowledge, may be developing a structural equivalence in society where scientists as early adopters are rapidly followed by non-scientists, who perceive that the technology is the price of staying in the game.

It is crucial in this and other investigations to recognize that there are social choices involved in technology change, and that meanings are inscribed into technologies as people adapt to them (Rohracher 2003). Simply put, the development and application of technology is a social process that requires complex management and adaptation across sometimes conflicting objectives; it is socially constructed (Beard 2002; Narayanan 2001).

Rohracher notes that the early stages of diffusion include an openness to adopting a product, and the development of the means for integrating it into existing socio-technical systems. Gaining a better understanding of the early diffusion stage therefore appears to be interesting from both a theoretical (understanding the social shaping of technology) and a practical (policy interventions in technological change) standpoint (Rohracher 2003).

Rorhracher notes that it is in the transitional period from innovation to the early stages of diffusion that user involvement has the greatest impact on the social shaping of technology. In the natural resource management world, it is safe to say that the innovation phase for GIS is over: the technology has rapidly become the presentation format of choice. What stage of diffusion any group of end-users is in depends to a great degree on the size of their operation. Watershed councils, for example, because of their funding and personnel constraints, will linger longer in the early diffusion stage than a federal agency. Rohracher observes that the embedding of a new technology is a complex issue, with several layers of discourse acting simultaneously to shape the direction of technical solutions. He writes,

> "Shaping discourses and shaping the way these discourse translate into technology can also be a long-term interactive and sometimes conflict-ridden process between users, producers, and other actors" (Rohracher 2003, p.187).

The battle over whether technologies have political or social values embedded in them has been raging for some time in the science and technology studies literature. As with the debate over qualitative versus quantitative methodologies, it is more productive to accord all sides of the debate at least some status, thereby learning from many perspectives. Thinking of technologies as boundary objects that continuously mediate expectations is a valuable perspective (Rappert 2001), and so, too, is treating as contingent the capacities of technologies, the practices of using them, and their consequences. The exclusion of certain groups from decisions, whether through lack of resources or through their own disinclination to become active, can tell us much about the wider social structure.

Considerable thought needs to be given, in evaluating a technology and its usefulness, to whether the technology abides by the formal 'rules' of its use, or the informal and contingent practices that emerge out of experience (Rappert 2001). GIS technologies are designed to locate data spatially, but this is far from the full extent of what GIS maps actually do, when they are laid out before a conflicted group, for example. While it is conceivable that the technology can be 'blamed' for such matters as uncertainty, fuzziness, and invasion of privacy, it is inconceivable to pretend no human decision is involved in each of those areas. In Rappert's words, at this point "the question of who has to deal with the ambiguities becomes an important practical consideration" (Rappert 2001, p.584). The most applicable research takes into account control of information, asymmetrical knowledge, marginalized expertise and learning, and the construction of individual narratives in order to make sense of the day-to-day use of technology.

Mapmaker, Mapmaker, Make me a Map

So who are the mapmakers, and what are their tools and assumptions, their language of representation?

If mapmakers see their GIS tools as a continuation and expansion of their ability to ramp up their channel capacity and get more information onto a single page, their defiance of communication theory and its tenets will maintain their positions as mere engineers playing with mathematical tools (Green and Courtis 1966). The simple fact that maps commonly generate conversation suggests they will be used in map-based argumentation and mediation; thus studying the use of GIS is as important as developing the technology itself (Nyerges, Jankowski, and Drew 2002).

Rather than pursue a single-minded goal of continued tool development, Nyerges and colleagues make the case for a reconstructivist perspective on the social-behavioral implications of tool use. Clearly, GIS maps are here to stay in the planning world, but tool use within organizations and their bureaucracies raises questions of structure and meaning in planning situations; the social norms that guide such tool use will doubtless repay critical evaluation.

Several researchers have focused on the area of framing the dimensions of an environmental problem. In a case study in Mexican land-use decisions, the findings demonstrate that experts play the double role of providing technical advice while at the same time complementing the data with other research (Bojorquez-Tapia, Diaz-Mondragon, and Ezcurra 2001), a typical situation in natural resource management decisions.

The crucial need for consensus between scientists and non-scientists on decision rules echoes Kasemir's finding that scientific researchers do not inherently have the capacity to frame the dimensions of an environmental problem in ways the public will understand (Kasemir et al. 2000), although other researchers point out that neither do they lack this capacity, as advocates of "value-neutral" science seem to suggest (Gethman 2001). Correctly framing the problem begins to place GIS maps in the position of serving, potentially, as conflict resolution tools (Bojorquez-Tapia, Diaz-Mondragon, and Ezcurra 2001).

This compelling perspective on a technology originally designed as a digital presentation medium is supported by findings from an experiment on collaborative decision-making using GIS (Jankowski and Nyerges 2001). Noting variable use of GIS maps during phases of decision-making, the researchers also observed that the exploratory-structuring phase had low conflict, and the analytic-integrating phase had high conflict. They conclude that GIS maps in the role of conflict management are likely to help work through it, such conflict now being recognized in public decision problems as routine and necessary. Recognized, yes; universally recognized, no.

In considering the unintended consequences of GIS development, Curry proposes that intellectual property rights seem so far to have trumped rights to privacy, a battle that could be played out in new ways as we attempt to manage natural resources across entire landscapes (Curry 1998).

Another reinterpretation of GIS as agent of change suggests it could instead become a changed agent:

> "Quite different from public agencies that may use GIS to reaffirm the status quo, GROs (grass roots organizations) may redefine GIS and therefore transform the meaning of issues to which GIS is applied.

> Asserting meaning for oneself allows one to throw off the yoke of being defined by the dominant class" (Sieber 2000, p. 787).

She found among the GROs she researched that they "apply GIS to goals loftier than efficiency, such as the transformation of meaning" (p.789). In this turnabout scenario we return to the concept of negotiated meaning (Weber and Word 2001), surely the locus of mutual learning. And in the quest to understand how GIS development could generate changes in natural resource management, surely the transformation of meaning, particularly the meaning of place, deserves a seat at the table?

Such findings introduce the question of whether the 'map idea' is following a trajectory starting from universal social icon, ranging through scientific stumbling block, and ending as a beacon of environmental policy-making. If the "best available science" is to be used consistently as a resource for environmental policy-making (Johnson et al. 1999), should we not ensure that the graphical devices we use to present any of it actually work across scales, cultures, and social space?

The idea of technological determinism that was made famous by Marshall McLuhan (McLuhan 1964)—we shape our tools and they in turn shape us—is coming back into vogue perhaps because its practical and theoretical implications are now more daily before us. Does a tool-using culture let its tools intrude on its beliefs and values? If indeed we have become a "technopoly" (Postman 1992), a society whose thought-world is monopolized by technology, Postman believes we are at risk of seeking our authorization from, finding our satisfaction in, and taking our orders from technology. Pickles added some acid to the discussion early, with his support of the idea that maps have always been precursors to exploitive behaviors: they chart and stake a claim to new territories, by wealthy investors, in a world that undeniably can be shaped, manipulated, and acted upon (Pickles 1995).

And yet the case of GIS maps does not conform completely to this idea. Knowing that postmodern thought guarantees a skeptical view of the science enterprise, knowing that numerous scholars, including ecologists, are contributing ideas of evolving investigatory frameworks to the literature, knowing that seeing at a landscape scale can be a learned ability, we can hope that less pessimistic options remain than to capitulate utterly to technology.

Little in the growing literature on GIS maps, their use and implications, seems to address the understanding of the term "map" at the basic conceptual level, and yet it is precisely at this level that the traditional idea of map as wayfinder and locator can be left rather abruptly behind by the continuing technological advances of GIS. The idea of a map as the tip of an iceberg of databases is particularly useful here (Schuurman 1999). If non-scientist citizens are to be fully engaged in decision-making about natural resources, their ability to "see" GIS maps in their staggeringly information-dense entirety is surely important. If scientists are to participate in or facilitate public debate about natural resource management, their ability to take outside conceptions of their GIS maps into account, and to work towards fully negotiated meanings for them, is just as crucial.

It is reassuring to think that we are, with GIS maps, at a crossroads. The history of cartography offers similar turning points, where explorers pushed the bounds of imagination into new areas of the globe, and those left behind lived in fear of the unknown. GIS maps, if we apply our imaginations to them and their potentials, may become one fulcrum upon which we can balance our multiple ways of knowing the world.

The idea here is not to prescribe social theory, nor algorithmic revision, to "fix the problem" of cross-cultural communication with GIS. The idea, instead, is to identify in what ways the maps produced by the ever-developing technology are understood or misunderstood, in order ultimately that intentional adjustments of both a social and technological nature might be made to the way GIS maps are used in environmental decision-making.

The starting point for such an enterprise is to think more profoundly about how we, scientists and non-scientists alike, conceptualize maps and the spatial data they represent, in the most practical sense: what do we think they are, and what do we think they can do? How do these ideas need to change and adapt in a GIS-oriented environmental decision-making context?

Natural Resource Decisions at a Crossroads?

One final area of social science research that could help shed considerable light on this inquiry focuses on the concept of managing transition (Rotmans, Kemp, and van Asselt 2001). Borrowing from the transition literature of ecology that has its roots in biology and population dynamics (Davis 1945; Notestein 1945), the development of transition management theory in social science allows us to consider explicitly how the concept of a balance point—an intentional turning point in social dynamics—comes into play.

Transition, according to ecological theory, generally passes through four phases—pre-development, take-off, acceleration, and stabilization. In general, it is accepted that multiple variables come into play during transition, that speed and acceleration are relative notions, and that transition is the result of developments in different domains. The notion of dynamic balance is paramount in understanding transition: while there may appear to be a status quo, much is changing under the surface. In the predevelopment phase the "status quo" is most apparent because it is not visibly changing and a relative dynamic balance is maintained; during take-off and acceleration the entire system is undergoing change and thus variable balance points are in play while elements of the system react to each other. Finally, in the stabilization phase, the speed of change decreases, and a new dynamic balance is reached, in its turn never to be anything but a relative notion (Rotmans, Kemp, and van Asselt 2001).

It is not an objective of this inquiry to locate the CLAMS project at any point on that transition spectrum. However, as Rotmans and his colleagues suggest, the idea of transition in a social setting, while not yet sufficiently developed to be considered robust theory, does provide a useful heuristic for considering to what point various interacting social forces have brought CLAMS over the past ten years.

Transition theory suggests that a combination of reinforcing developments take place concurrently in various areas, and that different social processes play a role during the various phases. Changes can range from minor details to fundamental shifts in perspective, and any one domain within societal dynamics has the potential to provide the spark causing ignition (Rotmans, Kemp, and van Asselt 2001).

In painting a broad historical context for CLAMS, we encounter, chronologically, the environmental movements that assisted in the development of the New Environmental Paradigm (NEP); the contribution of NEP to the social furor in the Pacific Northwest leading up to FEMAT; the concurrent development of the World Wide Web, a tool whose reach and power have yet to be fully understood; the introduction and rapid improvements of GIS; the frustration of a group of scientists with having to produce answers for natural resource managers before they had data; and finally, their willingness to recognize that science could no longer be conducted independently of the social world in which it resides.

Surely, if a true transition requires some kind of turmoil to trigger it, the stage was set when the CLAMS project was conceived and cobbled together.

What the transition concept also allows us to do is to accept uncertainties and embrace multiple perspectives as given elements in the parsing of natural resource management challenges. For the idea of managing transition accepts that the very imperfection of knowledge is the essence of uncertainty, and hence rather embraces the uncertainty in scientific enterprises than quails before it.

Sources of uncertainty in the sciences of the natural resource management context include variability and limited knowledge, according to a typology devised for considering integrated assessments of all kinds (van Asselt and Rotmans 2002). This approach is an early step in testing perspective-based outcomes in order to yield robust insights. It differs significantly from the more typical approach of developing a set of future outlooks and characterizing one scenario as the most plausible. Instead, these theorists write,

> "Pluralistic uncertainty management has the explicit aim to use insights about uncertainty to better inform policy in a way useful to decision-making" (van Asselt and Rotmans 2002, p.99).

Related research involving uncertainties and the importance of social learning processes focuses on linking analytical modeling and participatory approaches, with a view to fostering sustainability and transformations in technological regimes and institutional settings (Pahl-Wostl 2002). Pahl-Wostl hypothesizes the need for innovation and change in resource management; the importance of flexibility and adaptability in assessing social and technological systems; and the central role of different actor groups in designing human-technology-environment systems.

She identifies two key points pertinent to the current study: a mismatch between mental models of decision makers and the world represented in their models and analytical approaches; and the existence of system "lock-in effects" that can prevent innovation and change. The CLAMS project reveals ample evidence of both these factors.

In her conclusions, Pahl-Wostl observes that despite spreading post-modern beliefs that effective governance is more important than technological solutions in dealing with resource issues, technological and engineering approaches continue to dominate resource management. Noting that current understanding of social transformation processes is limited, she emphasizes the "complex interdependencies of human behavior, institutional settings, environment, and technology" in resource management regimes. In the quest for transformations aimed towards sustainability, uncertainty and dynamism are assured, so transition and its management are engaged.

The concepts of transition management, social transformation, and lock-in effects, fall squarely into the category of "post-normal" science (Funtowicz and Ravetz 2001), and are critical to the attempt to address the understanding, usability, and consequences of tools such as CLAMS produces.

The Rest of the Story

With communication, understanding, learning, and consequences at the heart of the current study, it is perhaps most fitting to conclude the literature review with a brief reference to the simple concept of story-making, and how it fits into the scientific endeavor. Why might story-making be important to science?

From the earliest fireside, story telling and story-making have been an integral part of human existence and people's interpretation of their surroundings. It is partly in recognition of this deeply fundamental aspect of our existence that symbolic interactionism takes as its point of departure the search for meaning (Lyotard 1979). And it is upon this base that the concept of negotiated meaning between "foreign" cultures, such as scientists and non-scientists sometimes represent, builds (DuPraw and

Axner 1997; Weber and Word 2001). Here in the process of story-making, loosely defined and not requiring a fireside, are built the schemata upon which we frame our worldviews.

Despite a tendency for scientists to write technical papers for peer review or make formal presentations—the one-way communication model writ large—as the approved means of presenting their findings, a preference for stories has never faded among their potential audiences. With the rise of post-modern ideas on the relationship between science and society, the ancient tradition of story-making might return to its logical place at the center of learning.

Scholars offer various perspectives in how story-making operates in the scientific world. The following two are instructive:

> "*Scientia* is knowledge. It is only in the popular mind that it is equated with facts. This is, of course, flattering, since facts are incontrovertible. But it is also demeaning, since facts are meaningless. They contain no narrative. Science, by contrast, is storytelling. That is evident in the way we use our primary scientific instrument, the eye. The eye searches for shapes. It searches for a beginning, a middle, and an end" (Polanyi 2000).

And:

> "The value of information does not survive the moment when it was new. It lives only at that moment; it has to surrender to it completely and explain itself to it without losing any time. A story is different. It does not expend itself. It preserves and concentrates its strength and is capable of releasing it even after a long time" (Benjamin 1968).

Story-making, then, is what science has always been about, simply because it is what the human experience has always been about. If we are indeed in a transition, our transition might be guided by resuscitating a story-making tradition that can once again be shared, this time across the landscape images that are GIS maps.

CHAPTER 3: METHODOLOGY

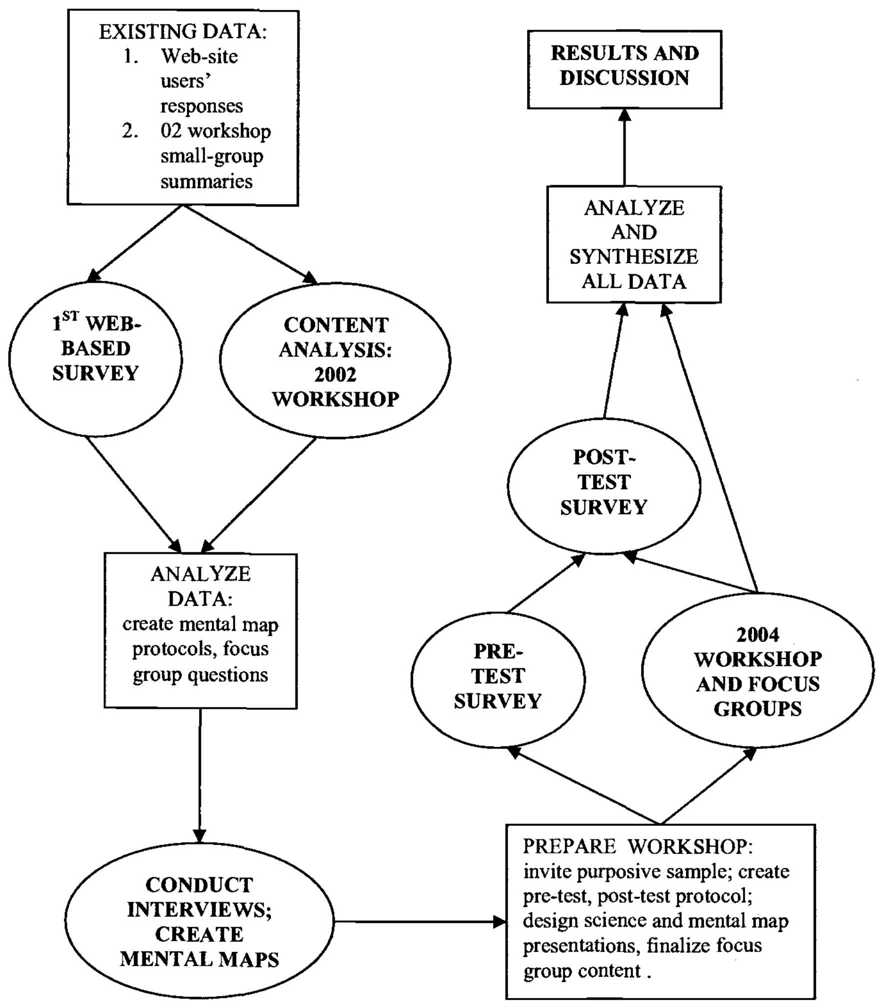
RESEARCH DESIGN

The design proposed initially for this study is represented graphically in Figure 1 (p.58). This process has been followed with few modifications: it is a case study, using a mix of methodologies, although inquiry is predominantly qualitative. Of five data sources analyzed, three are studied qualitatively, and two quantitatively. The two quantitative sources provide guidance, in the first case (Web-site Survey) for design of subsequent inquiry, and in the second case (Pre-test, Post-test Survey with Control), for clearer understanding of how thoughtful intervention could change perceptions of a technology and a process.

The first two sources to be examined (Web-site Survey, and 2002 Workshop) were essentially opportunistic, in the sense that the analysis took advantage of their pre-existence, and undertook to learn something from unexamined raw data. The remaining three (Mental Maps; 2004 Workshop/Focus Groups; and Pre-test, Post-test Survey with Control) were designed, with input from the "opportunistic" two, specifically for the current study.

Several broader aspects of this methodological approach will be discussed before the specific approaches are described.

Figure 1 Research design for CLAMS/GIS case study



Qualitative versus Quantitative

It is in the nature and definition of postmodern thought to embrace multiple epistemologies in any search for understanding. By implication, this suggests a multi-method approach to the proposed research project. As Fischer notes:

> "In many ways, the adoption of a multimethodological approach opens the door to a more subtle and complex form of rigor. Instead of narrowly concentrating on the rules of research design, combined with statistical analysis (which usually passes for empirical rigor), the post-positivist approach brings into play a multimethodological range of intellectual skills, both qualitative and quantitative...The interpretive judgments that are characteristic of every phase of scientific investigation, as well as the cumulative weighing of evidence and argument, are too rich and various to be captured by the rules governing inductive or deductive logic..." (Fischer 2000, p.77).

The qualitative/quantitative debate has enough warmth to continue indefinitely (Griffin 2003; Wallace and Wolf 1995; Feyerabend 1988), although there are now many scholars who no longer see its value. Feyerabend, for example, unsubtly frames the debate by asking if we are really to believe that the "naïve and simple-minded rules which methodologists take as their guide are capable of accounting for such a 'maze of interactions'" as history offers (Feyerabend 1988). He notes that there is not a single rule of methodology that is not from time to time violated, arguing that these are no accidental events but rather absolutely necessary for the growth of knowledge.

In general, symbolic interactionists tend to dislike quantitative techniques on principle, claiming that they distance the observer from the areas of life under study, and worse, ignore those aspects of life, or conflict, or meaning, not built directly into the chosen measurement instrument (Wallace and Wolf 1995). There is of course no set of rules here, either: an analyst can believe in both inducing propositions from experience, and using quantitative methods for verification, for example.

Without necessarily accepting the negative premise of diatribes against statistics (Best 2001; Grumet 1993), it is possible to recognize that for symbolic interactionists in particular, all but the simplest descriptive statistics rapidly lose their value in the face of the search for negotiated meaning between humans. Rather than taking up the cause for either side of this argument, however, it is more productive to consider an integrative approach to theory—the structuralist theory of science—as a useful analogy to integrating methodologies. Schweizer (1998) perceives, in this constructivist approach to theory building, the development of whole networks of theory, versus the long tradition of testing only isolated hypotheses by accepted scientific (usually empirical) methods. Recent attempts are focused on specifying the necessary conditions of scientific concepts while reconstructing some areas of research in order to gain deeper, sufficient understanding of what research is about (Schweizer 1998). This kind of "rational reconstruction" can be applied usefully to fields from landscape ecology to cognitive psychology.

By combining and integrating quantitative and qualitative methods to understand necessary and sufficient conditions respectively, researchers can deliberately engage in an iterative process of building complex theme pictures around research questions or hypotheses.

To paraphrase Robson (2002), the positivist/constructivist debate might have been useful in the 1980s and 1990s, but today languishes in the shadow of a spreading idea of rapprochement between the two camps. Particularly in applied fields, it has been proposed that the fundamental values of quantitative and qualitative researchers have a significant number of parallel beliefs: value-laden enquiry; theory-laden facts; multiple, complex, constructed, and stratified realities; and the underdetermination of theory by fact (Robson 2002; Schweizer 1998).

A thoughtful defense of qualitative methods in educational research touches purposefully on many of the issues on both sides of the lingering discord (Hammersley 2000). Identifying two models of the relationship between research and practice—the engineering model and the enlightenment model—he notes the tendency of the former to be deterministic in its underlying approach and by logical extension usually prescriptive in its findings. But this, he claims, is "systematically misleading, in giving the impression that practical prescriptions can be derived solely from factual research findings… obscuring the value assumptions that are always involved…" (Hammersley 2000, p.394).

The enlightenment model, on the other hand, tends to match more closely the assumptions about social life typically adopted by qualitative researchers, who doubt the possibility of discovering universal psychological or sociological laws, in the deterministic sense. Qualitative work, in its attempt to seek continually deeper meaning and understanding rather than definitive answers, is well-equipped to highlight practical social problems needing attention, and to reveal that such problems may have a different character from what is generally assumed (Hammersley 2000).

Hammersley's conclusions relate particularly well to the current study, arguing that any action contains a great deal of contingency, and that limiting people's responses and intent to yes/no or even five-point choices via survey research is to miss a great deal. Most pertinently, he notes that qualitative work can remind policymakers that innovation can have unintended consequences, and that "problems often cannot be solved by sheer act of will, by putting in more effort, or through trying to make practices 'transparent'" (Hammersley 2000, p.400). What Hammersley achieves with his analysis is a strong and carefully-designed argument in favor of qualitative research on the basis of its potential contributions, but without once claiming that quantitative research ought to be abandoned. His approach is worth taking as a model.

Case studies

"The case study has long been stereotyped as a weak sibling among social science methods," according to one of the research strategy's best-known resuscitators (Yin 1984). Yin has written extensively on the shortcomings of the stereotype, en route to making a convincing argument for the valuable contributions of this approach.

His definition of case study poses it as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used (Yin 1984). Progressing from this outline of the essential components, he addresses in turn the three key concerns that have given rise to the negative stereotype: lack of rigor, insufficient basis for scientific generalization, and the production of massive, unreadable documents(!).

Yin's remedy for case study rigor, shared by others (Bernard 1998; Robson 2002; Schweizer 1998; Horsburgh 2003) is simple: ramp up the rigor. Not only that, but he pointedly reminds us that experimental, survey, and historical research are also subject to bias and sloppiness, albeit more often documented and addressed.

Ability to generalize he addresses very specifically in the distinction between statistical generalization (enumerating frequencies), which case studies can rarely achieve, and theoretical generalization and expansion (analytic generalization), which is their potential forte. In other words, given sufficient case studies, with their topics, patterns, themes, and theories, careful synthetic analysis can discover trends and theoretical connections, or lack thereof, even where cases do not share common or like data.

Finally, the stereotype of lengthy documents and long field periods is not a feature absolutely required by case studies; this notion comes perhaps from the association with ethnographic methods and participant-observation data. If other methods are selected, the problems of elapsed time and quantities of data are essentially nullified.

It is useful to remember that much of the criticism of case studies originated in the positivist tradition, in which replication and control constitute the ordered means of establishing universal hypotheses (Toulmin 1990; Woolgar 1988). Horsburgh, for example, points out that evaluating qualitative research by quantitative conceptualizations of validity and reliability is unsuitable because they were not devised for this purpose (Horsburgh 2003). She suggests a qualitative framework for evaluation would help ensure that qualitative studies receive maximum recognition, citing as potential elements of the framework researcher reflexivity, the research context, the selection of participants and interpretation of their accounts, the acknowledgement of 'lay' knowledge, researcher flexibility, and the generalizability of findings. Her métier is health care research, but her recommendations clearly are transferable concepts.

Another perspective from the field of education argues that past reservations about the generalizability of qualitative research such as case studies produce turn out to be overstated (Firestone 1993). He suggests that qualitative methods are not at a particular disadvantage here, as researchers have understood for centuries that "generalization requires extrapolation that can never be fully justified logically" (p.16). One of three arguments is usually proposed to support generalizability of qualitative data, according to Firestone: sample to population; analytic generalization, or extrapolation using theory; and case-to-case translation.

Tracking the justifications for extrapolation developed by different research traditions, he finds that problems remain with sample-to-population extrapolations—sample size and selection, and the nature of the populations. For analytic generalization, the prospect is more promising: there are more ways to make links between cases, and threats to generalizability can be examined within cases. However, he notes that undetected and uncontrolled interactions can lead to a false belief in main effects, and masking of other potentially important ones.

For case-to-case transfer, the use of "thick" description provides the best hope for increasing the broad applicability of research findings; sufficient description is absolutely required to make judgments of similarity. Firestone's analysis is of great utility in the ongoing debate about qualitative versus quantitative research, for, in concert with the approach subsequently taken by Hammersley (2000), it does not require the dismantling of the one tradition to uphold the other. His differentiation of the three types of argument noted above contributes useful clarity to a discussion that too often fails to make such distinctions.

Ultimately, Firestone concludes,

> "The argument for qualitative research has never been that its claims for generalizability are exceptionally strong. Qualitative research is best for understanding the processes that go on in a situation and the beliefs and perceptions of those in it...qualitative methods should not be avoided because of the fear that their claims for broad relevance are especially weak. That is not the case" (Firestone 1993, p.22).

The question of sampling here becomes an issue for critics of case studies: what is the value of non-random (usually purposive) sampling? Again it is important to distinguish between statistical and theoretical generalization. Qualitative sampling, it is argued, is decidedly theory-driven (Miles and Huberman 1994; Arksey and Knight 1999), and thus can build more from limited numbers than can frequency-driven research. In the current case, for example, studying map use within the CLAMS project studies a single case, but allows the collection of data from a wide variety of backgrounds in training, interest-level, understanding, and social occupation. "Sampling like this, both within and across cases, puts flesh on the bones of general constructs and their relationships" (Miles and Huberman 1994, p.27). Furthermore, as suggested in the literature review, the current study has drawn from theory in multiple fields, hence attempting a broader integration and understanding than a more singular, or quantitative approach.

It was anticipated from the outset that the case study of CLAMS map use and understandability would learn and draw from other studies in similar arenas; would raise issues and questions that could readily be transferred to other settings; and could produce more data of its own which ultimately would contribute to case comparisons.

Surveys

Surveys might best be described as Pandora's box. The minute you open the box, you're in trouble. Many qualitative researchers tend to disparage the use, and overuse, of survey techniques, and cite the limitations of the form under many conditions. However, used within a multi-method approach alongside qualitative approaches, surveys can provide quantitative, confirmatory, or diagnostic views of selected aspects of a research question. What they lose in richness of detail, they make up for in summative and descriptive ability (Weller 1998).

Well-designed surveys feature specific, measurable objectives; sound research design; sound choice of population or sample; reliable and valid instruments; appropriate analysis; and accurate reporting of survey results (Fink 1995). Without the presence of each of these factors, surveys risk producing data that are unreliable, irreproducible, or invalid, externally or internally (Robson 2002; Litwin 1995). Advantages of self-administered questionnaires, such as those used in the current research project, include cost, geographic coverage, and wider coverage within a sample population; disadvantages include response rates, availability of lists of populations, and language and literacy issues (Bourque and Fielder 1995).

Web surveys present a particular set of circumstances relating to response rate (Dillman 2000). Unless multi-mode surveys are proposed, web-based surveys are at the mercy of dueling platforms and permanently significant differences in processing capability among potential respondents. While technology appears to offer unlimited options for attracting attention and pushing up response rates, any survey is quite literally limited by the lowest technological denominator; in other words, less powerful computers, older browsers, and poor telecommunications connections limit access for many respondents. Instead of helping web-based surveys become the great equalizer, and contributing to their representativeness, these problems further limit who is likely to respond, with obvious social ramifications.

To address this problem, web-survey designers can return to basic principles of survey quality: use only a portion of advanced computer capacity, design mixed-mode surveys to attract responses from people without computer access, and use PIN numbers to limit access to carefully defined sample populations (Dillman 2000).

Availability and language issues in the current study were eliminated by self-selection (prior users of CLAMS databases), and personal familiarity (previous workshop attendees). Furthermore, the basic technological level of the survey (simple format, no color, no graphics) was selected to assure the greatest level of access. These factors also addressed response rates to some extent, along with clear instructions, timed reminders, and pilot-tested survey questions.

Surveys are usually carried out for descriptive purposes, and work best with standardized questions—in other words, where the researcher knows what kinds of information is being sought, and the purpose is not merely exploratory (Weller 1998; Robson 2002). In the research described, three web-based surveys and an on-site questionnaire fit these criteria and were used to better understand specific aspects of both map makers' and map users' perceptions of GIS maps, seeking to produce descriptive information quite quickly; subsequently, as is also typical, the first of them was used to help structure succeeding, more open-ended investigations, such as focus groups (Arksey and Knight 1999). Most usefully for surveys that explore specific beliefs, responses were summarized by aggregation across demographic groups of informants.

Web-based surveys introduce several new considerations into the implementation of surveys. They dramatically reduce costs and time frames, they are trending towards universal availability in the United States and other industrialized countries, and, with technological advances, can be designed with dynamic interactive capabilities that greatly enhance both understanding and practicability of the questionnaire (Dillman 2000). However, as Dillman points out, technical sophistication sometimes eliminates accessibility, or changes it depending on type of computer or platform available. In a situation such as the current study, however, surveys are used for people with an established high rate of use of the web and e-mail, so coverage problems relate only to people who have changed e-mail addresses since last contact.

The design of web-based survey questions departs somewhat from design of paper questionnaires:

> "Meshing the demands of questionnaire logic and computer logic creates a need for instructions and assistance, which can easily be overlooked by the designer who takes for granted the respondent's facility with computer and Web software. The implication of these two logical systems is that great care must be taken in building e-mail and Web surveys in order to explain to respondents what they need to do to respond" (Dillman 2000, p.359).

Dillman has developed exhaustive principles for web-designed surveys, balanced essentially on clarity and simplicity—"designing with constraint"—in other words, a philosophy of conservative design to achieve maximum results. He also notes the tendency for people to question the true confidentiality of web-based data, a challenge that can only ever be partially met by associating with a trusted institution or research group (Dillman 2000).

Mental Mapping

Cognitive or mental mapping is a technique recognized for its use on diverse tasks, including structuring messy or complex data for problem solving; assisting the interview process by increasing understanding and generating further agendas; and managing large amounts of qualitative data from various sources. The technique is perceived by some scholars to be founded on the theory of personal constructs, which suggests that we make sense of the world in order to predict how the world might be in the future, and from there decide how we might act to change it (Ackermann, Eden, and Cropper 1996). Others relate it directly to schema theory, in that schemata tend to reveal themselves in the text of people's speech, and therefore can be represented usefully as networks of explanatory and related concepts (Bernard and Ryan 1998).

Mental maps are variously termed mental models, mindmaps, cognitive maps or models, mental frames, systems diagrams, and system influence diagrams. In discipline-specific literature, each of these may have particular meanings, but most of the designations refer to approximately the same concept, despite quite different approaches recommended by different disciplines and researchers. The following general definition is offered to clarify the current approach:

> "A mindmap is a coherent set of relationships, a systematic internally consistent picture of the theory in action that informs and guides a group's or an individual's understanding of the meaning of a particular phenomenon" (Northcutt and McCoy 2004).

Another view, using the term 'mental models,' notes that such models have been used extensively in cognitive psychology and cognitive science, in which they are useful for showing gaps between various models of the same phenomenon, and showing the existing state of knowledge (Morgan et al. 2002). Morgan and colleagues suggest the 'influence diagram' as a means of corralling diverse information into maps of existing knowledge, from expert to lay knowledge.

For Wilson and Morren, conceptual modeling represents a convergence of thought about the subject or subjects, particularly so that an improved condition can be imagined. They define modeling in general to be a stage in the learning cycle concerned with abstract conceptualization, the mental process used to make sense of events—hearkening back to schema theory (Wilson and Morren 1990).

In essence, the methodology requires capturing diverse data, frequently from open-ended interviews, in a diagram that separates and highlights key concepts or beliefs, and connects them with lines representing relationships, cause and effect, influences, or likely outcomes. In this researcher's experience, such diagrams provide an ownership to interviewees that is more likely than many other methods to offer a compelling reason for engagement in the research project (Morgan et al. 2002; Bella 1996; Wilson and Morren 1990; Checkland 1981; Northcutt and McCoy 2004).

Each of these techniques for capturing influences, relationships, active and abstract concepts, models of processes, has much in common: key concepts and themes, hierarchical ordering of expressed concerns, relationships between these concerns, flows of information and effects, patterns and disruptions. While they justifiably claim some differences in the objectives of their mapping, the overall goal of each approach adheres quite closely to the challenge of winnowing key concepts and connections out of complex data, finding patterns and surprises, and using the resulting diagrams to elicit further systemic thought.

Mental models are representations of networks of concepts, each of whose meanings are embedded in their relationships to other concepts. Importantly, they note that "the social meaning of concepts is derived from the intersection of different individuals' mental models" and that language is the key to understanding mental models (Northcutt and McCoy 2004, p.149). Here is the intersection, and the applied realm, of symbolic interactionism with schema theory.

Other scholars define a mental map as "a learned abstract framework that people use to impose order and meaning on their experience to transform it into knowledge" (Wilson and Morren 1990, p.356). Mind mapping displays patterns of thought visually; composite mind mapping, in which the input from a variety of people is used, is useful for displaying themes of concern from those people in a given situation.

All such techniques, of course, are based on the abstraction of modeling—conceptions that represent a simple or complex reality according to the interpretation of the modeler. In this case, the focus is on models of systems, albeit small systems—the production of GIS maps—embedded in larger systems, be it the scientific research enterprise, the ecosystem restoration effort, the legislative requirement arena, or any other. Thus the composite mind map of the GIS map production and use system, which was developed to present to workshop participants, is one interpretation of the elements of communication within that system. Those elements, of course, are utilized with varying degrees of success.

These applications of cognitive mapping to multiple situations—organizational, community-based, and interpersonal—underline the breadth of examples of its use contained even in this small sample of the literature: risk communication, agriculture and resource management, organizational development, and intra-organizational distortion of information. As an approach to text analysis, cognitive mapping holds the particular promise of combining "the sensitivity of human intuition and interpretation with the labor-saving characteristics of automation" (Bernard and Ryan 1998, p.624).

Northcutt and McCoy propose that the internal validity of mindmaps is the extent to which the mindmaps consistently reflect the hypotheses which comprise them.

Checking back with interviewees for input and comments allowed this researcher to confirm internal validity. External validity, being the extent to which mindmaps constructed by an independent sample of the same constituency on the same phenomenon are similar, is in this case only suggested by the similarities between maps drawn from several members of the same category, such as map makers or map users. Composites of these maps were produced to facilitate presentation at the research workshop, but also because the similarities between them far outweighed the differences.

Focus Groups

Focus groups originated in the arena of market research in the early decades of last century, based on the recognition that many consumer decisions are made in social, group settings (Robson 2002). The literature is replete with examples of cases in which their use revealed concepts and issues that might otherwise have been concealed, disconnected, or unchallenged (Pini 2002; Nolin and Peterson 1992; Balch et al. 1997). Providing space for discussion and reflexivity appears to have widely acknowledged positive benefits.

The multiple uses of focus groups suggest their utility in qualitative research. Three broad areas are generally agreed to be the domains of these groups: exploratory research where rather little is known about the phenomenon of interest; interpreting quantitative survey results and adding depth to the responses; and as a confirmatory method for testing hypotheses (Stewart and Shamdasani 1990).

The hallmark of group interviews with a subject focus is the opportunity to use group interaction to produce insights not otherwise easily accessible (Trotter and Schensul 1998). Reactions to ideas and to each other by group members encourages exploration of participants' feelings and experiences, illuminating the subject under discussion by understanding the cultural context and community conditions surrounding it. Other advantages include their ability to rapidly and inexpensively accumulate large volumes of data; the production of easy-to-understand data in the words of respondents; and the direct interaction with respondents by the researcher (Stewart and Shamdasani 1990; Arksey and Knight 1999).

Limitations of focus groups as research method tend to be the negative sides of the advantages noted above: small numbers of participants constrain generalizability; group interaction removes independence of responses, and may constrain some individuals; moderator influence; and difficulty of interpretation of some open-ended responses (Stewart and Shamdasani 1990; Arksey and Knight 1999).

Particular considerations for administering focus groups impinge upon their success in collecting valid data, and the selection of participants. In the first instance, the skills and attributes of moderators directly affect data quality; focus groups generally do not indicate consensus in attitudes of the group; and they tend to indicate nature and range of participants' views, rather than their strength (Robson 2002). In general, careful design of questions and probes for focus groups, use of experienced moderators, thoughtful analysis of data, and recognition of the differential appropriateness of one-to-one interviews versus focus groups help address such methodological issues.

Selection of participants directly affects the outcome of focus group discussions. While convenience sampling is the typical selection method, there is still a population of interest to be examined, and possibly particular mixes of individuals. Decisions about whether a group should be selected to be homogeneous or heterogeneous, or whether multiple groups with different characteristics should be employed, and whether groups include hard-to-reach participants, such as company CEOs, are crucial components of research design (Stewart and Shamdasani 1990). Homogenous groups are more likely to reveal the nature of participants' views and the level of consensus, but less likely to tease out the range of views or the differences in opinion. Heterogeneous groups should reveal both nature and range of opinions, but may exaggerate differences and thus the strength of varying opinions (Robson 2002).

Taking into account the power of social context, focus groups are a highly appropriate method within the frame of symbolic interactionism, in which meaning is negotiated through human interaction. What focus groups offer to the current research is the interactive probing for meaning in groups composed of both scientists and non-scientists, effectively map makers and map users; it is hoped that social constraints will be minimized by group members' mutual familiarity through previous participation in

CLAMS workshops. The use of focus groups here also serves to reflect and expand upon quantitative data collected earlier in the research process, a role widely acknowledged as one of their strongest.

Content Analysis

Content analysis has been selected as the methodology to examine several instances of scientist/non-scientist discussions of CLAMS, its achievements, and its possible futures. The transcribed recorder notes from the 2002 workshop form the first database, and the transcribed audio recordings of two focus group sessions at the 2004 workshop form the second. Each database was examined under the guidance of key research questions, although the wording and particulars of the questions were modified slightly between the two analyses, not least because of findings from the first analysis.

This researcher appreciates and accepts the definition of content analysis as "codified common sense" (Robson 2002). A more formal definition suggests, "Content analysis is a research technique for making replicable and valid inferences from data to their context" (Krippendorff 1980). Krippendorf elaborates that he believes content analysis to be one of the most important research techniques in the social sciences, seeking as it does to understand data as symbolic phenomena, not as a collection of physical events. The implication for any content analysis is that it will be systematic and objective, to the extent that that is possible when one human is interpreting the meaning implied by other humans.

Other researchers emphasize that it is not the words or how they are strung together but their meanings that matter in content analysis, their meanings in a given context (Miles and Huberman 1994).

Content analysis involves the coding or categorizing of bodies of text into themes or clusters of meanings, in order to understand patterns, relationships, sequences, or differences. Codes can refer to settings, definitions, perspectives, events, processes, strategies, relationships, and methods, for example. Codes can then be clustered to understand larger patterns. A valuable part of the analysis involves developing graphic representations of findings and relationships, a process which in itself frequently generates further insights.

The challenge in content analysis, not unlike many areas of qualitative analysis, is that messages rarely have a single meaning, and meanings are not necessarily shared. In a sense, then, this methodology is a perfect match for examining communication barriers between scientists and non-scientists!

The software package called N4, formerly known as NUD*IST, was used to sort and retrieve data, making full use of the memo and browse features, which allowed the researcher to capture thoughts, patterns, and connections to theory (memos), and to look through a group of associated text chunks in search of patterns or emerging meaning (browse).

Content analysis has several features that make it particularly useful in the kind of research required by the current study. Krippendorf enumerates four key benefits (Krippendorff 1980). First, it is an unobtrusive technique, thereby avoiding contaminating the act of assessment by awareness of subjects. People at a workshop, even members of a focus group, do not usually have the sense of being "watched" even if they know their words will later be analyzed. Second, it accepts unstructured data, in this case the open-ended kind found in group discussions. It also supports both qualitative and quantitative operations. Third, this kind of analysis is context-sensitive; meanings are specifically derived from the social and political context in which words and opinions are stated. Thus it gets at the central aspects of social interaction. And fourth, content analysis copes with large volumes of data, such as transcriptions of dialogue frequently produce. All of these features make content analysis a very useful methodology for the task at hand in the current study.

Drawbacks of the method include reliability and validity questions. In the current study, no consistency check was undertaken with other researchers, so it cannot be stated that the coding is consistent in its own right. However, the categories do bear clear relationship to conclusions, and have intersected and matched with several branches of relevant theory, as noted in Discussion and Conclusions. Validity of the analysis is reinforced by using *in vivo* coding where applicable, and by comparing selected categories with findings from other analyses for the same study. Thus ideas about decision-making power, trust, communication, the power of technology as a tool of inquiry, complexity, and access, for example, are found in all three of the databases analyzed qualitatively, and are addressed with questions in quantitative cross-checks through the two surveys.

Content analysis can be too liberal in its drawing of inferences and meaning from subject texts. Reflexive examination of coding patterns is the only method of checking against this outcome. An inherent problem with this method is the necessary reductive nature of compiling relatively scant numbers of codes and categories from very complex text. A partial response to this concern lies in the fact that humans conduct such a thought process thousands of times a day, to make sense of their world. It fits, in fact with schema theory, and the way we frame information to process it efficiently (Minsky 1975; Sadoski and Paivio 2001). An additional issue is that of interpretation, and the impossibility of back-mapping from theory to text (Weber 1990). In other words, while text can be checked against theory, the reverse could engender only impossible numbers of potential matches.

For this study, inductive coding was used. In other words, the analysis was not begun with a list of codes to which chunks of text were then assigned. Instead, codes emerged from the text, sometimes, but not always, using *in vivo* coding which borrowed actual words from the text. On reflection, a number of the codes could have been predicted from earlier phases of the research, but it was helpful to find these codes emerge in their own right, rather than assigning them ahead of time.

For the first database, text units were all brief statements in note form, since they were literally transcribed from flip charts. It was thus not possible to recapture the full context, nor to assign any one text unit to the original question to which it was a response. While this potentially weakened the overall analysis, by removing some understanding of context, the analysis was completed with the same procedures and rigor used for the second database, which was developed from scratch for this particular research project.

Research Design Steps:

1. Web-site Survey

This database consisted of the whole population of people who have downloaded maps or databases from the CLAMS web site since 2001. All visitors to the

CLAMS web site are asked their reasons for downloading, but not all respond; however, all e-mail addresses are automatically registered.

This database thus has several notable limitations. First, the rapidity with which e-mail addresses tend to go out of date always meant that many of the potential respondents would no longer be contactable. "Bumped" addresses reduced the total respondent number to 157, of which ultimately only 57 (37%) responded, after two reminder e-mails. Second, of the remaining addresses, many may have been temporary—the servers still accept the mail, but the user is no longer reading it. Student e-mail addresses are an example; even if the students have provided a forwarding address, this may have changed in the meantime. Third, if the purpose of the web site visit was for a class or research project as long as three years ago, users may have little or no recollection of it and thus be highly unlikely to respond.

However, the goal of conducting this survey was not to make definitive statements about users of the CLAMS web site. Rather, it was to develop a preliminary sense of some of the usability and understandability issues surrounding CLAMS maps and databases as currently offered. The findings were then used to inform subsequent research and protocols, specifically the unstructured interviews for creating mental maps, and the questions for the focus groups during the research workshop. Thus the relatively low response rate does not have a profound impact on the overall study, since the findings from this survey constitute only guiding ideas for later protocols, rather than a direct contribution to the final research conclusions.

The protocol was pilot-tested among a sample of scientists and non-scientists, and adjustments made to clarify certain questions. Ultimately, the questions were clustered as follows:

- One question on familiarity with CLAMS
- One question on purpose of downloading maps/databases
- Three questions on usability
- Three questions on uncertainty and levels of trust
- Two questions on assumptions
- One question on understanding of findings
- Four questions on demographics

For analysis, frequencies were summed, and comparisons made across demographic groups, sorted to separate scientists and non-scientists, as defined. The sample was too small to provide usable results from any more complex statistical test. Survey questions showing response frequencies are attached as Appendix A.

2. 2002 Workshop

In the summer of 2002, CLAMS researchers hosted a workshop designed to elicit information from stakeholders and the interested, attentive public, about their reactions to CLAMS research, its tools and maps. Approximately 100 people attended. Invited attendees' affiliations included forest industry, non-industrial forest owners, non-governmental organizations, watershed councils, business groups, state and federal agencies, tribal groups, county offices, academic researchers, and interested members of the public. Most were at least somewhat familiar with CLAMS.

After a morning of presentations on the latest CLAMS findings, the large group broke into four smaller groups to address four questions:

1. What values do you see in broad-scale assessments in general?
2. What specific benefits do you see in CLAMS?
3. What concerns do you have about CLAMS?
4. What changes/improvements in CLAMS research and models would you suggest?

Further discussions were categorized under an appended fifth question: What should be the next steps?

Recorders took flip-chart notes on small-group observations and responses, and those transcribed notes provided raw data of impressions and opinions about CLAMS that had not been analyzed in any depth until this study. The limitations of the database stem from the fact that recorders in small groups using flip charts are notoriously unreliable in fully capturing observations and comments, and some bias in recording was observed. In addition, no close accounting was kept of which comments were associated with which of the four questions, so full understanding of context was not available. In addition, the questions did not specifically address the use of GIS maps in the CLAMS project, thus generating more general impressions than this study sought.

Therefore, while the resulting analysis was rigorous, comprehensive, and productive of useful insights for pursuing the remainder of the study, it must be regarded as derived from somewhat compromised data.

Data were analyzed by traditional methods of content analysis, using N4 software to store, code, and synthesize data. No *a priori* categories were established; codes emerged solely from the reading and sorting of the data. Because a preliminary reading of the text suggested that discussions ranged rather freely across all subjects at all points in small groups, all comments were treated equally and no attempt was made to sort according to the question that generated them.

3. Mental Mapping

Mental maps were initially selected as a graphic presentation device for use at the research workshop, but almost immediately became a versatile and insightful research tool. They were used here to interpret, discover, and synthesize meaning, following a defined protocol, and in this case based on data (text) obtained by interviewing workshop attendees and transcribing their responses. Maps were built around rectangles designating foundational elements, circles or ellipses containing feeder elements, and arrows (one-way or two-way) designating direction of relationships or effects.

The sample selected for mindmap interviews was purposive, chosen to represent the variety of people who are likely to work with the CLAMS GIS maps and databases, already had a level of familiarity with them, and represented the broad definitions of scientist and non-scientist used for the purposes of this study. Thus, among the interviewees for constructing mental maps, were an ecologist, a GIS specialist, and an economist, all working directly and at least half-time on the CLAMS project. From outside the project there were two watershed council coordinators, a tribal lands manager, and a public lands manager.

Open-ended interview questions were developed from a combination of theoretical perspectives, trends analyzed in the content of the 2002 workshop, and trends discerned in the web survey of users of the CLAMS web site. Interview questions included the following, with probes:

What is a map?

What role does uncertainty play in maps?

What is the responsibility of the map maker?

In what ways can maps teach?

Has GIS changed how you "see" maps?

How do you use GIS maps?

In what ways might GIS maps contribute to mutual learning or conflict resolution in natural resource management?

What kinds of unintended consequences does the use of GIS maps have in the arena of natural resource management?

Several of the resulting mindmaps were composites of multiple interviews, folded together where the responses and themes within a map coincided closely with each other. Thus the responses of the ecologist and the GIS specialist were combined (Figure 2, p.102), as were those of the two watershed council reps and the tribal lands manager (Figure 3, p.109). The remaining two maps were left independent of the others (Figure 4, p.114, and Figure 5, p.118), as they tended to represent rather different perspectives from each other and the two composites.

Borrowing guidelines from *Interactive Qualitative Analysis* (Northcutt and McCoy 2004), methodology for creating the mental maps proceeded as follows:

1. review transcribed interview notes to highlight key elements and apparent relationships, then
2. list elements in order to cluster them into categories, and
3. identify which are drivers, which are outcomes, to help
4. establish relationships/processes and feedback loops between categories, then
5. draw System Influence Diagram (Northcutt and McCoy 2004), uncluttered, in order to
6. draw System Influence Diagram, cluttered, providing a rich description of data.

Following initial creation of mental maps, or system influence diagrams, each one was sent to its subject interviewee for review and comment. The purpose of review was to check validity of the researcher's viewpoint, and potentially to learn more from each interviewee via the response to the diagram. The process was instructive where interviewees found the time to respond. Several changes were made as a result of this interaction, but it would have been more effective to have face-to-face meetings with interviewees to make certain they fully understood the mapping process and could then have contributed further to mental map content.

Once several maps had been constructed, it was possible to begin to identify shared patterns and differences, to clarify which maps could form composites because of their overall similarities. From the composites and individual maps, emergent properties could then be identified, arising from the interaction of lower-level factors, none of which shows the emergent property, and none of which is capable of predicting its emergence.

Identifying these properties allowed the researcher to consider the relationships and conflicts between them, and understand what factors contributed to their sustained presence. Because interviewees had not taken the opportunity to step back from their own environments, nor to respond to the perceptions of an outsider about that environment, it was typical for them to describe the emergent properties in a variety of ways without ever naming them, or singling them out for attention.

After identifying emergent properties, it was possible to interrogate the data across all four mental maps, seeking patterns, similarities and differences, broken communication links, or failed communication opportunities. What also emerged from this process was a substantial list of unintended consequences, some of which were initially articulated as such by interviewees, others having emerged through other questions. The identification of unintended consequences allowed the researcher to consider how visible each was to interviewees, as well as how each might contribute to mutual learning, or further communications difficulties between scientists and other players in natural resource management.

These mental maps provided some level of predictive power, in suggesting responses across various demographics to epistemological differences, adaptive story-making, and technology diffusion/transition effects. Theoretical meaning in the maps—

confirming, extending or challenging existing theory—emerged to support later findings in this study.

4. Focus Groups

For the current study, focus group participants were attendees at the 2004 workshop, selected from 2002 workshop attendees, and to the extent possible, representing the same heterogeneous population in similar proportions. Attendees included seven CLAMS team members, as well as representatives from one forest industry corporation, one non-industrial forest, two watershed councils, two non-governmental organizations, two federal agencies and one state agency, and a tribal confederation.

Morning sessions consisted of introductions, completing the pre-test, presentations from CLAMS team members with group interaction, and a presentation of the mental maps. Two focus groups assembled in the afternoon, divided in a manner as equally representative of the whole as possible. Groups were facilitated by the researcher and her advisor.

Questions derived from preceding data analysis included the following, with probes:

What is a GIS map?

What are the elements of trust between map makers and map users in GIS?

What new ideas and powers does GIS bring to the table?

What unintended consequences emerge from GIS technology?

How do we go from the abstract to the concrete in using GIS maps?

How are GIS maps useful in mutual learning and conflict resolution?

Transcription of focus group responses allowed analysis with N4 software. Coding of focus group data was done without creating categories, or themes, from *a priori* knowledge. This inductive approach leaves the process open to reveal ideas that could be constrained by the attempt to fit themes into pre-existing categories. To a significant degree, coding was *in vivo*, deriving labels from actual words used repeatedly by focus group participants (Strauss 1987).

Ultimately, focus group data sorted themselves into 26 categories. Because the selected coding units were for the most part the full text of what each speaker said in turn, which could range from partial sentences to relatively long paragraphs, multiple coding typically emerged for each unit. In most cases, one code was dominant for each unit, with additional codes providing alternative references. As relationships between codes began to emerge, multiple coding highlighted the connections: for example, if Information Control repeatedly coded a text unit that also fell under the Funding & Science code, the relationship between the two became more robust.

Two separate processes were used to sort codes, the first with a specific view to seeing the mix of positive forces and constraints on communication between map makers and map users, the second a free association to establish code clusters and their potential relationships. It was this second process that established the relationships that revealed key themes and links to theory. Four main clusters were established: Effects of Clashing Epistemologies, Effects of Alternate Story-Making, Shifting Learning Goals, and Process as a Tool of Change.

In the resulting diagram of codes (Figure 7, p.125), within each cluster, codes were placed as closely as possible to those they directly affected, but cross-cluster links also became important, and could not always be illustrated by adjacent placement. The idea of indirect links between clusters—manifested by multiple and cross-cluster coding—underscores the tight coupling and interaction between this code structure and the links to theory established in discussion and conclusions.

5. Pre-test, Post-test, with Control

The goal of the test had two parts. The first was to discern whether focused discussions of GIS maps and databases, their drawbacks, potentials, and conflicting perceptions of them, would change the perspectives of either or both map makers and map users towards their best use in natural resource management. In tune with the research questions, we wanted to find out whether inter-group discussions would reveal clearer and previously underutilized opportunities for mutual learning, and also whether the groups could envision unintended consequences of their use, whether positive or negative, which may in the future affect that use. The attendees of the workshop were the subjects of this investigation, with the control group for comparison. The second goal was to discern if possible any marked differences in how map makers and map users view GIS maps and databases, their production, and use. Both control group and workshop group were used to address this comparison.

Participants for the 2004 workshop, where the first pre-test was conducted, were selected from attendees at the 2002 workshop, in approximately the same demographic proportions. The control group consisted of the remaining attendees from the 2002 workshop. The pre-test was conducted manually at the workshop for attendees; their post-test was posted on the web, as were both pre- and post-tests for the control group. Six weeks passed between the end of the pre-test and the beginning of the post-test, in order that immediate impressions from the workshop were no longer prominent in the mind of the workgroup.

The questions for the pre-test, post-test were based on themes that emerged from the review of relevant literature as well as the preceding data analysis: content analysis of the 2002 CLAMS workshop, the CLAMS web site users' survey, and mental mapping interviews and development.

Several hypotheses were developed to assist in the design of the protocol for the pre-test, post-test survey.

1. Technically-trained scientists are more likely than non-scientists to recognize the potential analytical power of GIS databases.
2. Non-scientists are more likely than scientists to accept "map tyranny" (the power of a map to appear as "truth" to most observers).
3. Non-scientists (especially as map users) are more likely than scientists (especially as map makers) to comprehend the power of access to data and/or technology OR to feel pushed aside from the map production process.
4. The idea of mutual learning will be more familiar and appealing to non-scientists than scientists.
5. A guided and thoughtful dialogue is more likely to generate ideas and change minds than a single presentation.

The utility of this database lay particularly in assessing the value of an intervention such as the workshop in focusing attention on technology, learning, and communication issues around the use of GIS in the CLAMS project. The opportunity to compare scientist and non-scientist responses was effectively precluded in the control group by the extremely low number of scientists—just two in the pre-test and only one in the post-test.

Because the numbers were so small—17 in the workshop group, 19 in the control group for the pre-test, 13 in the post-test—it is obviously not feasible to run most statistical tests on the data. Instead, this database offers a form of bonus insight into, or illustration of, some of the themes that other methodologies had revealed. Frequencies for each question and among groups were used, along with several demographic cross-tabulations and comparisons. As a result, we could directly observe whether focused deliberation served a useful learning purpose, as well as considering the difference between map makers and map users in their views of mutual learning and unintended consequences in the workgroup.

CHAPTER 4: RESULTS

I. WEB-SITE SURVEY

A low response rate (~37%) to the web-based survey (attached as Appendix A) in part reflects the ephemeral nature of e-mail addresses and web use. Many addresses would have slipped out of use in the three-year period under study, and many users would have little recollection of a one-time visit to the site. Nonetheless, the results give us some insight into user trends.

Respondents were a highly-educated group: over half (58%) had post-bachelor's degrees and 97% had at least a bachelor's degree. The predominant fields of study were the natural sciences; the most common areas of study were ecology, biology, forestry, fisheries and wildlife. Just over a quarter listed disciplines outside the natural sciences as their major area of study; these included geography, landscape architecture, engineering, economics, and political science.

Almost half (49%) of respondents had encountered multiple references to CLAMS before going to the web site. Another quarter (25%) had heard at least two presentations about CLAMS. Thus almost three quarters of respondents were relatively familiar with the broader goals and content of the Oregon Coast study.

Responses to question 2 (For what purpose did you request CLAMS maps from the web site?) indicate that two thirds (67%) of people downloading material from the web site were doing so for the purpose of academic research, ranging from class assignments to postgraduate research. Forty percent used data and maps for agency planning and research, and interest in development of data display techniques prompted 16% of respondents to download materials. A further 9% were seeking materials for watershed analysis and planning. These results suggest that the category "users" can be defined to include a range of activities and requirements, and that CLAMS findings and tools, including GIS maps, are definitely already in use.

Question 3 (scale at which used) responses showed that the majority of uses (61%) fit the coarse-scale planning or assessment that would focus on large watersheds or basins. Fine-scale planning, at the small watershed or local scale, was the goal of

47% of users. A further 26% of uses involved assessing general trends in bioregional landscapes. Specific answers to questions about bioregional landscapes was the purpose in 12% of cases. These latter two uses, of course, also fit the coarse-scale category of use. A small number (11%) sought aquatic-related and other information. This figure could probably be subsumed into the larger planning numbers.

The usability of maps/databases for selected purposes was addressed by question 4, with responses shown in Table 1. (All tables in this section show percentages rounded up.) Materials downloaded from the CLAMS web site seem to have served the purpose for which they were sought, the level of technicality in maps/databases was generally not higher than expected, and only about half the respondents felt maps/databases would be more helpful if they provided greater detail.

Table 1 Responses to web-site survey Question 4.

QUESTION 4: usability for selected purposes. N = 57.	Agree	Uncertain	Disagree
Served purpose for which downloaded	79	9	12
More technical than expected	17	19	65
More helpful with more detail	54	19	28
Helped understand regional scale	55	32	13

While over half of respondents also agreed that the maps/databases helped them better understand regional-scale land-management challenges, a relatively high percentage was uncertain about this, possibly reflecting unfamiliarity with the landscape scale.

Question 5 addressed different types of use, and responses (Table 2, p.85) show that stakeholder dialogue and public education are already the most likely uses. All three management planning uses—forest, riparian, and small watershed restoration—showed a relatively even spread among people who felt they were likely and unlikely to use them this way, including a significant group of people who are still uncertain.

Table 2 Responses to web-site survey Question 5.

QUESTION 5: type of use. N = 57.	Likely	Uncertain	Unlikely/ Never
Small watershed restoration projects	44	23	33
Riparian management	39	20	41
Forest management	46	18	36
Stakeholder/policy dialogue	51	16	33
Public outreach and education	58	18	24

These slightly lower numbers for management uses possibly indicate lesser confidence levels in the utility of the tools at the finer scale, or for actual, on-the-ground applications.

The understanding of uncertainty was probed by question 6 (Table 3). While there was a reasonably high degree of understanding about uncertainty in models, and a very high comfort level with the uncertainty in CLAMS, it is clear there is also ongoing confusion about whether this uncertainty renders the maps unusable, or unrelated to reality.

Table 3 Responses to web-site survey Question 6.

QUESTION 6: understanding of uncertainty. N =57.	Agree	Disagree	Don't Know
Contain high degree of uncertainty	43	36	21
Comfortable with level of uncertainty	77	18	5
Understand all models contain uncertainty	98	0	2
Uncertainty level makes maps mostly unusable	39	43	18
Closely represent reality on the ground	23	50	27

Among the components of trust held to be most important for respondents (addressed by question 7), the most important was the use of a peer-reviewed process for developing the maps; 40% of respondents listed this as most important. A further 30% needed to know that the maps and databases come from a legitimate source; 23% needed to trust the high degree of surface accuracy of the maps. Just a very small fraction needed to be reassured that the scientists as map makers had no hidden agendas.

Question 8 further probed levels of trust (Table 4). Although a majority agreed that the maps could be trusted for use in decision-making, there was much less clarity on the questions of whether including stakeholders in ground-truthing would make the maps more reliable, and whether CLAMS scientists make unbiased decisions about what GIS maps will show and not show.

Table 4 Responses to web-site survey Question 8.

QUESTION 8: levels of trust. N = 57.	Agree	Uncertain	Disagree
Trust enough to use in decision-making	72	21	7
More reliable if stakeholders could check accuracy	46	35	19
CLAMS scientists unbiased about map content	43	46	11

Questions 9 and 10 (Tables 5 and 6, p.87) listed some assumptions included in several model-based CLAMS maps, and sought to uncover levels of *awareness* of and *agreement* with assumptions, respectively. In both cases, the rather varied results could reflect partial use of the maps (eg. full projections were not downloaded or viewed). [Note that N = 26 in these two questions, as only web-site users who had downloaded specific maps (vegetation projections) were asked to answer them. Further, N varies through question 9, due to an undetected coding problem in the survey software. Percentages and data interpretation have been adjusted accordingly.]

Table 5 Responses to web-site survey Question 9.

QUESTION 9: awareness of assumptions	Aware	Uncertain	Unaware
Forest management policy will not change; n=26	15	31	54
Habitat condition indicates level of biodiversity; n=22	23	59	18
Private timber harvest can remain unchanged; n=10	0	70	30
Clearcuts will not return to 80s size; n=23	9	57	35
Land management has reduced salmon habitat; n=26	62	23	15

Table 6 Responses to web-site survey Question 10.

QUESTION 10: agreement with assumptions. N = 26.	Agree	Uncertain	Disagree
Forest management policy will not change	4	16	80
Habitat condition indicates level of biodiversity	69	15	15
Private timber harvest can remain unchanged	27	12	62
Clearcuts will not return to 80s size	58	31	12
Land management has reduced salmon habitat	85	15	0

Most notable in the awareness of assumptions is the consistently high levels of respondents who are "uncertain" about exactly what assumptions are driving the model.

Except for the question about salmon habitat, respondents were more likely to be unaware than aware of the assumptions. This result portends later requests by CLAMS map users to make assumptions explicit, suggesting they are aware of the constraints imposed by their limited knowledge of what goes on "under the hood" of the models.

Agreement with the list of assumptions was tested in Question 10 to gauge to what degree respondents might perceive the maps and models to be valid. Here, where the questions are about beliefs, rather than knowledge of CLAMS, the "uncertain" responses were markedly reduced in all cases! The strongest agreement was for the idea that land management has contributed to loss in salmon numbers, and the strongest disagreement with the assumption that forest policy will not change in the next 100 years. The greatest level of uncertainty clusters around whether clear cuts will return to their 1980s size or frequency.

Without benefit of direct verbal explanation, the maps have, overall, delivered some of their findings to their users with moderate success, according to responses to question 11 (Table 7), which sought to establish users' understanding of the findings.

Table 7 Responses to web-site survey Question 11.

QUESTION 11: helpful in understanding. N = 57.	Helpful	Unhelpful	N/A
Oak woodland declining	81	17	2
Ownership affects future vegetation	67	30	4
Fish habitat not saved by reduced federal harvest	63	28	9
Young diverse forests rare on all ownerships	57	35	7
All ownerships contribute to biodiversity	59	37	4

The clearest message received was that oak woodland savanna is declining through time in the Coast Range, and that ownership strongly affects future vegetation development and habitat condition. The more complex ideas that followed were not quite as clearly portrayed, but still helped people understand more often than not.

The results from this survey outline several trends. The predominant one is the overall prevalence of uncertainty about the usability of CLAMS maps and databases. Despite considerable explicit interest in using the maps, and reasonable levels of confidence in using them in general public outreach, concern continues about how maps and models might be used—or misused—in policy discussions or decisions. The other trend, paradoxically, is that there is a small but measurable level of confidence in using these maps right now. Without comparative data, we have no way of knowing if this trend is increasing.

II. 2002 WORKSHOP

Small group sessions at the 2002 workshop, from which results were analyzed by content analysis, were framed around four issues, with discussions centering on responses to open-ended questions. The four issues were the value of broad-scale assessments; the benefits of and the concerns about CLAMS; potential changes and improvements in the project; and next steps.

Quantifying of comments showed that various levels of support for the CLAMS enterprise among this population was wide-ranging, and amounted to roughly 60% of all comments. Matters of trust, skepticism, and direct criticism took up about 30% of total comments.

In coding terms, the data broke down into 11 groupings, and further analysis suggested they clustered into four key categories: Decision-making, Tools of Inquiry, Public Education, and Confidence Levels. Table 8 (p.90) shows the clusters, with supporting codes, and summarizes the results via key questions and key findings.

Each column of the matrix represents a brief summary of each of these clusters, with the title code followed by one or two supporting codes. Thus under Decision-making, after summarizing that code, there follows a summary of Adaptation, and Institutional Constraints. The key code of Tools of Inquiry is supported by Belief Systems and Tool Evaluation. Under Public Education the supporting code is Integration. Under Confidence Levels, Assumptions and Scaling are supporting codes.

Table 8 Summary of node clusters and key questions from 2002 workshop.

TOOLS OF INQUIRY	DECISION MAKING	PUBLIC EDUCATION	CONFIDENCE LEVELS
Excellent science forum. Strong foundation for future assessments. Need non-forest, roads, fire components.	High value in context-setting for policy, stakeholders, researchers. Vital to understand trends, cumulative effects.	High priority on moving knowledge to new audiences. Goals of awareness, partnerships, access, visualizing futures and connectedness.	High priority on validating data and models. Shows uncertainty of forest mgt. Relates directly to understandability and usability.
Belief Systems: valuable in defining starting point for dialogue; need more social and economic data.	**Adaptation**: strong potential in AM; need to extend to larger area, broader land use types.	**Integration**: importance of systems approach across ownerships, resources, and disciplines.	**Assumptions**: need to make explicit; clarify maturity of science; value of static and public assumptions.
Tool Evaluation: useful forum to test science ideas; develop ground-truthed data rather than scavenging old.	**Institutional Constraints**: long – term funding challenge; interface with other modeling projects; public: who owns, who runs?		**Scaling**: mostly "works" at broader scales, sets context; need finer scales not available from this project.
Key questions: What core data do we need? Are data and concepts transferable? Are tools sufficiently flexible, and accessible to public? What range of scenarios should we analyze?	**Key questions:** How are CLAMS tools most useful? What are broad-scale consequences of our actions? Can CLAMS help broker landscape-scale solutions? How does CLAMS help community dvlpt?	**Key questions:** How do we manage "map tyranny"? How do we carry out the public discussion? Who is the customer for CLAMS? What are limitations of current knowledge institutions?	**Key questions:** What is appropriate use of models in policy dialogue? How do we deal with uncertainty? Can this work at a finer scale? How do we go from abstract to concrete?
Key summary: High potential to change questions we ask, track trends and cumulative effects.	**Key summary:** Need formal links with decision forums and decision support models.	**Key summary:** Need broadly respected process for interpreting outputs.	**Key summary:** Consider limits of reliability and expectations: abstract→concrete

The summary matrix helps to draw out important key questions from each of the four clusters. Some of the key questions, selected and sometimes paraphrased from among the many raised by participants, begin to address research questions. Several of these matrix questions were subsequently imported directly into mental map interviews and focus group sessions; others provided further links with ideas revealed in later inquiry.

The key questions under each category are linked together through the key summary. As difficult as it is to distil a single summary point out of all the entries in each category, in each case the questions selected as most representative of the general findings in that category helped point towards the key summary, thus supporting the internal connectivity of the content analysis. For example, under Decision-making, the need for formal links with decision forums and decision support models hearkens back to making tools useful, taking the broad-scale consequences of our actions into account, brokering landscape-scale solutions to natural resource management challenges, and tightening the link between costs and benefits. And so on across the key summary row of the matrix.

Results and explanation of the content analysis (four major clusters, 11 codes) follows.

Confidence Levels: questions of validation and reality

More than a quarter (about 26%) of total comments were coded under Confidence Levels, Assumptions, and Scaling. In general in this database, Confidence Levels and its supporting codes acted as a constraining variable upon mutual learning.

Overall the concern expressed was about how to improve data quality levels, or at least to indicate high levels of uncertainty, so that anyone using the data would clearly understand its limitations. "Risks coming up with wrong trends or conditions based on poor data" captures the concern, as does "Will not replace site specific data gathering." A clear example of direct criticism of data quality related to terrestrial habitat on private lands.

Sensitivity analysis, ranking of uncertainty levels, and validation of models are suggested by a number of participants as approaches for addressing a pervasive uneasiness about the robustness of various datasets, and certainly about the models derived from them.

Usability questions arise around how stakeholders might actually use CLAMS, how confidence levels will vary with questions, scale, and stakeholder, and how/whether CLAMS dovetails with other modeling systems. There is a closely-related concern about "appropriate use of models in public and regulatory dialogue." The point is made that credibility must be established before public use, because otherwise it will be all too easy for "credibility to be attacked by those who don't like the outcome." Thus the recommendation: "Characterize decision environments where the model would be useful, make sure the model is useful in those environments."

Understanding of current conditions may be more important to some users than the correctness or appropriateness of future simulations; thus ground-truthing (accuracy checking) of data takes on increased importance from this present-oriented perspective, and is a recurring theme in comments. One suggestion was to take risks with the models and release them, complete with uncertainties, to agencies, in order that the agencies can contribute to the validation process.

It is clear to participants that the ideas embedded in the presentation of data and the designing and selection of models is a matter of concern and influence. The most pressing need perceived is that assumptions must be made more explicit; without this step, stakeholders cannot be expected to know "which are science, and which are expert opinion." It is noted that different stakeholders will want different assurances of accuracy.

Again portraying a level of sophistication in understanding of CLAMS by outsiders, several observations raise concerns about buried understandings. First, there is the "illusion that great complexity equals greater accuracy." This comment parallels the idea of "map tyranny." Second, one participant asked whether CLAMS is a flexible tool for examining 'what if?' scenarios, in other words for truly examining quite different alternatives, or are some of the results at least partially hard-wired into the model? And third, the observation is made that some components of CLAMS have greater scientific maturity than others—a fact openly acknowledged by CLAMS scientists.

Another question—"how do you overcome the inherent disbelief in the model?"—is answered by the idea that by being open about assumptions, the CLAMS work may be more vulnerable to criticism than more closed models. A Catch-22 indeed! Along the same lines, it is noted that the project could become divisive rather than unifying if assumptions are not agreed upon. The static policy example is mentioned as being relatively unrealistic.

Several suggestions tie the challenge of embedded assumptions back to the public arena and the need for education. "Allow people to put their own assumptions into the model" is a widely-acclaimed idea, but one fraught with complexity and potentially hundreds of hours of model runs. Another, more immediately achievable idea, is to create a multi-interest advisory group to examine assumptions and spread information through their networks. These match a suggestion for a public document to lay out assumptions and show maps to clarify their application.

Scale questions covered both general approval of taking a broad scale view, and serious concern about at what scales the CLAMS data are reliable. "Define where and at what scale this tool is used appropriately (or not)" and "Will this work at a basin level?" and "Crossing scales is problematic" were typical comments.

There was a level of agreement that the landscape scale of the project was essential because not only ecological but social and economic processes of course operate across such spatial extent. Questions remain, however, around what broad-scale truly means.

That the project did not at this date offer robust fine-scale information, however, was widely understood, and perceived to be a weakness: "Large-scale modeling can put off local people—needs fine-tuning to local conditions." And yet its role in providing a context for fine-scale decision-making was applauded, as was its perceived ability to aggregate individual decisions and see what the cumulative effect was across the landscape.

Tool of Inquiry: the science

Comments on CLAMS tools that related to its purpose of science inquiry constituted 20% of total comments at the workshop.

The idea of CLAMS databases, models, and maps seems to have developed quite strongly in the minds of many participants. Among the perceptions of what CLAMS represented in the longer term were the potential for changing the questions we ask, for providing a regional context to track trends both ecological and social, for delineating feedback loops, and for testing new hypotheses along with the sensitivity of assumptions. Future bioregional assessments, it was noted, would be improved by the ability to crystallize current scientific understanding of biophysical interactions, and to examine multiple ownerships. The enterprise can also provide a locus for monitoring and implementation information. It was suggested that the collective outcome would provide ways to validate the Northwest Forest Plan, to consider alternative futures, and to run additional management scenarios.

It was proposed that the project is now developed enough to consider the transferability of its data and concepts to other regions, possibly beyond Oregon, certainly beyond the Coast Range. The technical challenges of this endeavor were not discussed. There was encouragement to add more detail on roads and their cumulative effects, as well as investigating non-forest regions (primarily agricultural lands) in more depth. The recognition of CLAMS as a set of tools that could track broad trend lines but not yet answer specific questions suggests attendees have moved beyond the stage of seeing CLAMS as an "oracle," a concern expressed by project scientists. It was noted that the "GIS maps alone are hugely valuable."

Many comments suggested a greater emphasis on social and economic data was broadly required for the project to increase its credibility. Missing socioeconomic foci included the lowlands, whose neglect to date in the project "reflects lack of national concern for rural America"; how human behavior might change recreation, and forest to non-forest transitions; and what businesses the landscape might support, with what effects on communities. These comments concur with criticisms of the project's assumption of static policy conditions through time, and reflect a clear awareness of social state as a highly dynamic condition.

The underlying implication is that the research questions that drove the building of CLAMS were not derived from outside the interests of biophysical science. While this is hardly a crime, nor was it represented as one, it is now regarded as insufficient for addressing complex environmental problems. Coded under Epistemology, this and associated comments relate to a divergence of worldviews between scientists and non-scientists that was also reflected in approaches to learning.

Running parallel to this criticism, however, was a related but more positive spin on the value of the CLAMS project in helping people reconcile very different worldviews and find common starting points for dialogue. The research "allows us to agree on what is the core data" and provides a "platform for everyone to begin discussions at the same place." That the project can recognize the existence and challenge of quite different epistemologies, and propose airing them, supports the hypothesis that efforts to make epistemological differences explicit at the beginning of such an undertaking, repay the considerable complexity of doing so (Benda et al. 2002). The call for more social and economic data can be interpreted as both criticism of the shortcomings of the current project, and support for its longer-term value.

A somewhat neutral 9% of comments are about technical content of databases and models, coded under Tool Evaluation in the Tools of Inquiry cluster. Participants recognized that the CLAMS project's value as a means of developing, testing, and refining analytical tools with a possible view to utilizing them in policy decision-making is in itself an achievement. However, they had numerous specific suggestions for areas that should be considered in further/ongoing work. These spanned a variety of ideas: develop deer and elk habitat indices; select 6-8 key policy variables for a simpler version of the policy model; include snags and down wood, road dynamics, and biotopes; adopt higher resolution in parts of the vegetation maps, particularly riparian areas; include more fish species; allow for changing recreational uses; and evaluate the consequences of using two growth and yield models. The idea of developing ground-truthed data rather than "scavenging" old data suggests participants' growing awareness of currency and reliability of data.

Decision-making: the potential policy tools

Comments on CLAMS tools that related to their purpose of decision support constituted 25% of total comments at the workshop, coded under Decision-making, Adaptation, and Institutional Constraints.

There was broad recognition of the potentials of CLAMS tools to address longer-term and larger-scale decision questions, although as noted above, support stopped short of having CLAMS tools guide directly any actual policy decisions. Nonetheless, it was seen as a "useful tool to do assessment in shorter times, with fewer people, visually."

Again, comments indicate a level of sophistication in understanding what the products of CLAMS research might actually address. Observations ranged from the need for clarified, formal links with decision forums and decision support models, to the need to recognize the difference between strategic and tactical management planning, and again to the importance of providing a context for decision-making and a broad view of cumulative effects. It was noted that the research outputs allowed stakeholders to "broker solutions" and that it was a "giant leap forward" in visualization.

The most commonly proposed uses of CLAMS tools were to "allow people to see broad-scale consequences of their actions" and "use a model to ask 'what if' questions." Strategic goal-setting across social, ecological, and economic boundaries was revealed as a highly-regarded potential of the research.

There was explicit discussion, coded with other comments under Adaptation, of the utility of CLAMS in adaptive management, allowing "policy adjustment under changing conditions by constant revisiting." Other adaptive uses included understanding and possibly avoiding unintended consequences, putting the past in perspective, and better understanding cumulative effects.

Institutional Constraints were raised in a number of contexts. The most often repeated observation was the question of funding. Recognizing the difficulty and cost of supporting such ventures, participants expressed the need to seek such funding, but also suggested a test of return on investment: "are the benefits worth the cost?" A "business decision" is needed on whether to continue investing in CLAMS. Notably, in this instance, CLAMS was seen as an investment, not just a money sink! Concerns about losing support just as it becomes useful, and the continued investment to bring it to the level of policy tool also surfaced. The idea that it may absorb funding more effectively by working now at finer scales, in ways such as custom mapping of local areas, was also raised. It was concluded that the outputs of CLAMS highlight "limitations of current institutions and decision-making processes."

Public Education: the spread of ideas

Public Education and Integration codes combined made up 17% of total comments.

The widely recognized need to "educate the public"—often a poorly-defined goal—was at this workshop posed to mean a number of things. These ranged from making the public aware and providing access; coordinating with organizations and creating partnerships; showing interested publics ecological connectedness across ownerships and the nature of dynamism in the landscape; illustrating the importance of conserving natural disturbance processes; and including public input through such means as engaging in validation and examining assumptions.

The question of accountability and ownership of CLAMS was also raised. Marketing plans and materials were suggested, and coordination of efforts across different stakeholder groups was identified as an education/marketing goal. The concept of "map tyranny"—described as the credibility of pretty pictures—was raised to indicate that care needs to be taken in how the research findings are conveyed to the wide range of publics. One central unanswered question that emerged concerned the process for interpreting output: for whom and by whom?

While the how-to of gathering public input to incorporate into models and databases remains hazy, this idealized feedback process arose frequently in the discussion. The fact that CLAMS data are non-proprietary was observed, revealing a preliminary understanding of the implications for privacy in general, and private property in particular.

Integration was recognized in an associated suite of comments. The "systems versus single-issue approach," "simultaneous examination of multiple ownerships," and the recognition that natural and social processes both occur at large scales, all attest to understanding of the cross-disciplinary nature of many natural resource management issues, not least in the Oregon Coast. "Highlights limitations of current institutions and decision-making processes" captures a number of expressions of frustration with disciplinary constraints within the research/academic world. "Offers opportunity to integrate across a variety of resources" is the on-ground mirror image of this, along with "quantitative integration of physical effects over space."

A general awareness of the importance of systems integration in natural resource management comes to light through suggestions such as broadening the investigation to include agricultural lands, as well as the idea of developing models of urban and rural influences on the environment, which could be integrated into existing models. The "inadequate" integration of aquatic and terrestrial components was another opinion showing awareness of the importance of systems approaches to natural resource management.

The matrix in Table 9 (p.99) suggests relationships between the four broad clusters of nodes outlined above, and three main variables of interest: mutual learning, communication barriers, and consequences of GIS development. Each cell contains potential outcomes indicated by workshop attendees; some of these are already underway, but others will require attention or commitment or resources from the CLAMS side. Larger potential changes are in italics, in their closest-fit cells.

Three focal changes emerge across the matrix: change the questions we ask, change the focus to proactive collaboration, and change the breadth of possible solutions. A fourth, change the maps to include assumptions explicitly, was repeated enough times to suggest it is a practical requirement, related to trust, understanding, and learning, in the near future.

Each of these focal changes essentially summarizes the variable column in which it resides.

Table 9 Potentials for change, 2002 workshop.
Matrix showing opportunities for change in three research variables (top row) in each of the four main categories of interest (left-hand column) identified by attendees of the June 2002 workshop. Key change opportunities are shown in italics, in their "best-fit" cells.

	MUTUAL LEARNING	**COMMUNICATION BARRIERS**	**CONSEQUENCES OF GIS DEVELOPMENT**
TOOLS OF INQUIRY	Provide broader access to data and images. Maintain high-quality forum for testing science ideas.	Explicitly consider limits of reliability and expectations. Add social, economic, non-forest, fire data.	Challenge privacy, private property, anti-trust issues. Analyze social and economic change through time. *Change breadth of possible solutions.*
DECISION MAKING	Set context for trends, review cumulative effects. Broker landscape-scale solutions.	Define starting points for dialogue. Represent multiple perspectives. *Change focus to collaboration.*	Increase speed of analysis, test more scenarios. Provide access to finer scales for localized decisions.
PUBLIC EDUCATION	Jointly interpret new knowledge and outputs. *Change the questions we ask.*	Adopt systems approach across ownerships, resources, and disciplines.	Visualize futures, connectedness. Obscure old boundaries with new partnership goals.
CONFIDENCE LEVELS	Recognize uncertainty of forest management. Recognize nature and value of models.	*Change maps to make assumptions explicit.* Involve public in ground-truthing.	Allow stakeholders to view and challenge data, import their own data ("guerilla ground-truthing"). Reveal conflicts in belief systems.

III. MENTAL MAPS

One central question, and three central themes guided the development/creation of mental maps. The question was: what are the elements and processes involved in producing and using GIS maps for natural resource management?

The three themes relate to the fields of interest outlined in the literature review. First, communication between scientists and non-scientists is easily skewed by language, experience, and worldview (Weber and Word 2001). Second, technology is socially constructed; in other words, it is as important to understand the human interactions component of technology and its diffusion as it is to understand the inanimate forces "under the hood" (Rohracher 2003; Campbell 1996). And third, technology diffusion has unintended consequences, both negative and positive. Key among these is social change in general (Masser 1996; Wegener and Masser 1996).

The process of creating mental maps turns out to have a great deal in common, not unexpectedly, with the process of creating GIS maps. Namely, omission and inclusion are conflicting forces at work in the process of data selection, in this case specifically the use of certain terminology, and the choice of terms to synthesize ideas; the synthesis of multiple inputs, most evident in the case of creating composites and distilling many ideas into few; and the danger of distortion that comes with simplification, in which imposing structure can mean ignoring properties.

In short, the maker of the mental maps—the researcher—assumes something similar to the decision-making power of the maker of GIS maps, in which hypothetical worlds are constructed with only limited assistance from the people whose mental geography has been borrowed.

The importance of recognizing systems-within-systems, of thinking holistically, became apparent as patterns, revealing similarities and differences, began to emerge among the sample of mental maps. Simply put, the mental maps began to formulate their own questions about the technology at the center of the inquiry.

A core map could be drawn that would show the fundamental elements identified by each interviewee, and expected by the researcher to appear. These elements include data, models, technology, GIS maps, map users, and some kind of outcome or change, variously called expectations or options. If this core map were drawn, relationships between these elements could be assumed to be somewhat linear, following the order in which they are named here.

Each interview revealed some version of these elements. In some cases they were named and then re-named; each interviewee gave them different weights. Thus, while the core elements can be found in each mental map, the different terms, weights, processes, relationships, and emerging properties are where the research interest lies.

Composite Map #1: Scientists

Scientist interviewees (an ecologist, a GIS technician) followed the classic core map, with small but significant exceptions, as shown in Figure 2 (p.102).

Feeding into **Data and Models** are the oft-referenced components of uncertainty and error, assumptions, and multiple sources. Related, but feeding most directly into **Technology**, are the need for quality control, and the powerful ability to query for multiple views. Numerous references establish that views by scientists of the **Data/Models/Technology** trilogy are based in the traditional epistemology of given quantities, or "facts."

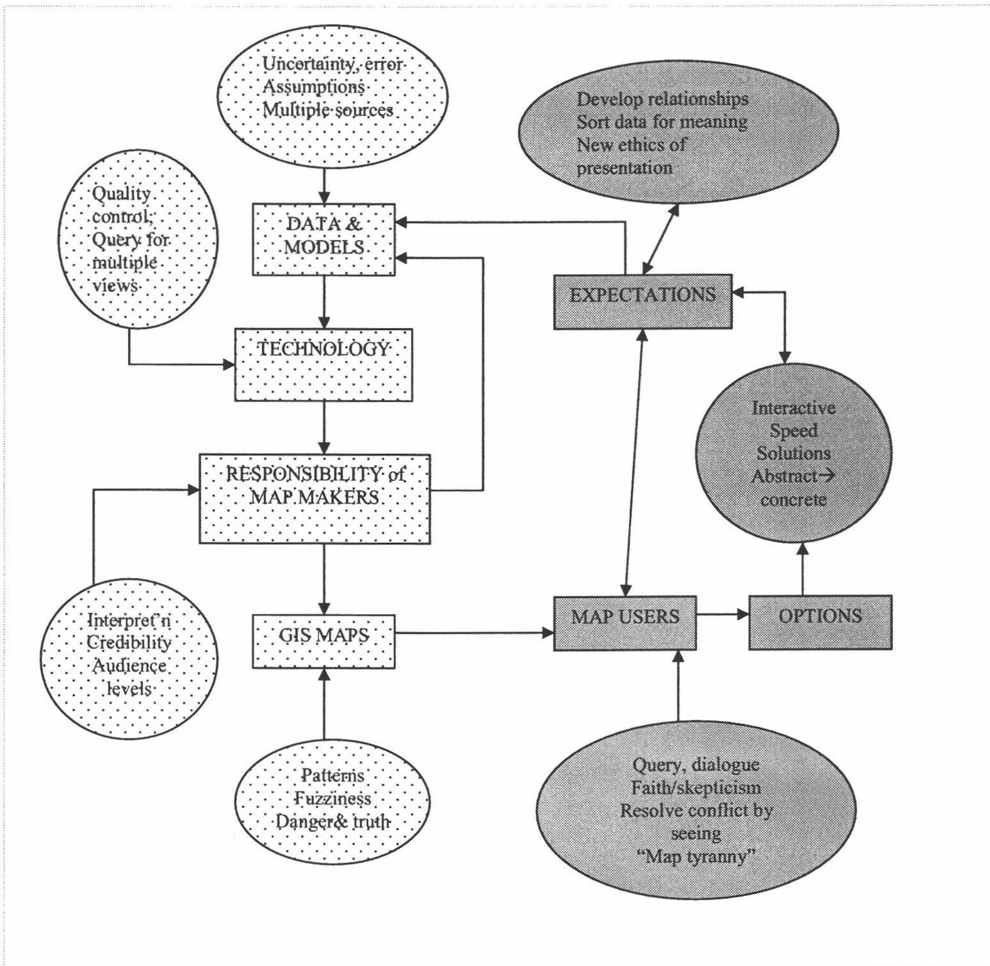


Figure 2 Composite map/scientists.
Dots indicate the privileged knowledge or power grouping, relating to unilateral story making. Grey indicates the agents of social change grouping, relating to collaborative story making.

Their views of the purpose of GIS outline the perspective upon this technology that is typically held by technically-trained scientists:

> "GIS is a computerized tool that keeps track of attributes and their association with coordinates and allows that information to be displayed visually; it also allows underlying spatial data to be manipulated in way traditional maps could not be. Data can be used to generate new map layers that might not be entirely intuitive in plain hard maps. Data can be underneath models, it can produce new patterns that may emerge spatially that may not be apparent."
>
> And:
>
> "I see GIS as basically using computers to store vast amounts of data in databases and project that info onto the landscape, that's one level. At the next level you take these databases and ask interesting questions and make more maps. Obviously the power of GIS isn't just displaying information but querying multiple levels of information and trying to gain better understanding of the greater picture of all the data."

What neither of these excerpts fully embraces is the understanding of technology as being socially constructed: it creates meaning, it requires management, and it addresses sometimes conflicting objectives (Rohracher 2003; Narayanan 2001; Beard 2002). It is possibly in their perception of technology as tool-only that scientists here lose a valuable connection with map users, whose relationship with technology is typically less under their control, and thus more reactive. Tool-only becomes tool-effecting-change, as subsequent maps indicate.

Despite the epistemological bias toward "truth-seeking," somewhere between **Technology** and **GIS Maps, Responsibility of Map Makers** became a driver in its own right, based on the number and kind of references scientists made to it. The presence here of the **Responsibility** driver suggests an incipient level of awareness of the power held by scientists who are in command of the technology. It is remarkable, however, that the word "power" was used only twice to refer to the social power of providing improved access to map users; otherwise, the very few references denoted the analytical power of the technology itself. In other words, power per se in the social sense was not something the scientist interviewees explicitly named.

Responsibility was perceived as a built-in requirement of GIS map production that exceeds what existed for traditional map-making. One interviewee expressed it thus:

> "I feel personally a responsibility to create a map that is immediately understandable, with not too much information on it...I feel responsible to only display information I feel is from a credible source, that is documented enough that I feel confident it was created accurately. In a situation where people are trying to decipher different forest uses, I feel I have a responsibility to display all the information there, not bias the map..."

The explanation for the higher level of responsibility—the feeder elements—included the need to interpret so much more data from multiple sources, the question of credibility, and the need to recognize differing levels of comprehension among audiences.

The elements feeding into **GIS Maps** include the search for patterns, the inevitable fuzziness, and the presence of both danger (in misinterpretation) and "truth" (in representation). Here both the search for patterns and the inevitable fuzziness of the process are perceived by scientists to be primarily their domain, and best understood by them. Thus when they come face to face with the public, they see problems of misinterpretation and "truth" in representation as natural outcomes of involving non-technical people.

Feeding into **Map Users**, scientists identified various potentials: that of GIS for query and dialogue; the presence of both faith and skepticism about data, models, and technology; the opportunity to resolve conflict by seeing data laid out spatially; and—reflecting their concerns about understanding by non-technical people—the effect of "map tyranny"—the iconic ability of maps to persuade many or most users that they represent truth. Said one interviewee:

> "I think that because of the history of relationships between people and maps, there's definitely a willingness to believe what a map says. It looks like reality, so it's easy to make the mental step of saying that it's correct. But most people don't know how the data came to be."

The separation of outcomes into both **Expectations** and **Options** distinguishes between the recognized changes resulting from GIS map production (**Expectations**), and the possibilities still opening (**Options**). This explicit separation represents a phasing of change, of which scientists appear to have some understanding, and which is widely acknowledged in the technology diffusion literature (Rohracher 2003; Brunn, Dahlman, and Taylor 1998; Masser 1996).

Elements feeding into **Expectations** include the expanded requirement of sorting data for meaning, since the database selection can be so vast; and a new ethics of presentation, the considered result of having to make sense of multiple queries of data, and having far more choices in display than traditional maps ever offered. Developing relationships refers to the understood need to work with data, technology, and map users to build the best understanding of individual maps. For example:

> "Sometimes the resolution to any issue isn't going to be noticeable or understandable to people until they see it on a map, if it's swapping this many acres for that many acres, just seeing it on a map is going to give people the ability to develop a relationship. If you can believe in the map as an honest broker in the conversation, then seeing your solution portrayed on the landscape is a way of invoking that brokerage. Then both sides can look at the map and say OK I'm fine with that."

Options include interactivity (of people with computerized GIS maps)—which is currently available but rarely used in the web context implied; solutions and speed to portray alternatives rapidly to stakeholders or researchers; and the potential in GIS maps for helping decision makers move from the abstract to the concrete. For example:

> "I described (GIS maps) as temporary or transitional, having the ability to be flexible and change the terms of what you're looking at quickly; change the viewpoint, scale, or any of the factors that could play into conflict resolution."

With the above elements and the relationships between them laid out, it was possible to identify emerging properties in the scientists' mental maps. In the scientists' composite map (Figure 2, p.102), a clear division appears between the power or privilege-based frame of its left side, and the agents of social change frame of the right.

Privilege as conceived here is multi-faceted, incorporating access to and use of technology, the right and ability to frame questions and initiate inquiries of the data, and perhaps most importantly, the resultant ability to select and tell the stories offered by the data when it is uniquely manipulated by scientists. Social change agents are just as complex. They encompass the wide range of elements and forces working towards an alteration of current ideas, a shift in power balance or dynamics, or a movement away from habits or factors that tend to hold the current dynamic in place. They can be quite large, such as a gradual change through time of the public role in policy-making, or can appear quite small, such as being able to point at a map while asking a new question about landscape effects. None of these change agents, however, lacks the potential for contributing to major changes in worldviews.

Power relationships within organizations are known to affect methods and styles of communication (eg. Waldron 1991; Weber and Word 2001). The privileged knowledge property emerges where we can see the influence of only a single group—in this case the scientist map-makers—on how data are used or displayed. Thus, to take several examples from the feeder elements, we see quality control, assumptions, interpretation, and credibility, all essentially under the control of scientists, serving to support the status quo.

On the portion of the map where social change agents emerge (right-hand side), there are small hints of potential change: the development of new relationships, a new ethics of presentation, interactivity, and the space for query and dialogue, just to name several examples. The potential exists for each of these feeder elements to increase its influence sufficiently to effect change, change that might act alone, or combine with other forces, to alter the existing dynamic between scientists and map users. For example, if a new ethics of presentation means that scientists seek dialogue with map users, which develops improved relationships, then the process can become more interactive. In other words, the story-making capacity *could* become collaborative, under the right conditions.

However, in their interviews, the scientists portrayed map users thus far as relatively passive recipients of scientific input. Although they each mentioned such improvements as web-based interactivity to improve access for larger numbers of people, overall they suggested that the potential for collaborative story-making remains thus far only that: a potential. One ecologist commented:

> "If you come back to web-based platforms, there are constraints on the kinds of information that can be portrayed, but it does allow the user to have a menu of things they can take a look at, it gives them a little more

> power. Communication of this kind between end users and map makers would be healthy."

Notably, however, scientists appear to perceive most clearly of map users as responding to maps rather than creating them from scratch with their own data and technology.

These interviewees did not explicitly recognize any strong forces likely to change the current locus of power or privilege, in which, for example, map users might generate dialogue directly addressing "map tyranny" by challenging data sources and selection, models, and technology use. Instead the scientists replaced the idea of changing or expanding map authorship with increased responsibility for themselves as map-makers.

When interviewees (for this and all other maps) were asked directly about unintended consequences of GIS map production, they were able to articulate very few. However, unintended consequences did appear in various contexts at other points in the interview.

Most notable in this composite, a new ethics of presentation encapsulates a considerable change in how map-making is viewed and could be changed by the GIS technology, thus suggesting a positive unintended consequence that embeds a kind of morality in the effort to impart what could be viewed as privileged knowledge. And privileged knowledge, of course, is a second unintended consequence that cannot be ignored in this mental map composite: if data, models, and technology combine to make GIS maps relatively inaccessible to other players than scientists, the knowledge available from any given GIS map is definitively selective, and the selection process is privileged by definition. The status of the knowledge produced remains in accord with the kinds of perspectives scientists themselves have demonstrated towards communicating with lay audiences (Mills and Clark 2001; Lubchenco 1998).

A third unintended consequence of the introduction and spread of GIS technology, typical of most technology diffusion (Rohracher 2003), is the phasing of change suggested by the separation of expectations (present and achieved) and options (future and possible). While the initial hype around any technology suggests it will change the way the world does business, it is rare for the technology to cause social change that leads to immediate and holistic adjustments. The consequence is that different powers, expectations, options and privileges develop during the phasing period, before diffusion is complete (Brunn, Dahlman, and Taylor 1998; Beard 2002). One possibility deserving further research is that this phasing changes the initial trajectory of diffusion and in fact can either prevent or enhance its completion.

It is too early to tell whether that will happen in the case of GIS maps and natural resource management: if the world of cartography is to become a world of mass access and a level playing field as promised with the advent of GIS, it has not happened yet.

Composite Map #2: Non-scientists.

In the non-technical composite, Figure 3 (p.109), the familiar foundational elements appear, but with several notable changes in perception, each highly supportive of the communication challenges suggested by Weber and Word (2001).

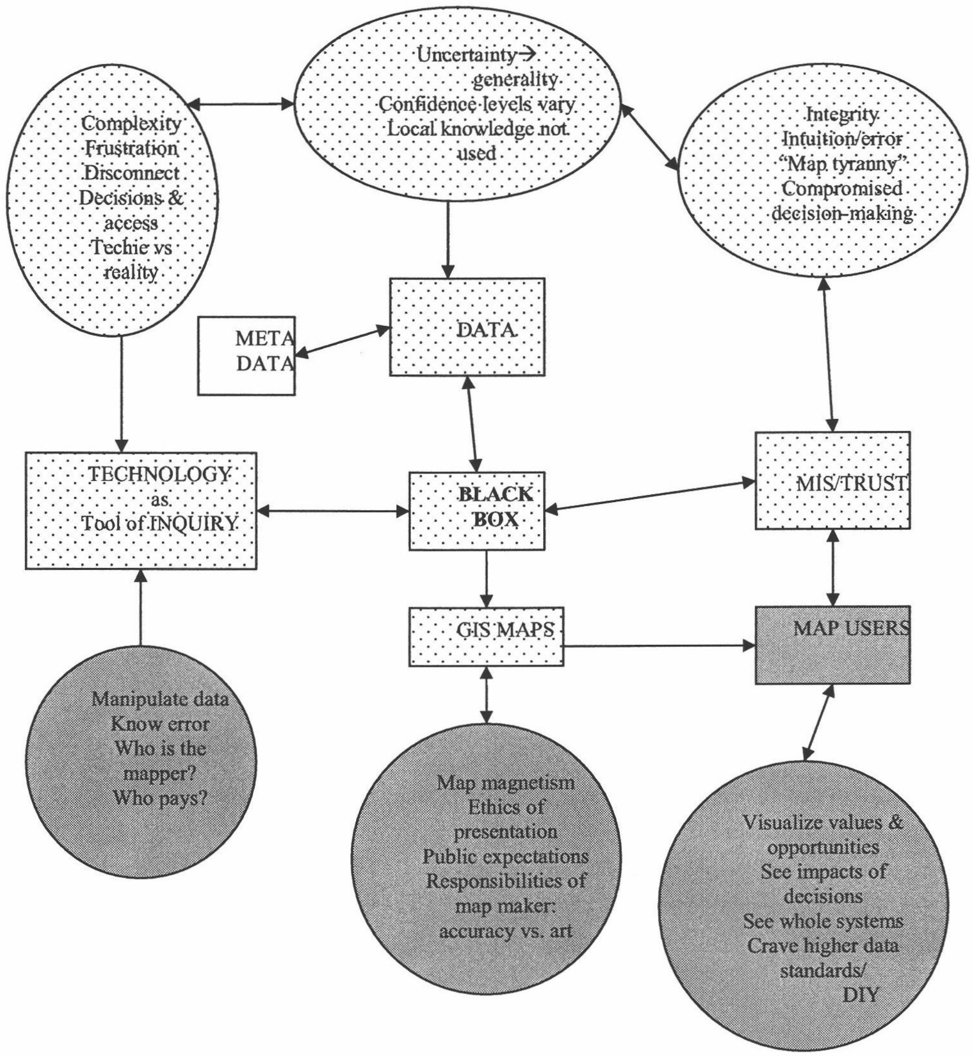


Figure 3 Composite map/non-scientists
Dots indicate areas where barriers to power generate unilateral story making. Grey indicates areas where social change agents could elicit more collaborative story making. Metadata here play a checkpoint role, where non-scientists gaining technical knowledge can "keep watch."

First, the appearance of **Metadata** in a separate box illustrates the importance these interviewees placed on the fact that outsiders could not always know how GIS maps came into being, exactly what datasets were used and in what combinations and inquiries.

Second, and not unrelated, the designation of a **"Black Box"** is central as a metaphor for the general impression of GIS technology under current conditions. In many cases, watershed councils or tribal representatives were exposed to GIS technology early in their watershed management roles, but time requirements and continued funding universally failed to materialize. After they abandoned early attempts to train themselves in GIS techniques, what was left was the sense of being outside the map-making process. While no interviewee specifically expressed feeling powerless, they did express the concept of frustration, along with the privilege accorded by the complex technology to those who had time and resources to master it. One interviewee spoke of it thus:

> "If someone could work with us, go from council to council, take the very best data, and run the decision-making model for us, instead of trying to burden us with how to use it...otherwise how are we going to do this? It's a problem area for us, we're underfunded and overworked, and we can't get the type of funding needed to help with capacity building."

These concepts ultimately connect to the **Mis/Trust** driver, symbolizing the challenge of accepting working tools designed by other parties, when design, content, and purpose are all unknown. The conclusion drawn by these interviewees is that the overriding questions about integrity of the data, along with the knowledge of error but the need to rely on intuition to detect it, results in compromised decision-making. In turn, and here in counterclockwise fashion, we see the connection to the elements feeding into **Data**, where uncertainty in GIS maps is recognized by non-scientists to lead to generalized representation, confidence levels are highly variable, and local knowledge is left without a home.

What feeds from here into **Technology/Tool of Inquiry** is a combination of complexity, frustration, and disconnects—from decisions and access, from reality on the ground in the watersheds, back to the technical folk constructing the maps. One interviewee commented:

> "We don't use GIS right now because we have no GIS person. It's back to the old system of taking the map out and matching it with photos, doing it by hand… I know enough about GIS to be dangerous. I was spending so much time trying to get a product generated, it took a lot less time to generate it by hand; trying to get the information into the system was very difficult."

Another notes:

> "I have a sense that there's a highly sophisticated decision-making process connected with all GIS mapping and analysis. It's a wonderful tool for prioritizing where you should do work and why and when... There are people out there doing it, but a disconnect exists between us and them, how are we going to get there?"

Frustration, then, is a key ingredient at this stage, and the outcome is just as likely to be abandonment of map-making as it is to be adoption, not through lack of desire, but through lack of funding. Control over map-making is thus involuntarily handed over to outside parties.

Thus we see, not surprisingly, a formative connection between funding and power, reflected in the questions feeding into **Technology/Tool of Inquiry**: Who is the mapper? Who pays? The interviewees know there is error in the maps, as noted, and they know the data are manipulated as part of the process of producing GIS maps. But they have no access, no power, no privilege, and so no clear method of discerning reliability and trustworthiness among maps.

In this composite map, we see interviewees reflecting back some of the same concerns as map makers, here feeding into **GIS Maps**: the need for a new ethics of presentation, public expectations of accuracy, the compounding responsibilities of map makers. Each of these is at play when map magnetism—that dynamic that draws a group to gather around a map—takes effect.

The elements interacting with **Map Users** include recognizing the importance of seeing the impacts of decisions on whole systems quickly, and the potential for visualizing values and opportunities spatially. The do-it-yourself approach and the explicit craving for better data occur in the same arena. These interviewees know the difference between solid and bad data:

> "We try to be careful when applying GIS map findings too specifically because some detail might be wrong. Basically we have given up working with roads layers, for example, because we know they're junk."

> Said another:

> "Basically the outcome for us, once we got into it, was we started thirsting for better maps and data. When we started doing our assessment, they were just coming out with GIS layers. We got caught in the middle, and felt some of the pain of having bad data layers."

The properties emerging from this composite map are not unlike those in the composite produced by scientist interviewees. All foundational elements but **Mis/Trust** and **Map Users** fall into the privilege/power category. In this case, the feeder elements arrayed along the top of the map all support the privileged production of maps, even more directly than the feeder elements on the power side of Composite #1 (see Figure 2, p.102). The inputs suggest careful, experienced thought.

In the agents of social change property, recipients of GIS map-based knowledge appear as more active than passive. The unilateral story-making capacity of map makers, and the collaborative version of non-scientists as map users and people in the watersheds, is portrayed as being much more distinct. This is not surprising, given that it is the potential story-makers of the collaborative variety who are being interviewed. For example:

> "If (the maps) are based on good data, it's a good way of showing something you're trying to explain. Most people are visual, they're not as good at processing written material, or listening while you're talking data at them. If they can see it, it makes it easier. Mutual learning could happen."

Among the unintended consequences articulated by these interviewees we find the trust/mistrust issue of compromised decision-making. This theme has been consistent throughout all databases examined, and is possibly the most persistent of outcomes revealed in the study of CLAMS experience. It relates to both meaning and organizational structures. It mirrors the communication problems identified in the literature (Weber and Word 2001; DuPraw and Axner 1997), and likely also reflects the challenges of the shift to larger landscape perspectives (Franklin 1993; Shindler 2000). If people cannot relate to the visualization of larger landscapes, or cannot conceive of whole ecosystems and their connected functions, being forced to deal with them via the medium of GIS technology will certainly not increase trust in the map makers.

The softening of ownership boundaries, another noted unintended consequence of working with GIS maps, is similarly more likely to be a result of the large-landscape approach facilitated by remote sensing than a result of the GIS technology itself.

Reflecting the idea that in fact the non-scientific public is not without sophistication (Van der Vink 1997), a third unintended consequence identified in these interviews was a change in public expectations—indeed, a desire—for higher data standards. This perhaps relates back to the phasing of technology diffusion noted above, and it is important to note that both scientists and non-scientists wish for better data layers! A final unintended consequence on this mental map, the frustration of having to work outside the existing power structure, mirrors the low resources/high privilege idea noted above.

Map #3: Manager/agency

In the manager/agency map (Figure 4, p.114) we see a noticeable change in the structure of the map, reflecting a perspective that takes a little from the two preceding perspectives, but adds its own twist. Again, the familiar drivers are present: **Data** and **Technology** interact, and metadata is coupled with credibility as part of a loop with these two primary drivers. Feeding into **Technology** is the known and desired capacity of the technology to conduct comparisons and inquiry, along with acknowledgement of map magnetism.

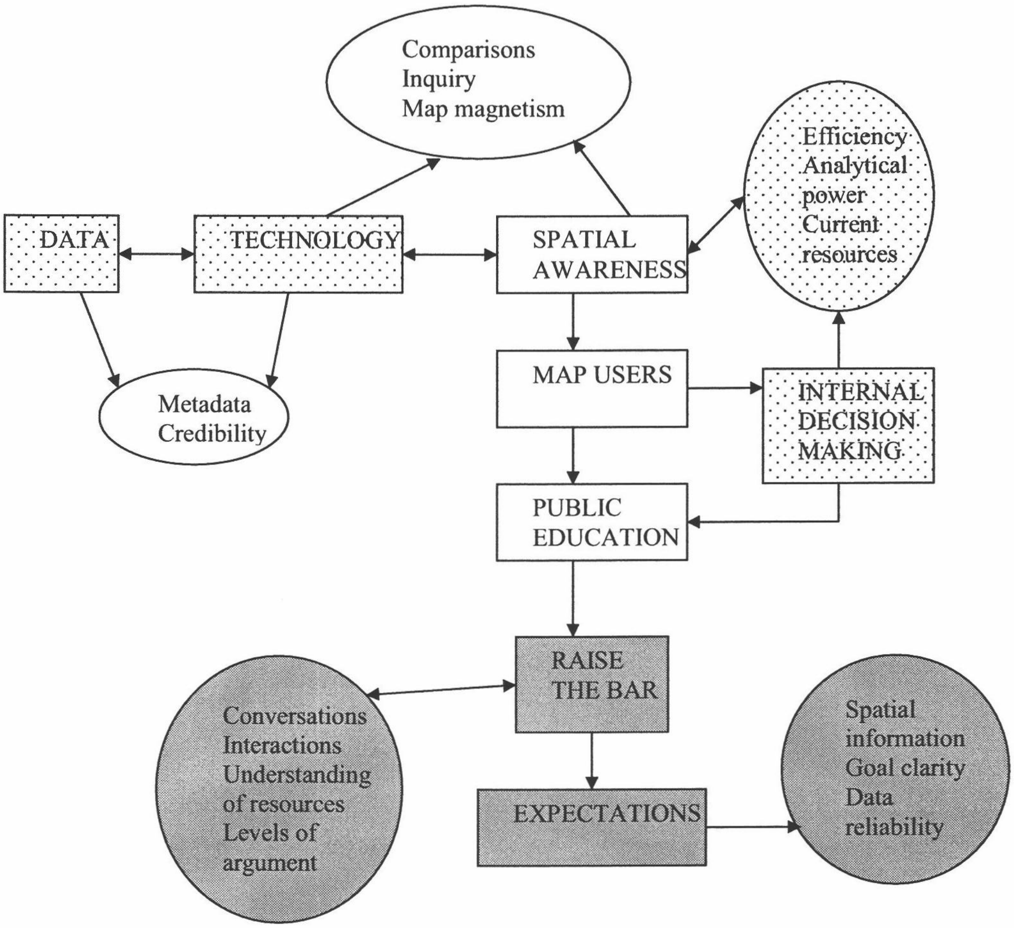


Figure 4 Manager map.
This map shows a strong emergent property invoking agents of social change and collaborative story making in grey. Privileged knowledge (dots) is a very weakly emergent property, and not cohesive in one area of the system.

From this point the differences from the two composite maps start to show. **Spatial Awareness** was a term used so consistently that it subsumed and replaced GIS Maps as a foundational element. It represents a broader concept that comprehends more than just the maps themselves, suggesting the maps, their use, and their understanding. As a result, it relates in multiple directions to other elements, both foundational and feeder. **Map Users** here are more clearly both internal to the agency and external, for here the path separates into **Internal Decision-Making** and **Public Education**—two different audiences and purposes.

In **Internal Decision-Making**, which feeds back into **Public Education**, the emphasis is on efficiency, analytical power, and knowing the current resources:

> "From decision-making analysis, (GIS technology) gives much more analytical power than we ever had before. We're able to go way beyond the old type of analysis. It makes our decision-making more efficient."

Public Education initiates a stream of relationships that take **Raising the Bar** as a foundational element. **Raising the Bar** was a repetitive theme that was clearly a driver in the mind of the interviewee: rather than being a subordinate form of expectation, it affected interactions in its own right as a *modus operandi*. Indeed it was designated by the interviewee almost as an agency mission, affecting both internal and external activities. The raised bar, then, in its turn influenced **Expectations**, particularly concerning spatial information in general, clarity of goals, and reliability of data. The interviewee noted:

> "(The use of GIS) has brought a huge amount of spatial awareness. Information used to be shown in crude maps, tabular format graphs and charts…just the ability to display information in a spatial format has been huge. When you display some information not seen before in a spatial context, you get a reaction: oh wow, that's really interesting! It raises the level of the conversation, the analysis, and improves awareness of what you're trying to do."

Raising of the bar then, potentially occurs in conversations and interactions, in the understanding of resources by non-agency as well as agency people, and in levels of argument. As the interviewee explained:

> "Everybody will have a better understanding of the attributes of our natural resources, the condition of them, as we perfect our data sets and our ability to analyze them. It will raise the bar in terms of the information that is expected to make decisions. It will hopefully put the arguments at a higher level of understanding of the characteristics of the resource."

In identifying emerging properties, agents of social change was the first to be discerned, in this case with a relationship between developing more widespread spatial awareness through raising the bar at a number of levels of interaction. Interestingly, the power/privilege property emerged only very weakly in this map, suggested only by the need to make decisions that are internal to the agency, which GIS and other tools greatly assist. The desire to educate the public has outweighed the privilege of access to the technology and to specialists who can engage it. Agencies tend to have very specific public interaction mandates, and an immediate past history of considerable criticism for overstepping their rights. Thus the failure to evoke a strong emerging property focused on power or privilege is not surprising.

Story-making in this map is mostly perceived as a collaborative process, personified in the references to higher levels of argument and improved interactions and conversations. There is very little to suggest unilateral story-making of any kind: where internal decisions are made, the sense is that they are conveyed rapidly to the public as a goal among equals. According to the interviewee:

> "Public education has dramatically changed. (GIS has) given me the ability to emphasize or portray the points I want to get across, create maps that express that much more efficiently and clearly than I could with regular maps."

Among the unintended consequences noted in this interview, the spread of spatial awareness, which in turn generates improved understanding of natural resources, is a key one, and would perhaps be designated by some as a less unintentional consequence of the development of the technology than others. What we see here is a different perspective on the privileged position of map-making. It focuses more on the interactive decision-making process and how it is enhanced by GIS maps, than on the privileged one-way position of producing GIS maps for subsequent dissemination to stakeholders or use for further research.

This shifting or unclear locus of power might have been located among the original intended consequences of the development of this technology, for much has been written and said about how GIS will change the balance of power in the world of cartography. Nonetheless, this consequence is particularly interesting when contrasted with the preservation of the status quo—as uncomfortable as it may be to all parties—suggested by the two composite maps.

This spread of spatial awareness consequence is of course also linked closely to the improvement of public education and interaction by agencies using this technology. Raising the bar in terms of levels of argument, for example, is a relatively rare acknowledgement of the value of what can be quite heated interaction, and indeed is beginning to find its place among recommendations for tackling difficult resource issues on an international level (van de Kerkhof 2004).

Map #4: Economist/social researcher.

In the fourth and final mental map (Figure 5, p.118), we see an entirely different structure. **Metadata** reappears as a foundational element based on the importance accorded it, and interacts again with **Data**. **Technology** and **GIS Maps** combine, and from here almost all similarities to previously discussed maps disappear.

Unclear Liabilities, fed by error, fuzziness, and complexity, appears as a foundational element. The interviewee explained this, in part, as follows:

> "There is an insufficient relationship between user and technology, and I'm not certain it can be resolved. It relates to the broader problem of computer technology in general, and the difficulty of making its liabilities clear to the user. GIS is just another example of the problem of non-technical users confronted with computer technology."

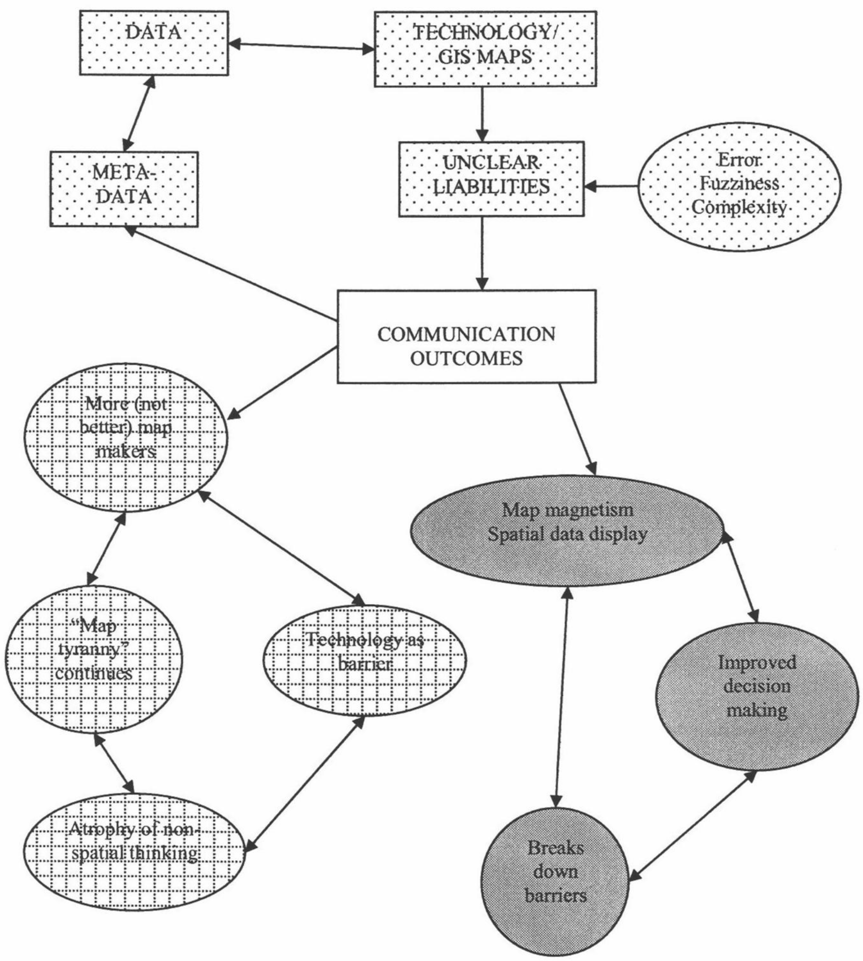


Figure 5 Economist/social scientist map.
Dots represent a concentration of privileged knowledge and the power of unilateral story making. Grey shows where agents of social change contribute to collaborative story making, and crosshatching shows where technology can become a barrier through its misuse, with the unintended consequence of dysfunctional story making.

What happens, then, when those liabilities feed into attempts at communication? This interviewee discussed a dichotomy in **Communication Outcomes**: one of the resultant loops has an undesirable outcome, the other a positive one.

For a start, we see more, not better, map makers:

> "Faster is not necessarily better...but it sort of puts the technological means in the hands of anyone, even people who don't really have the technical background to understand the statistical complexity of the endeavor. There are probably a lot more bad maps as a consequence."

Bad maps or good maps, map tyranny continues to play its role, and interacts with the quality-of-production barrier created by the complexity of technology. Within the same loop lies the interesting suggestion that the expectation of society as a whole to interact with spatial data around natural resource issues, simultaneously reduces our ability to deal with non-spatial types of data such as tables, graphs, and text.

However, this interviewee links map tyranny with the generalized spread of spatial data display, and does not see a bad outcome as being automatic:

> "I'm not sure the whole tyranny thing is necessarily a bad thing on balance. Being able to look at maps of data is a really valuable way of visualizing the data. Without that ability, a lot of times it just gets ignored. I guess I'm agnostic about whether the tyranny is on balance a bad thing."

With this theme, the interviewee recognizes the breakdown of some communication barriers, and resultant improved decision-making. The interviewee notes:

> "Conveying the spatial dimension of information has greatly improved decision-making. In general, it allows the spatial disaggregation of data to a much greater extent than could be done tractably before GIS was built. On balance, it's been very beneficial."

Clearly, communication in general is a key theme and driver in this mental map, from the consistent production of metadata files to the breaking down or setting up of barriers between interested parties of all kinds.

Emerging properties in this map present some interesting diversity. Where we might expect to see a somewhat similar privilege property, here it is greatly undermined by the presence of **Unclear Liabilities** as a foundational element or driver. While the story-making in this segment could still be unilateral, here it is portrayed as being under much greater doubt as to veracity. Ironically, the existence of GIS technology "privileges" a larger number of people to produce maps for their own purposes, without quality control, and hence to become a form of "dysfunctional" story makers, a property not addressed explicitly by the other maps. Where the technology assists in breaking down barriers and improving decision-making—elements combining to create the social change emergent property—story-making's potential to become collaborative and inclusive is fully expected.

Thus as an unintended consequence, we have here three kinds of story-making—unilateral, dysfunctional, and collaborative—only the latter being desirable in the post-modern sense of social engagement with science. If science and community interaction have become much more a quest for meaning than for truth, unilateral story-making falls away as a useful option.

Multiple story-making paths also combine to generate the same unintended consequence found in the manager/agency map: a shifting or unclear locus of power. With clear questions about liabilities—to some degree an extension of the concept of responsibility of the map maker identified by the map makers' composite—and a separation of communication outcomes into desirable and undesirable, the question of privilege or power is opened and will not likely close until some of these issues are resolved through time.

The final unintended consequence is the intriguing notion of the atrophy of non-spatial thinking. No proof is presented for this, but given the heavy emphasis through all interviews on the social expectation of the availability of spatial data in conversations about natural resource management, it is a potential outcome that cannot be dismissed lightly. Again, as technology diffuses, the robustness of this observation will be tested.

All maps: summary

Across the four maps, the emergent properties of privilege/power and agents of social change remained steady, with their relationships to unilateral and collaborative story-making, respectively, relatively similar. For local reasons, the manager map played down the privilege/power property, and the economist map sorted themes more by story-making capacity than by power or change, although the same properties still tended to emerge.

Each map had its own identity, revealed first by overall structure and then here by fill colors. For example, the manager map showed a heavy emphasis on raising the bar in areas that fell in both social change and privilege categories, almost overriding the latter emergent property. The economist map centered around communication flow, abstracted from the map-making process. Non-scientists and scientists laid out their thoughts in very similar structures, but saw different outlines and horizons in terms of privilege and change, with different feeder elements predominating as a result. Scientists tended to perceive no need for change in their primacy as story-makers, although they do sense the need for a new ethics of presentation. Non-scientists saw both the potential and the need for collaborative story-making as part of social change, having identified the technical and social "black box" of technology that has erected a barrier to their participation.

Consequences (many unintended) identified through mental map interviews tended to emerge during the course of interviews, rather than be immediately obvious to participants when asked. This phenomenon suggests that among interviewees there is a greater awareness of change at an almost subconscious level than a conscious level; small changes in attitude and practice as technology diffuses through society are to be expected (Brunn, Dahlman, and Taylor 1998; Rohracher 2003; Wejnert 2002). Whether they add up to become large changes when critical mass or critical time becomes involved, is not initially predictable. The mental maps as a whole make clear, however, that there are indeed social choices involved in technology change, and that meanings are inscribed into technologies as people adapt to them (Rohracher 2003).

IV. 2004 WORKSHOP: FOCUS GROUPS

In content analysis of focus group discussions, the first sorting procedure arose from the general question about what was going on in general with communication between scientists as map makers and non-scientists as map users. In response to this inquiry, the nodes or themes emerging from coding of focus group discussions at first separated into two broad categories, one representing a positive force trending toward improved communication and understanding between scientists and non-scientists, which could be seen to represent improved social involvement in science-based natural-resource decision-making. The other category represented a negative force tending away from improved communications, in other words, persistent communication problems deriving from epistemology and/or professional training.

The positive list focused around learning in general, and opportunities for mutual learning in particular. The negative force consisted of communication barriers in general, and those generated by GIS maps in particular. Figure 6 (p.123) shows these two "lists" of categories, leading jointly to Consequences and Change.

The next stage of analysis involved a more complex ordering and grouping of categories. This time, nodes were first clumped simply as independent concepts, in other words they were clustered together according to a common or intuitive understanding of what their category title meant, without reference to data content. The idea in this process was twofold: first, it began to identify larger patterns and themes within the data, an objective not actively pursued in the first listing of data categories into simple lists of positive and negative forces acting on communication. Second, it checked the validity of category selection by testing whether this "logical" clustering held once actual data were incorporated.

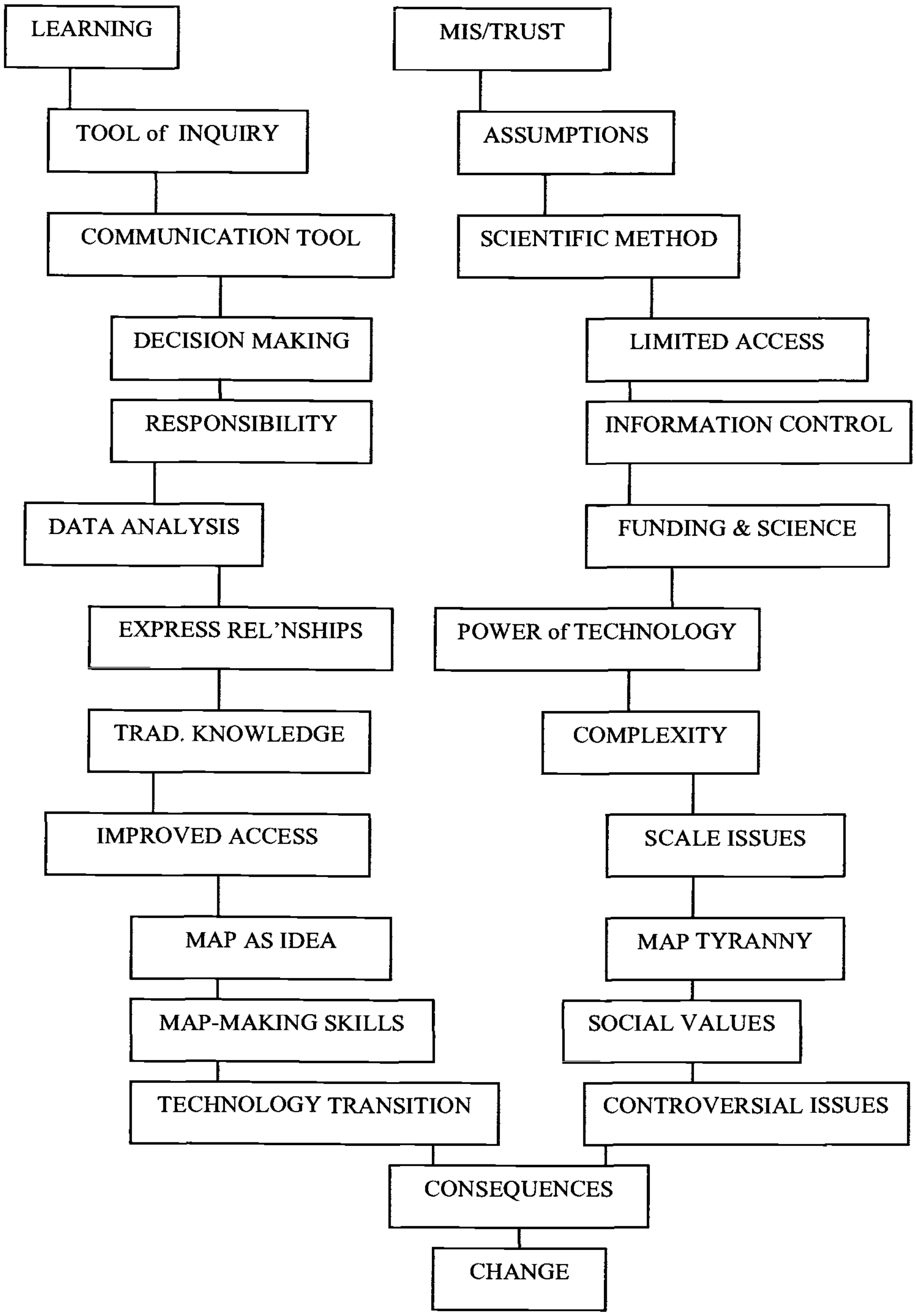


Figure 6 Preliminary coding.
Coding nodes showing positive (left side) and negative forces acting on communication, leading to consequences and change.

This process resulted in name changes for several categories, and a gradual emergence of relationships that were borne out by data, and supported by existing theory. The resulting relationships are shown in a cluster diagram in Figure 7 (p.125), with coding concepts summarized in Table 10 (p.127).

In general, coding categories for the 2004 workshop focus group data fell into four key clusters—**Effects of Clashing Epistemologies**, **Effects of Alternate Story-Making**, **Shifting Learning Goals**, and **Process as a Tool of Change**—that helped define a transition trending toward system adjustment. A group of consequences, mostly unintended, could coalesce to contribute through time to **System Adjustment**. These included issues of social structure, issues of application, and issues of social justice, and are described further in Table 11 (p.151), discussed at the end of this section. The elements (codes) within the clusters will here be detailed in turn, and a broader view of overall patterns will be analyzed to reveal trends, connections to other databases and to theory in the Discussion section.

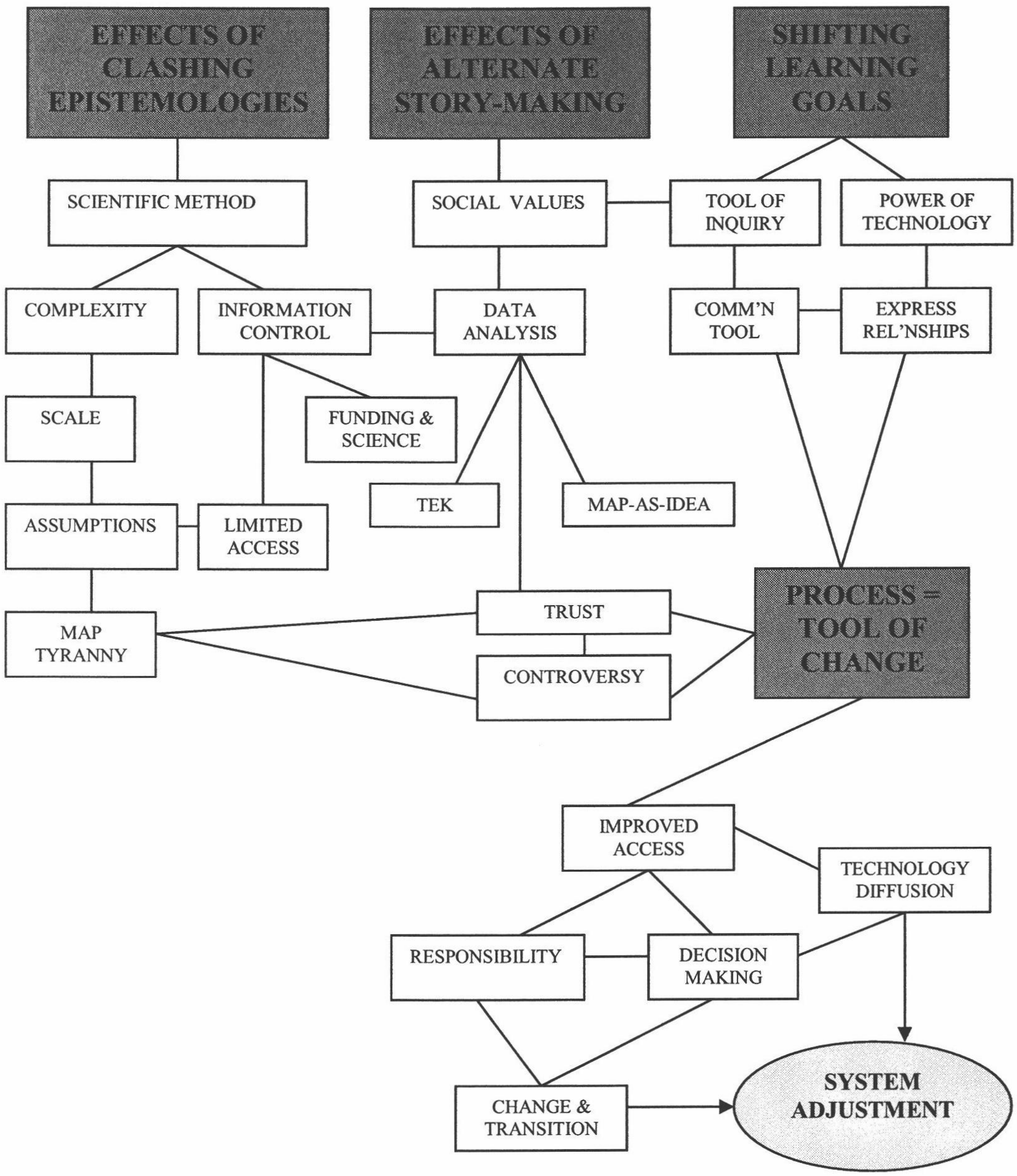


Figure 7 Themes in Content Analysis
Codes clustered around four key themes—Effects of Clashing Epistemologies, Effects of Alternate Story-Making, Shifting Learning Goals, and Process as a Tool of Change—and contributed to the System Adjustment identified by charting consequences (intended and unintended) of using GIS maps in natural resource management.

To set the context—provided by perspectives on how GIS technology is affecting our natural resource management environment—a brief selection of the commentary by focus group participants of what GIS "does" and "brings" is provided here:

> "It's a representation of somebody's view of what reality is, so it's an expression of that idea, and it happens within GIS to be able to be displayed in a variety of different ways so you can express a variety of different ideas."
>
> "One mode of communicating the results of models."
>
> "The technology makes map-making more accessible to a greater number of people. You still end up with a map."
>
> "It's not just a map of information, the GIS part allows you to combine different themes to produce a new map that you couldn't get very easily some other way."
>
> "What I think is emergent is the capabilities of the system to allow the asking of questions and the contemplations of kinds of analyses that no one would have tried without the tools."
>
> "From a research perspective it allows you to learn what the outcome of the relationships are more quickly than you would be able to do without that technology, so your learning capabilities are greatly enhanced."

Each of these comments raises issues that will be discussed in their turn below.

The Clash of Epistemologies

As deep background to all scientific endeavors, the scientific method developed so long ago on Cartesian principles can lay claim to a great deal of success through many centuries. More recently, it must answer for a rising number of conflicts. The question from the public—why do you base your science on lies?—was essentially based on a misunderstanding of how the scientific method builds knowledge. Habermas's idea of "pre-linguistic" development of people along different paths here applies to the training that sends scientists down very different paths from those of audiences they must face or members of the public with whom they must work in twenty-first century environmental problem-solving (Habermas 1970).

Table 10 Content analysis codes, 2004 workshop.
Concepts contributing to understanding of codes within content analysis.

Scientific Method—*deeply entrenched effects on approach of Western-trained scientists. CLAMS group may be a in transition phase in trying to move from positivist approaches to post-modern: how do we address different kinds of knowledge, and how do we accord equal status to other ways of framing questions?*
Complexity—*comprehended in a specific way by CLAMS scientists, whose concern is the amount of time it could take to describe the complexity, let alone just work around it on any given project. They have to deal with complexity pixel by pixel, map users have to take it in one swallow.*
Scale—*refers to temporal and spatial problems, but can also refer to the scale of the decisions to be made with the help of the tool. Changing the scale of questions improves our ability to look at emergence of different answers at different scales, providing new perspectives.*
Assumptions—*represent the "hidden language" of GIS maps, and may represent a way through the trust issue. Request for their inclusion in map layers becoming insistent.*
Map Tyranny—*can act to stop people questioning a particular map and possibly therefore not contributing usefully to policy discussions. Also plays into understanding, or failure to understand, the fact that landscapes are dynamic.*
Information Control—*in terms of audience levels as well as how information is presented, who has access to both the information and the presentation technology.*
Funding & Science—*generally constrains access of non-scientist "outside the system" to funding for inquiry; can also constrain scientists within the system, especially ecologists.*
Limited Access—*commercial considerations (cost of software), time pressure, openness of the peer review process, complexity of relationships or models, and limitations of data. All limitations appear to be circumstantial, rather than deliberate, perhaps suggesting they are institutionalized?*
Social Values—*reflexively understanding the social values driving the kinds of maps and types of inquiries taking place today, compared with those that might have happened in the past. Also addressing social values within the maps, so that they can be part of the analysis.*
Data Analysis—*what happens to data when they are analyzed? How does data analysis divide scientists from non-scientists? GIS data analysis adds the power of new layers and combinations, helping us see new aspects of landscapes. Map as hypothesis (scientist worldview) versus map as truth (map tyranny/non-scientist worldview).*
Traditional Knowledge—*attentive publics come to GIS maps with pre-existing maps of how the world looks, and ideas on natural resources sometimes distant from the findings of scientists. So far TEK (traditional ecological knowledge) is playing the role of informing map users of maps' integrity, not yet of informing the map.*
Map-as-Idea—*does this idea give greater freedom in interpretation of maps? How does map-as-idea relate to map-as-hypothesis? Concept of map magnetism also applies: the ability of maps to pull people in, leading either to map tyranny, or to enhanced dialogue.*
Trust Issues—*affected by understanding of the model and comfort with the data; personal experience and relationships; the level of controversy and crisis, or the level of pressure for a decision. Trust can be built around taking responsibility for knowledge.*

Table 10, continued

Controversy*—could develop a spectrum in natural resource issues from non-interest to crisis, and see where enterprises such as CLAMS fit on that spectrum. What role, if any, do CLAMS maps have in high-pressure policy decisions?*
Tool of Inquiry*—maps provide new perspectives beyond what the naked eye provides, combining of data in new, previously unexamined ways; thematic thinking allowed by GIS maps may assist in mutual learning. How do our inquiries relate to our social values? Also includes use of the tool: how it's used, to what end, in what settings. Tool as enabler.*
Power of Technology*—GIS allows the move from information to themes, relates to how people more typically process information? How does it therefore open opportunities for mutual learning? Is the technology an enabler? A constantly improving set of tools? "A more formulated way of generating hypotheses"?*
Communication Tool*—can be used to communicate selected information. Can also be used to teach about itself, how to think about information. How well are we using GIS to teach ourselves ways of thinking? Scientists are new to the field of communication and distinguishing among audience levels; agency people used to thinking it terms of control of information.*
Expressing Relationships*— Relates to thematic thinking and schema theory. Tool has allowed us to take scientific investigation into a new realm, spatial thinking and perception. Projections take us "beyond what we can see" and "to the next level." What does spatial representation do for us that tabular or other graphical representation did not? And vice-versa?*
Improved Access*—applies to data, technology, knowledge, and learning capabilities. How do we measure impact of improved access? People not used to dealing with maps as such powerful tools. Relates to responsibility.*
Technology Diffusion*—attitudes toward new technology stay grounded in practicality, functionality, seeing the technology as merely a tool. It might be faster, prettier, but it still needs to be understood as something that can help us with decision-making. Phasing of diffusion influenced by numerous social and technical variables.*
Responsibility*—need for an interactive relationship? Scientists appear to be asking people to come into their parlor, and help frame the questions; second-guessing isn't working any more. Non-scientists asking for the same thing--in what ways can joint responsibility be structured, then institutionalized, without losing its flexibility?*
Decision-Making*—where/how does this kind of technology fit in the spectrum of tools available for natural resource management decisions? Can these tools be used for policy? Or should they just help organize our thoughts, or build dialogue? Given that there is no rational decision maker, how do we answer these questions?*
Change & Transition*—links to responsibility, societal values, reframing the debate, new technology and its capabilities; moving from mylar to pixels. Responsibility of map users to become "attentive public." How might we create an attentive public? Links to concepts of landscape, changing views of science, schema theory, changing social theory.*

Scientific Method emerged early as a key code, as it underlay many of the comments made by map makers about current challenges, some of which relate back to communication barriers between them and map users.

One CLAMS ecologist commented:

> "There are three types of science that are done. One is description, you're describing something, another is looking for association, and another is you're looking for a cause-effect relationship. In medicine you want to confirm these cause and effect relationships and you do in ecology too. What we're doing here is taking the descriptive and associational work and saying we've looked at the associations for plants, we've looked at the associations for animals, we've looked at the associations for water, we've looked at the associations for people, how do all those things fit together into a hypothesis that integrates among all those things? And then that hypothesis becomes the basis, possibly, for a policy, and if the policy is implemented then that's the beginning of the experiment."

We might immediately ask, how clear is it to map users that a GIS map is merely "a hypothesis"? That any given policy is merely "an experiment"? Perhaps here are the grounds for some of the misunderstandings behind questions from the public. But more importantly, this framing of map-as-hypothesis, and policy-as-experiment, captures at a fundamental level the very epistemological viewpoint which, until recently, has provided the only guideline for policy information. Indeed, according to another CLAMS ecologist:

> "I think we often don't focus on how scientists come up with hypotheses. That whole hypothesis-generating part of the scientific process is often highly subjective, it comes from experiences we've had in various different places, we think this is my view of how the world works. And this way (GIS map-making) is a more formulated way of generating hypotheses."

Who knew? Additionally, scientists feel the dual attractions of resolving environmental problems, and expanding scientific knowledge, because both are worthy pursuits (Pielke jr., Sarewitz, and Byerly 2000).

The primacy of the scientific method for moving knowledge-building along, for formulating hypotheses, for establishing the understanding that feeds policy, affects and is affected by **Complexity**, **Scale**, and **Assumptions**, three subsequent components of the Epistemology cluster.

The astounding complexity of the CLAMS undertaking, as with many scientific endeavors, defies any simple comprehension, and generates its own set of problems. Modeling complex relationships is itself a deeply complex operation, unlikely to be delved into or fully understood by untrained outsiders.

Complexity, for the most part, is understood best by the map makers who must grapple with it, pixel by pixel. Map makers are dealing more frequently now with audiences who do not necessarily have the tools or the training to comprehend all the complexities to be encountered in landscape ecology, or the bioregional assessments they can produce. One possibility is to reveal the complexity to map users, by letting them see the massive volume of individual decisions, small and large, required to build a GIS map or run a model. For the most part these decisions outnumber by far, the number made in a scientific endeavor less dominated by technology. It is possible to build trust by openness, but that engenders its own challenges, described by another CLAMS ecologist:

> "We can document the process that we've used to make these maps but it would fill volumes for all the little decisions that get made that we don't really write down… there's a certain energy required to verify the quality of something and if we had to verify the quality in great detail of everything that's out there we'd be totally immobilized trying to make these decisions, so there has to be trust, otherwise the system gets overwhelmed."

At some point the ability of map users to comprehend complexity, to accept it as a given and also accept the map makers' interpretation of it, comes into play. Whereas scientists are under a professional obligation to embrace complexity continually when working with landscape ecology and developing GIS maps from their data, non-scientists can distinguish between issues that need to be understood in all their depth, and make choices about others that ask only a passing familiarity with what's under the hood. In the words of a watershed council member:

> "Well, the first filter there is how important is the decision, if this is going to be how you're going to proceed for the next 50 years in how you're going to attempt to prevent the extinction of spotted owls then it's worth spending some time and effort on (delving into the complexity). If this is going to be something a little less momentous, then a little more trust is easier then."

Grappling with **Scale** in both modeling and data analysis can also be a confounding part of the scientific process that calls on GIS maps to aid in interpretation. It can also be a powerful learning process. Two CLAMS ecologists articulated it thus:

> "I guess that's the advantage (of using GIS) though, that depending on the question, you can explore the answers to that question at appropriate scales or multiple scales and at multiple scales you probably will get multiple answers to the same question."
>
> And:
>
> "If you assume that a lot of answers to questions are scale-dependent, then this allows you to work at different scales and see how a decision made at one scale can get a different outcome (at another scale)."

Scale can also be an issue in terms of the kind of decision to be made. Decision scales are perhaps as important in the minds of map users as temporal and spatial scale are to map makers: there are varying urgencies—potentially scalable—to types of decisions, and they each require different treatment, as noted in the comment from the watershed council coordinator above. Scale will continue to be a challenge for both groups, but the recognition that GIS technology allows us a new take on it is a potential step towards landscape-scale understanding of complex processes.

If scale and complexity are elements of the scientific trade that must be managed by map makers, recognized by GIS technology, and somehow translated for other audiences, then assumptions are surely the "hidden language" of GIS maps. As a stumbling block, **Assumptions** fully deserves its own category.

CLAMS scientists are not insensitive to this problem, and have found themselves frequently explaining assumptions when delivering public talks. The result is, they recognize the problem, as voiced by a CLAMS fish biologist:

> "It seems to me that it's incumbent upon the scientists to be as explicit as possible about the assumptions and any other things that are in these maps, in other words we're just not laying this out there without trying to explain it...that then puts the burden on the people who want to use it to understand what the limitations are and what the assumptions are. If you believe the limitations and you accept the assumptions then you can use it."

As in other databases analyzed for this study, the request from map users to include assumptions in the GIS map layers is becoming a drumbeat that recognizes several key developments: the growing sophistication of interested members of the public in their understanding of technical data, and the ability of the technology to provide a relatively simple solution that wasn't previously available. For example, from one non-scientist:

> "The other suggestion I would have is at some level with the variables that you think are the particularly important ones, for you to make that part of the presentation. OK this is the variable that if you budget 10% the map really looks different, this is one that's in there but we can put pretty wide swings and it really only tweaks things. That's information that I think is really powerful in getting people to understand what you're doing."

Directly related to Assumptions, but in a category of its own, **Map Tyranny** was seen to be capable of wreaking havoc with the best-laid inquiry. A tribal manager saw it thus:

> "I think it's really important that when a product is produced that somewhere it is explained what the assumptions were that made that product and where the information came from. Because to Joe Blow on the street it's a map, and it might not necessarily be portraying what's going on now but they look at it and say oh wow, this is the way it is! And that's.. people are visual, most people are very visual people."

One landowner expressed reservations about the ability of policy makers to distinguish between complete and incomplete data, given the visual power of a map:

> "These maps have kind of shock value or awe value or stick in your brain value, you can make a little movie and have it show whatever you want it to show. I'm just...the unintended consequence is that regulators and government...may not be good enough to get the whole data, what are we looking at, all the images."

A watershed council representative described a specific example of such "leading by maps" in the policy arena:

> "I can see that map, the spotted owl map, I can see that getting out and going to a bunch of city councilors, metro planners, county commissioners, they've ordered a decade of mitigation, we've got all this great habitat over there and coming into play over the next hundred years, that's a great excuse for us to expand our boundaries and to incorporate more land and to take out of this production and put it into

> residential and industrial. It plays right into these other maps that the CLAMS guys are putting out because these organizations, the integrity of these organizations, are above reproach."

These are real fears, sometimes based on real experience, of how policy makers, just like many map users, can be swayed by the highly persuasive visuals emerging from the GIS factories. The groups conveyed very little sense of any deliberate manipulation of data in this respect: these were not accusations of attempts to bias policy. The trust factor here addresses policy-making entities and individuals, rather than the scientists producing the maps as interpretations of their data.

These well-informed concerns about the appropriate use of technology in the application of science to policy raised several related themes of interest under the Epistemology cluster: **Information Control**, and **Funding & Science**.

Information can be controlled by relevant institutional structures, such as when results can take years to get published, or by other limits to access. Its dissemination can also be controlled by availability of resources. One public land manager commented:

> "It depends on the audience you're working with too. If it's important you have to think about the audience you're presenting the map to and what it's going to take to make your process transparent as to how you got to it. The more maps are handed out though, the less control you have but in situations where you're just going to work with a small group, you can control that situation as opposed to hosting something on the web where it's going to take a lot of work to set something up that people could determine if it's good information or not. It's probably the reason it doesn't happen very much, it's because it's so time-intensive."

The sense of "control" here appears to have more to do with the ability to explain assumptions and sources of data, than it does with limiting information. A CLAMS GIS technician questioned whether spreading the "control" around would net us more information and thereby contribute to the discussion, or just give everyone the ability to set up maps to show the world the way they want it to be shown. Certainly this latter is a capability of GIS technology, and could operate to muddy the dialogical waters by starting "map wars," as has occurred in environmental problems previously. The idea does, however, reveal how closely linked **Information Control** is to the themes of **Assumptions** and **Map Tyranny**.

An alternative viewpoint, again from a public lands manager, notes that another pertinent issue in information control is whether a given entity stays up to speed with GIS technology:

> "Everybody who wants GIS in coming years on the big issues is going to have it and so basically the bar is just going to be raised in terms of...the level of discussion and the tools people use on both sides and as technology increases the bar is just going to keep going up and if you want to win or lose on your side, you'd better keep up with the technology...you're going to have to know all the tools to be in the game, because the tools are going to be out there..."

Technology diffusion literature suggests that there are always winners and losers with new technologies, and the references here support that idea—a pragmatic recognition that the technology is not going to go away, but that the benefits might be unevenly disseminated.

Tightly associated with **Information Control**, **Funding & Science** represents a briefly-discussed but powerful theme that conjures institutional structure as an inanimate but active player on the natural resource management scene, and an ever-present potential constraint on mutual learning. Interestingly, some of the comments from ecologists suggest that they already feel they are playing a little outside its rules, merely by being ecologists, where the conditions are notably different from those of medicine, physics, or engineering, for example. Efforts to follow the rules of the scientific method have not always met with success:

> "If you're doing a grant proposal for NSF or one of those outside funders, and you're trying to replicate what somebody else has already done, you won't get funded...
>
> "Or you try publish a paper with the exact same study that someone else has already done with the exact same results, forget it."

Even as map makers themselves lament some of the funding issues that directly affect the conduct of their inquiries, map users note their own lack of access to both the process and the content of those inquiries. On the topic of **Limited Access**, participants mentioned factors ranging from the obscure source or use of data, to the "closed shop" process of peer review, from the expense and complication of software, to the delayed rate of publication of scientific results. Each of these factors—offered across the board by both map makers and map users—has the potential to create noticeable separation between map users and the understanding they need to use the full range of CLAMS tools. This separation compounds the effects of complexity and scale issues within the scientific enterprise.

Effects of Alternate Story-Making

Findings from preceding mental maps research helped frame the next cluster, effects of alternate story-making. The central theme here is **Social Values**, specifically changing social values, and relates back to the question from a public meeting cited in the Introduction, "why do you try to force us to accept your values?"

Despite how long science has been touted as value-neutral, post-modern thinking supposes that it is not possible to construct a reality the way scientific investigation does, without being influenced by your own values, however slightly. Many scientists themselves are coming to see this, and one CLAMS ecologist put it this way:

> "I think one thing that we need to think about within CLAMS and some of the other projects is that the products we produce now are designed to provide information to users that reflect societal values today. And if we were able to step back in time to 20 years ago and have the same technology, the products we'd be producing would be very different, because the social values driving those products would be very different. One thing I think that we need to think about is what are likely to be the social values that will be really driving people's decisions five years from now, ten years from now. What's out there on the horizon that we need to be concerned with? ...I think we've all had our heads kind of pointed at the science and the ecology of the natural resources questions without reflecting so much on the social questions and social values that are going to be driving decisions in the future."

A CLAMS economist supported the idea that values continually change and can be reflected in certain CLAMS maps:

> "There's another map where we show the...environmental protection in 1960 and now, and the amount of the landscape that's managed for ecological values. And by showing that, or even some of our simulations, you can no longer just hone in on one ownership to talk about sustainability, you have to look at the whole landscape. When you have to look at the whole landscape, you have to acknowledge that a number of the ownerships are already doing a lot of different things."

As a piece of this puzzle, an NGO representative raised the question of when we could stop arguing about the science behind the various models, which is quite often agreed upon, and start debating at the point where the conflict is, in the social values? As follows:

> "It strikes me as we become more familiar with them (maps and models) then we will get to the point where we can stop arguing about what is the best available science about these questions...then we can make that choice honestly as a society rather than having the various sides either pretend that there's a scientific debate or fabricate one when there isn't one. So let's talk about the things that are really uncertainties and a lot of times they're arguing about political and social choices..."

The **Data Analysis** theme addresses some aspects of these questions, within the story-making cluster. To paraphrase a CLAMS ecologist, we are now capable of producing multiple, layered, empirical, theoretical, and new images of our landscapes—images that we couldn't produce previously without great difficulty—and producing them rapidly. How do these new images of landscape affect our ability to think about managing natural resources?

In one example, as noted by a CLAMS fish biologist:

> "The other way of looking at (creating GIS maps) is it's allowing us to take the results and the lessons we learn from them and apply them across the broader plot. I mean that's exactly what's been the intention. You can look at the literature and we took that and developed it, we developed our information with a series of quantitative models and actually applied it...so you're taking these ecological concepts that are spatially undefined in our studies and taking the lessons from them and being able to project those lessons across the landscape."

There is value in the analogy here—do new images engender new thinking? If we subscribe to schema theory at its most elemental, when our frame gets rattled hard enough, we are capable of making changes (Crocker 1984; Sadoski, Paivio, and Goetz 1991). Observations by participants suggest that they perceive a middle ground, however, in which we try to adjust internally to the new image. For example:

> "Of course the first filter there is unfortunate but that's the way it happens, is it doesn't agree with my perception therefore what's wrong with it, as opposed to gee that looks different I wonder what I have been missing."

Within the **Data Analysis** arena, two threads from the **Epistemologies** cluster can be detected again, complicating the story-making process: map-as-hypothesis (**Scientific Method**) and map-as-truth (**Map Tyranny**) is a conflict that traditionally tends to divide map makers from map users in their understanding of spatial information. What happens to data when they are analyzed spatially? Who selects the range of outcomes?

One watershed council coordinator notes:

> "...sensitivity analysis...is something I think should be part of the discussion, when you're talking about how much yellow's here versus there, if you talk about that in terms of well if we vary this criterion, here's how much difference that makes in the product and not only in what the map looks like but in what the data table looks like."

Once again illustrating relationships across clusters, **Data Analysis** and **Assumptions** link to each other in a way that is affected also by **Information Control**. There was also the suggestion from a CLAMS GIS specialist that the so-called information explosion affects natural resource management in the sense of changing the equation between skill sets and resources:

> "My view is historically that map makers had a high level of skill and low level of resources to make the maps, and now it's kind of flip-flopped to where we have the map makers who have low level of skill, but lots of resources to pull the data from. So...the accuracy of the maps (can be) probably a little bit disappointing, because even though there's more data available to people that are producing maps they aren't as skilled at making maps."

In the hustle of truckloads of data and rapid transmission of new maps, however, have we undermined our ability to think really deeply about those data? Are breadth of vision across the landscape and depth of thought about the issues equally important, and if so, are we serving both masters effectively with spatial displays such as GIS offers?

There may be, as part answer, more room now for creativity in map-making, certainly in terms of content, although it would take something more than GIS to best the fabulously artistic maps of medieval explorers, for example. In tribute to **Map-as-Idea**, a CLAMS ecologist expressed it thus:

> "I think your idea...that a map is an idea is accurate. It's a representation of somebody's view of what reality is, so it's an expression of that idea,

> and it happens within GIS to be able to be displayed in a variety of different ways so you can express a variety of different ideas."

This meshes with the potential playfulness of GIS technology, as imagined by an industrial forest manager:

> "Wouldn't it be interesting if we could take the brown blob map (showing land use change as a growing brown element) and as it moves from green to brown the laws go away, or the forest practice laws no longer apply, and if we could run that simulation of the laws disappearing and no longer protecting the stream as the brown blob grows? Wouldn't that be very political but it would be very effective."

The technology is there to do such exercises, the motivation is there in terms of finding out what would happen under certain changing values. Does the concept of map-as-idea give us greater freedom in our interpretation of our landscapes? Are we prepared to use the tool this way?

There may also be, with the capabilities of new technology, more room for incorporating other kinds of knowledge into existing or new maps.

Traditional Knowledge (shortened to TEK in Figure 7, p.125) became a small but necessary theme in considering story-making. To date, it appears, traditional knowledge, whether handed down through generations such as by Native Americans, or more directly experiential, such as by a non-industrial tree farmer, is playing the role of providing a check on the maps' validity, rather than actually informing the maps. Several map users commented that they know, intuitively, whether a GIS map is "right" or not, because they are familiar with the landscape and how it works. They do not accept maps "totally blindly", because they have "background knowledge of how it is." This finding resonates with the idea that traditional ecological knowledge is inherently more "social" than scientific knowledge, and to date is effectively shut out of the decision realm (Berkes, Colding, and Folke 2000).

The idea of linking with map users through interactive technologies—possibly gaining access to previously underused bodies of alternate knowledge—could play a role in building that necessary edifice in the scientific and decision-making enterprise: trust.

The **Trust Issues** theme has emerged in all five databases investigated for this study, and is not surprisingly linked conceptually to many of the others. How, especially, does trust interact with decision-making? How do societal values and complexity affect levels of trust?

Trust is affected by a broad suite of factors, according to focus group comments. Among these are: (1) Comfort with the data and understanding of the model: one watershed council coordinator referred to stakeholders' needing to reach a "tweaking comfort level" with models as a necessary condition of developing trust. (2) Personal experience and personal relationships: another watershed council coordinator referred to the "rules of engagement" agreed to between various landowners in how much will be revealed by a map. (3) The level of controversy and the level of crisis: a CLAMS ecologist spoke of "finding the middle ground" between issues so contentious there's no room for new information, and those that are not yet on the political/environmental radar screen. (4) Pressure for information versus pressure for a decision: a watershed council coordinator spoke of the change in attitude towards maps when they're "no longer just a pretty picture" but are being used for real-life decisions. This list is not exhaustive, but gives an idea of the sociological reach of Trust Issues.

The "black box" plays a role in trust development between unfamiliar parties when the intervening factor happens to be some extremely complex information. As noted by a CLAMS ecologist:

> "There's also an irony in that to model a complex system requires complex relationships that most of the map users are not going to dig into, and they're just going to look at that map and make a judgment. The issue of trust is still going to be there, even though the metadata are there available for people to dig into, there's still a trust issue simply because of the complex thing that people aren't willing to go into."

While the "black box" aspect of science may be exacerbated in GIS by the sophistication of the technology, it does at the same time produce images—mapped space—that may help unlock that box to some productive degree. A CLAMS social scientist notes:

> "(There are) advantages of (GIS) maps in terms of trust. All science is a black box in some degree, but the results of the black box can be laid out

> in the context that people experience the world in which is spatial, and then people can do their own verification."

A potential barrier to communication, then, that could also become a bridge. A CLAMS GIS specialist spoke of "maximizing the trust that's possible" as a more realistic goal than aiming for complete trust.

Nonetheless, participants recognized that the likelihood of trust holding its ground during a crisis is vanishingly close to zero. The point at which trust loses its bridging capacity was addressed by a CLAMS ecologist:

> "There's really a sort of gradient of visibility in the sense of this type of information, depending on the amount of contention or crisis or urgency, and type of emergency. The more we're in crisis mode the less useful this type of information is because we can't turn it around or the political process is so polarized that this information just can't...handle it... If we can try to anticipate things and attack them before they get too contentious then I think we have a better chance of informing them. That's my hypothesis anyway, I don't know if we have a better way to do it."

Issues of **Controversy**, then, may override the capabilities of an anticipatory assessment such as CLAMS represents, but ultimately this underscores its intrinsic value as a set of tools that anticipates landscape-scale environmental problems, and offers ways to prepare ourselves to face them, not least among which is the capacity for framing our environmental stories on our own terms.

Shifting Learning Goals

As a **Tool of Inquiry**, GIS maps bring noteworthy advances in how we can conceive of our world, offering outlets for information quests from many perspectives, along with a rapidly accessible view of the whole landscape. Shifting Learning Goals, then, is a cluster of themes representing the potentials for change, for enhanced mutual learning, brought about by the GIS technology component of CLAMS. It might also be termed new perspectives, as the following exchange suggests:

> "Watershed Council Coordinator: Well, it allows us to...ask different questions which tend to be more traditional questions put into a spatially explicit context or...

> "CLAMS ecologist: It allows us to see things from perspectives that we didn't...it's not unlike a microscope or a telescope in the sense that you

> can get a new perspective, the tool allows you to see things in a way that you couldn't very easily see with your naked eye.
>
> "CLAMS wildlife biologist: From a research perspective it allows you to learn what the outcome of the relationships are more quickly than you would be able to do without that technology, so your learning capabilities are greatly enhanced."

A CLAMS economist noted that people have "differential levels of information" with the result that GIS maps can become a leveler, where everybody's knowledge is brought to a similar point by the spatial information in front of them.

Perhaps just as importantly, the ability of the technology to respond to a far broader suite of questions has enabled our thinking to expand beyond traditional borders and roles. Numerous references to questions arose in the focus groups, regardless of demographics, and the common thread seemed to be the power of the technology to address new questions and new kinds of questions, including some that could not feasibly be addressed before.

Thus, GIS as **Tool of Inquiry** is a central point, raising an array of associated issues, of which precision may be first among equals. If precision on the maps is difficult to achieve in the face of complexity and scale issues, how important is precision in driving our inquiries of the maps? One CLAMS ecologist addressed concerns on this front:

> "It's gotta be required to use this in a very concrete way in terms of driving policy …so that we require the users to ask very precise and specific questions and be very clear in what it is that they want. Because right now what we're doing is basically second-guessing what the policy folks might want, and kind of laying it out there for them to react to, or putting it out there for people to use or download. It may not be exactly what they want, and when it really is going to make a difference in people's lives, we need to have very clear questions or requests asked of us so that we can provide the information in the way that they want it."

Recognizing the problem of passivity in serving up answers to policy makers, participants discussed the potential for allowing map users to interact with the maps and experiment with variable values and outcomes. An industrial forest researcher put it thus:

> "I think it offers an unprecedented opportunity to go beyond the standard way we present results. The printed maps are great, but...the opportunity exists for us to go to small groups or meetings and not bring the map, but bring the computer along and ask what questions do you have, and someone brings up a counterpoint and says well I don't really like this assumption. We may not be there yet, and some of these things take immense computing time, but there will be a time when we can say let's try that out and see if that makes a difference. I think then we will get to a mutual learning approach instead of a here it is for your consumption approach, and I think that will get us down the road."

General agreement on this vision came from across the board, and was expressed strongly by an NGO representative:

> "I guess I would echo (that)...I can't count the number of times and workgroups I've been on where it would have been so great if the scientists were there and have just a computer and an Infocus projector and throw out different assumptions and have the group work through these things together rather than go back to their separate caucuses and argue and then come back and fight together rather than have this sort of stuff shown up and then we can move together. I think that would be a great tool."

The resources in time and personnel of setting up such interaction were acknowledged to be considerable, but as a public lands manager noted, these technologies are here to stay, people are going to have to engage with them to "stay in the game." The question of whether we are leading or being led by the technology at some point becomes almost irrelevant.

The prospect of interactive GIS maps, of course, links to the question of how our social values relate to our inquiries. Can we at some point debate the issues rather than getting hung up on the science? Several threads lead out from this point. One involves learning from the unexpected, a process noted by a number of scholars as central to the idea of changing individual schemata, and the subsequent effects on our perceptions (Crocker 1984; Priest 1995; Minsky 1975). Undetected information needs can become large, but invisible, players. As observed by a CLAMS GIS technician:

> "I think maps really challenge our expectations. When someone sees a map for the first time if it relates to how that person visualizes the world it's like wow this is a great map, whereas if it challenges how they see the world they say what's this stupid map doing? (laughter) And the interesting thing is that if it's not what you expect, the question becomes

> do you learn something from that? That's almost more where the learning starts rather than if it's what you expected to see."

Another thread relates to the quality of argumentation. Given a broader view across the landscape, given the ability to look at different outcomes of different actions, are we better equipped to discuss alternate futures? Can we improve the quality of argumentation, as the NGO representative suggested, by moving on from arguments about the science to discussions of issues, values, and the future?

Participants seemed to recognize that, since GIS maps are tools of inquiry, we are on a trajectory toward giving ourselves many more choices in how we learn, how we engage with each other and with new information and new ways of viewing it. Thus the **Power of Technology** theme directs our attention towards the short-term capabilities and longer-term effects of perceiving GIS technology as a medium of interaction as much as a medium of presentation.

As one CLAMS ecologist observed, the difference between traditional maps and GIS maps is that the latter have moved us from dealing with information to dealing with themes, even combining themes, to get a new map that provides a new perspective. And it can be done very quickly. Another ecologist noted the technology allowed us a "more elegant" expression of our ideas. Tools of change, indeed.

In regard to concerns about the power of maps for conveying ideas, participants seemed to agree that the aha! power of GIS maps was a feature not to be underrated. An NGO representative expressed it this way:

> "These maps are sort of an aha or a revelation to people. We've all talked about their projection of the future or people compare them to their perception of reality, but we don't talk about people who actually don't know what's out there in the coast range and they look at the map and say oh my god what have I learned that I didn't know?"

A non-industrial forester concurred, noting that you "just get your own view" when you drive or walk your own place, so the aha! comes when you can see the big picture. The aha! response is markedly more likely to happen with a map than it is with tables and graphs. Comments from CLAMS map makers about public response to their maps supported this view, although it does pitch us back into the question of whether the aha! moments are generated by accurate data. While the specter of map tyranny still lurks behind an aha! moment—have map users had an epiphany that they should have questioned?—several participants noted that pixel by pixel accuracy of the maps was not important from a policy perspective. As an NGO member noted:

> "We don't care about specifics on the number of trees on one person's piece of property, we care about the big picture, and it's a pretty powerful tool that just didn't exist before."

GIS technology has power as "a more formulated way to generate hypotheses" for map makers, opening their eyes to the landscape just as dramatically as those of the map users who support different worldviews. So is the technology just a convenience, or is it more than that? An enabler? A constantly improving set of tools, which we have choices about using? Its power at the negotiating table may be quite simple. As a non-industrial forester noted:

> "...just bringing people up to a level of spatial analysis that (they) might not have (had before)...Even if you don't do anything more than that, just give them a snapshot I think that it's really useful in just bringing people to the same level and that helps people talk. It also brings up people's concerns when they see these maps, they can say you know this isn't right, or this is full of whatever, or I don't believe it, that's good too."

Its power overall has to do with thematic thinking, based on expressing relationships. As a category, **Expressing Relationships** supports the power and communication aspects of the technology, and stems from the observation that GIS allows us to express, spatially, relationships that are otherwise expressed as mathematical or ecological and thus potentially quite obscure to map users. An NGO representative observed that this is a step forward that has been much needed:

> "I'm thinking that this whole way of investigation of being more spatially explicit about trends and effects and biological relationships is really relatively new, so that we have a lot of time to make up for when we weren't thinking that way and that this is really allowing us to think in the way that conservation biologists and others have been pushing for for a long time, and it's making it more real."

As well as this, the ability to produce projections of future conditions takes us "beyond what we can see" and "to the next level." While these features of GIS-based tools trend naturally towards mutual learning, they can also be undermined by trust issues, as a CLAMS ecologist observed:

> "The complicating factor is that others can look at (one of our maps) and say yes it makes sense or no it doesn't make sense, but then they have to trust that we've implemented those relationships, they have to trust that we know what those relationships might be. The black box thing becomes darker and larger the farther you get away from actually developing those relationships. It's a tough one."

Which leads to the question, what does spatial representation do for us that tabular or other graphical representation did not? A non-CLAMS social scientist put it this way:

> "The question that comes up in a sense is what are the questions that CLAMS thinks it's going to answer that are different from these other kinds of programs and does it, is it related to the GIS activities of the project? Are pixel-level answers part of what's going on in CLAMS?"

Given the dual concerns of accuracy and trust, the best answer is probably: yes, part of it. Whether the maps are looking at pixel-level or landscape-level relationships, they are functioning, in one sense, as intermediaries between the data and technology that are more available and more accessible to map makers, and the map users (including policy makers) who must make sense of the visual outcomes of looking at themes and relationships spatially. Thus the category of **Communication Tool** looks at how GIS maps might function as a bridge to changing the decision process in natural resource management.

Scientists, as a group, are relatively new to the practice of communication outside their own fields and peers. New perspectives on knowledge development and knowledge sharing are a central challenge to the practice of science in the post-positivist world, and can easily be set aside as too time-intensive to activate. This does not mean that scientists in general are not open to change, just grappling with the implications. According to a CLAMS ecologist:

> "I think the level of communication between the users and the builders, if that's increased it can only lead to a greater degree of trust. The question is…how much time do they have to do this sort of thing, it's pretty impossible to expect a continual level of input, so the question I have especially to the users, what level of communication is adequate for you, what level of communication do you want, what kind of information would you use? I don't know the answers to those questions."

Such questions indicate the preliminary stages of considering the elements of appropriate communication, along with the trepidation about addressing unfamiliar audiences, as another ecologist noted:

> "That audience thing is very important. When I give a talk to an audience of scientists I spend a lot more time on methods. I've given talks to some user groups, they don't want to hear about methods, it's tell me what the results are, tell me what's the bottom line. If I launch into more than a couple of slides about methods, people are falling over asleep."

The suggestion from a fellow participant to try to make that stuff more interesting may not have immediately solved the problem! An industrial forest researcher noted that tabular data are "a horrible way to present data and communicate results" because many people prefer a visual representation to communicate, and "isn't that what we're trying to do?"

Process as a Tool of Change

Spatial analysis, then, seems to be offering at least a portal to an improved mode of communicating some kinds of information. What emerges from the focus group commentary is the clear sense that GIS technology is not going to do this alone, as its developers may have envisaged. Instead, the process of communicating over a map becomes, in itself, the tool of change.

Improved Access is a category that embraces several ideas. **Power of Technology** and **Communication Tool** threads suggested that access to information in its spatial form becomes more important in successful communication than direct access to data or technology. In the spatial format it provides access to improved learning opportunities. A watershed council coordinator made the comparison between looking at numbers to understand population dynamics in the old days, versus looking at "geographic sub-units that are much more comprehensive." Utility of information is improved. Even passive use—in the sense of downloading CLAMS GIS data rather than trying painstakingly to produce it independently—was noted as a beneficial form of improved access.

But the favorite dream of map users is to have the hands-on experience, as noted by a watershed council coordinator:

> "I think getting back to something very important,...having an interface where a user who doesn't have the skill to have made the map in the first place can go in there and play with levels and do that. I think it's very important to see some platforms that are easier for that kind of manipulation and what ifs so that you can broaden the base of people who have at least a tweaking comfort level with your products."

Unquestionably, **Technology Diffusion**—its use, its diffusion, its fundamental meaning—which has strong social implications, is at play here. A growing sense of understanding the tool on a social level, rather than exclusively on a technical level, is apparent among all groups and in many comments. Outside of established research institutions, the transition is most typically in the earliest of stages: GIS cannot be a useful tool while map users have not the time to learn it or the resources to train, upgrade, or hire their way to full use (Brunn, Dahlman, and Taylor 1998). It is not unusual for map users to have tried "the new system," briefly becoming map makers, and abandoned it for time or resource reasons:

> "I've gone back to the old way of pulling out the topo map and property lines and know where the monuments are, and I could kick out a map in a day and if I was using GIS it might take me a month. I just don't have the time to do that, I have other things I have to do, and being the GIS guru is not my top priority. My top priority is getting my work done and map-making is a part of that. It doesn't have to be glitzy with pretty colors. It needs to be functional."

Another feature of early transition is that there is not an easy way for GIS map users to know the source of a GIS map; for example it has no professional stamp on it such as a surveyor uses on a plat map, a GIS specialist pointed out, and thus no "reassurance" for the map user. In the case of CLAMS maps, the three sponsoring institutions provide a level of credibility for some users, a quasi-political target for others.

But at some point, the stage of technology diffusion becomes a moot issue, with GIS adoption occurring at a sufficient level throughout research and administrative settings to guarantee that it will become part of the decision landscape. A public lands manager noted this about technology diffusion in general:

> "All this has been going on since long before GIS, you could have the same conversation over spreadsheets and charts and...making fancy

> graphs…It's just this new tool and it can be used, misused, the gee whiz factor is there and you gotta deal with it..."

Regardless of the stage of adoption, improved access is possible now by engaging other technologies, and provides a direct link to the themes of **Decision-making**, and **Responsibility**, in which changes in approach to natural resource management start to be stated explicitly.

A somewhat heated exchange at the morning workshop between a fisheries biologist and a watershed council coordinator about a current set of interpretations of salmon habitat, was referred to in the afternoon as being particularly useful as the kind of discussion needed around any maps that were "relevant to a decision" in policy. The "gradient of visibility" in terms of how useful data and maps are to an actual policy, particularly around a crisis, generates questions about whether these maps can realistically be used for policy. Should they just be used to organize our thoughts? To formulate hypotheses for researchers? Or to build dialogue?

A public lands manager—often in the hot seat of natural resource decisions—noted that he saw the agency role as keeping "a level playing field" in terms of making data available for stakeholders, so that decisions could be made on the basis of the best possible tools. It should be remembered that from the map makers' point of view, policy is essentially the beginning of another experiment on the ground, whereas a map user interested in resource management issues is likely to view a policy as the end point of a struggle, complete with winners and losers. Hence the relationship between mis/trust and decision-making.

One NGO representative noted that critical questions in the political arena are being avoided while the science appears muddled, but the real reason, she suggested, is that we don't know how to use some of the newly-formatted information.

The greatest departure from the 2002 workshop was the emerging idea of **Responsibility**, the conscious engagement of interested publics in learning and understanding the information they need to assist at the policy table. This can take several forms, as comments below from an NGO representative and a CLAMS GIS specialist, respectively, indicate:

"I think that because anybody who's going to think critically about this information is going to have to go back to the tables and look at well how did you come up with that, what is that data, how does that model work, what is that stream reach data, what is that veg layer?"

"I think the tools really ask people to be savvy, you know just like everything else around us in a culture of information, there's so much information out there you can fire off 100 maps. I think what it comes down to is people have to say well I'm looking at an image and making a contribution. The maps have to start requiring people to ask the question of where it's coming from, is it really saying (this), who made it?"

Connecting many threads under the theme of **Change/Transition**, it was observed that taking the time to consider how we think about our scientific and environmental problems, as some scientists have suggested (Benda et al. 2002), before we launch into policy, could be a productive exercise. As a watershed council coordinator observed:

"The very act of putting the issue into a spatially explicit framework really reframes the issue and changes the debate. When someone's talking about too much clear cutting or too short a rotation or not enough salmon or whatever, and you can look at that on a map and say OK now here's where your experience is and here's what's going on down here or here's what's going on over there, it will really reframe the debate in ways that are generally positive."

When we re-frame the debate, the indirect links between **Social Values** and **Responsibility** become yet more compelling. Engagement in the process of change is realized, suggesting a distinctive phase of technology transition.

System Adjustment: Facing the Consequences

As noted in mental models results, the direct questioning of respondents about consequences of GIS technology (for the most part clearly unintended by the developers of the technology) did not yield a large number of categories, but closer study of the transcribed data revealed that such consequences had emerged in the course of answering broader questions. In this study, they clustered into three groups with relationships across the full spectrum of content analysis themes: issues of social structure, issues of application, and issues of social justice. Table 11 (p.151) shows a matrix listing consequences in their respective clusters, and relating them to key themes revealed both by content analysis of focus group discussions. The consequence clusters (top row, left to right) show a progression from structural matters to symbolic matters of meaning. Likewise, themes from content analysis (left-hand column, top to bottom) loosely suggest a similar trend from structure to meaning.

The matrix helps illustrate how each of these relationships can reveal a congenial or adversarial nature. In other words, the *consequences* of a technology's development and use do not always mesh smoothly, or even align, with the gradual dispersion, acceptance, and implementation of the technology. Disturbances of established practices (how ownership is reported), or changes in perspective that might affect power structures (how one policy might constrict another in terms of land use), can alter or obstruct the trajectory of technology diffusion. Alternatively, they can be outweighed by other forces, such as broad and rapid spread of improved efficiency or understanding (effects of ecosystem management on biodiversity across the landscape), which in turn accelerate acceptance and implementation.

Table 11 Interaction between consequence clusters and content analysis themes.
Consequences fell into three clusters (top row), which each showed relationships with themes developed during content analysis (left-hand column).

	SOCIAL STRUCTURE	APPLICATION	SOCIAL JUSTICE
EFFECTS OF CLASHING EPISTEM-OLOGIES	Mistrust undermines public involvement in decisions. Non-scientists stay/move outside power structure.	Privacy issues threaten dialogue. Anti-trust laws threaten ecosystem management.	Privileged knowledge compromises decision-making.
EFFECTS OF ALTERNATE STORY-MAKING	Unilateral story-making no longer satisfying or sufficient.	Softened property boundaries encourage ecosystem/ landscape thinking.	Ethics of presentation rises in priority. Story-making becomes multiple and collaborative.
SHIFTING LEARNING GOALS	Funding and institutions constrain extent and type of inquiry.	Atrophy of non-spatial learning skills affects framing of questions.	Improved argument-ation enhances quality of dialogue and framing of questions.
PROCESS AS TOOL OF CHANGE	Shifting locus of power re-frames debate and status of partners.	Improved spatial awareness changes dialogue. New ethics of presentation generates more thoughtful use of data and technology.	More sophisticated data expectations offer common ground for dialogue. Epistemology recedes as a barrier to communication.

Structural issues related to power, in the sense of both privileged knowledge and access to knowledge, emerged in content analysis most notably in the epistemology cluster, particularly in themes such as **Information Control, Complexity, Map Tyranny**, and **Limited Access**. Power and the barriers to it also evoked social change questions that arose in the alternate story-making cluster, where **Social Values** and expectations interacted with **Data Analysis** and ultimately **Trust Issues**.

The issues of application tended to be those that respondents could name when asked explicitly: privacy issues; softening of planning boundaries; functional matters such as categorizing of data leading to averaging in a way that affected outcomes of maps; the craving for higher standards in data and the technology gap between the resource haves and have-nots; and the need for a new ethics of presentation. These issues tended to relate most closely to such coding themes as **Data Analysis, Power of Technology**, and **Express Relationships**, thus linking to the learning goals cluster.

Social justice issues were predominantly those which emerged in broader conversation. Issues of justice come down to who gets heard, how they get heard, and where the issues are constructed (how the issues are defined) in relation to the public sphere. In this study, issues of social justice included mis/trust compromising decision-making; truncated story-making; shifting or unclear locus of power; decisions to work outside the power structure; changed public expectations of data standards; the spread of spatial awareness and resultant better understanding of natural resources; the improvement of both public education and argumentation about natural resource management. Dominant related coding themes here are **Decision-making, Trust Issues, Tool of Inquiry**, and **Responsibility**. Clearly, these issues are linked to the tools of change and technology diffusion clusters.

V. PRE-TEST/POST-TEST SURVEY

The pre-test/post-test survey (attached as Appendix B) had two purposes. It was designed to (1) discover whether intervention in a workshop providing close attention to GIS maps, combined with group discussion of their production, content and use, might change participants' views of them, and to (2) reveal differences in perception of GIS maps between map makers and map users.

Control Group

Control group demographics were over half public land managers or agency people (58% pre- and 64% post-test), and the remainder other non-scientists (42% pre- and 36% post-test, spread among watershed councils, NGOs, non-industrial private landowners).

Each test included responses from only *one* CLAMS representative. Because of this low representation, the control group was not useful in comparing map makers and map users by the definitions used for this study. Instead, the CLAMS representative's responses were thrown out, and the remainder treated as one group. This then allowed an overall comparison with the effect of intervention on the workshop group.

In general, the control group numbers showed little significant variation in responses between the pre-test and the post-test, as can be seen in Table 12, p.154. The only variation of particular note in the post-test was an increased level of concern for the idea that GIS technology is too complex for most people to use (question 5). However, given the small number of responses it is not possible to speculate on the reasons for this change, which can be caused by slight alterations in response by a small number (1-2) of respondents.

Table 12 Control group responses pre- and post-test, questions 5-7.
Numbers show "average rank" of answers on Likert scale of 1 through 5.

Q5. Some people have ongoing concerns about GIS maps and their use. How much does each of the following attributes of GIS maps concern you, where 1 is "no concern at all," and 5 is "a great deal of concern"?

	AVG.RANK Pre / Post
i. GIS technology is too complex for most people to use.	2.4 / 3.3
ii. The ability to produce GIS maps is in the hands of too few people.	2.5 / 2.6
iii. Producers of GIS maps have more decision-making power than users of GIS maps.	2.3 / 2.8
iv. GIS maps display only a tiny fraction of the available data, from one viewpoint.	2.8 / 2.5
v. Many people do not realize that GIS maps may not be highly credible.	3.6 / 3.5

Q6. Some people believe that GIS maps may make it possible for people to learn together. How likely is each of the following attributes of GIS maps to lead to mutual learning, where 1 is "highly likely," and 5 is "highly unlikely"?

	AVG.RANK Pre / Post
i. GIS maps integrate data across ownerships.	1.8 / 1.7
ii. Many people can explore databases and contribute to problem-framing dialogues.	2.1 / 2.1
iii. As GIS maps become more commonly used in management, their inherent uncertainty will become better understood.	2.2 / 2.1
iv. GIS maps represent powerful opportunities for analyzing data from multiple points of view.	1.8 / 1.5
v. GIS maps offer a valuable starting point for dialogue.	1.6 / 1.6

Q7. Some people believe that GIS maps set up communication barriers between technical and non-technical people. How likely is each of the following attributes of GIS maps to widen that communication gap, where 1 is "highly likely," and 5 is "highly unlikely"?

	AVG.RANK Pre / Post
vi. Many GIS maps are developed from databases that are too technical to articulate in public settings.	2.9 / 2.8
vii. GIS maps seem like truth to most non-scientists.	2.6 /2.2
viii. GIS maps are based on data with varying levels of quality.	2.3 / 2.2
ix. GIS maps present subjective viewpoints.	3.1 / 2.7
x. Limited access to technology will move decision-making power into the hands of a small minority of technical people.	3.3 / 2.9

Workshop group

Workshop group demographics were 31% public and industrial land manager or public agency representatives, 44% CLAMS team members, and 25% other non-scientists, thus a little under half map makers (CLAMS), and a little over half map users (land managers and non-scientists). There was no dropoff in response rate between pre- and post-tests for workshop participants.

By contrast with the control group, changes in responses for the workshop group between the pre-test and post-test suggested that intervention (via guided and thoughtful discussion of GIS map production, content, use, and understandability issues) made a difference in the way respondents viewed the role of GIS maps in natural resource management decision-making.

Question 5 asked for levels of concern about various attributes of GIS maps. As can be seen in Table 13 (p.156), map makers' responses show reduced concern in the post-test for the complexity and accessibility of GIS, but some increasing awareness of the privileged position in decision-making of map producers. Map makers showed less concern after intervention about the single viewpoint in GIS maps, and a small reduction also occurred in their concern about the number of people who don't realize that GIS maps are not highly credible.

Table 13 Question 5, pre-test/post-test comparison.
Concerns about GIS maps and their uses. **M** = map maker (n=7); **U** = map user (n=9).

	NO CONCERN		**SOME CONCERN**		**NEUTRAL**		**MORE CONCERN**		**GREAT CONCERN**		
	PRE	***POST***	***PRE***	***POST***	***PRE***	***POST***	***PRE***	***POST***	***PRE***	***POST***	
GIS too complex for most to use	14	0	29	43	14	43	43	14	0	0	**M**
	33	11	11	11	11	33	22	44	22	0	**U**
GIS production in hands of too few	0	0	14	71	14	0	57	29	14	0	**M**
	0	0	22	33	44	44	22	22	11	0	**U**
Producers have more decision-making power than users	0	0	14	29	71	14	14	57	0	0	**M**
	0	0	22	11	33	33	33	44	11	11	**U**
GIS maps show only single viewpoint	14	0	0	14	14	29	29	57	43	0	**M**
	0	0	22	0	11	44	33	44	33	11	**U**
Many do not realize GIS maps not highly credible	0	0	0	0	14	14	43	57	43	29	**M**
	0	0	11	0	0	11	44	33	44	56	**U**

Map users, on the other hand, increased their concern about whether GIS is too complex for most people to use, but did not change their opinion between tests about whether GIS production is in the hands of too few people, nor whether producers have more decision-making power than users. Their concern about GIS maps' showing only a single viewpoint trended towards a slight increase, as did their concern about the fact that many people don't realize GIS maps are not necessarily highly credible.

The area of greatest difference between map makers and map users after the workshop intervention fell in the area of decision-making, with map users showing more concern about the higher level of decision-making power held by producers of GIS maps than by users. Map users also concluded with a higher level of concern about GIS's complexity making it too difficult for most people to use.

Question 6 sought to find out which aspects of GIS maps respondents believed would most support mutual learning. The responses (see Table 14, p.158) show three measurable shifts in map maker beliefs. First, they came away from the workshop less confident that increased GIS use would clarify the inherent uncertainties of GIS maps. The second notable shift came in the slightly increased and consolidated belief that GIS maps represent powerful opportunities for analyzing data from multiple points of view. Third, there was an increase in their support for the idea that GIS offers a valuable starting point for dialogue.

Table 14 Question 6, pre-test/post-test comparison.
Likelihood of GIS maps enhancing mutual learning. **M** = map maker (n=7); **U** = map user; (n=9).

	HIGHLY LIKELY		SOMEWHAT LIKELY		NEUTRAL		SOMEWHAT UNLIKELY		HIGHLY UNLIKELY		
	PRE	*POST*	*PRE*	*POST*	*PRE*	*POST*	*PRE*	*POST*	*PRE*	*POST*	
GIS integrates across ownerships	43	29	29	43	0	29	29	0	0	0	**M**
	33	11	44	56	11	33	11	0	0	0	**U**
Many can explore & contribute to problem-solving	14	29	43	43	14	14	29	14	0	0	**M**
	22	0	56	33	11	44	11	22	0	0	**U**
GIS uncertainty will become better understood	0	0	57	29	14	29	14	43	14	0	**M**
	0	0	22	56	44	33	22	11	11	0	**U**
GIS allows data analysis from multiple viewpoints	43	0	14	86	14	0	0	14	27	0	**M**
	44	33	44	57	0	11	0	0	11	0	**U**
GIS offers valuable starting point for dialogue	29	57	29	29	14	0	14	14	14	0	**M**
	33	22	33	57	22	22	11	0	0	0	**U**

The opinion shifts for map users in question 6 typically were small, and tended to move away from the "highly likely" and "highly unlikely" extremes. Four of the five postulates for supporting mutual learning found the majority of map users clustered in the "somewhat likely" category after the workshop intervention.

In general, it can be said that support for the idea that each of the postulates could improve mutual learning was relatively strong among map users, particularly after the workshop. This tended to be true also of map makers, with the exception of their lesser optimism for having uncertainty better understood. Map users also seemed to have somewhat more faith in the value of analyzing data from multiple viewpoints than map makers.

The purpose of question 7 was to establish which attributes of GIS maps tend to create or exacerbate acknowledged communication barriers between scientists as map makers and non-scientists as map-users. Several shifts among map makers are worth noting (see Table 15, p.160). Concern about databases' technicality has become more neutral, and concern has risen about the idea that GIS maps seem like truth to many map users. Supporting this trend, a jump occurred in the map makers' concern about the tricky communication problem of GIS maps' representing subjective viewpoints and thus further confounding communication. The other noticeable jump occurred in concern about whether limited access to the technology would concentrate decision-making power in the hands of a technical elite; map makers appeared more confident after the workshop that this would *not* tend to occur.

Table 15 Question 7, pre-test, post-test comparison.
Likelihood of GIS maps to exacerbate communication barriers. **M** = map maker (n=7); **U** = map user (n=9).

	HIGHLY LIKELY		**SOMEWHAT LIKELY**		**NEUTRAL**		**SOMEWHAT UNLIKELY**		**HIGHLY UNLIKELY**		
	PRE	***POST***	***PRE***	***POST***	***PRE***	***POST***	***PRE***	***POST***	***PRE***	***POST***	
Databases too technical	0	14	29	14	14	43	43	29	14	0	**M**
	0	11	33	44	22	33	33	11	11	0	**U**
GIS seems like truth to non-scientists	14	0	29	57	14	43	43	0	0	0	**M**
	33	22	33	44	22	33	11	0	0	0	**U**
GIS based on data of varying quality	29	29	43	43	0	14	14	14	14	0	**M**
	67	22	22	56	11	22	0	0	0	0	**U**
GIS maps present subjective viewpoints	14	0	29	86	43	0	14	14	0	0	**M**
	50	11	0	22	25	56	25	11	0	0	**U**
Decision-making power into hands of technical elite	14	0	29	0	29	29	29	56	0	14	**M**
	11	0	33	33	33	44	11	11	11	11	**U**

The two most notable shifts for map users after the workshop were trends towards slightly reduced confidence in data quality consistency, and slightly reduced concern about the presentation of subjective viewpoints by GIS maps.

Map user responses show the greatest areas of difference from map maker responses after the workshop in the ideas that GIS maps present subjective viewpoints, and GIS could put decision-making power into the hands of a small technical elite. The map makers saw the latter as less likely to widen any communication gap, but saw the presentation of subjective viewpoints via GIS maps as more likely to raise communication barriers, than did map users.

For question 8, which asked respondents to name both negative and positive unintended consequences of the use of GIS technology (see Table 16, p.162), no significant change occurred between pre- and post-tests in the list of consequences generated by map makers. This was also true of map users, although this group did generate three additional consequences in the pre-test: (1) poor communication regarding use of the GIS tool between map makers and the public; (2) GIS may lead to application of "landscape management" policies and regulations which may trample private owners and force them to provide public benefits ("more than they already do") without compensation; and (3) rigors of creating credible/testable data outweigh benefits of creating and sharing that data. In the post-test map users added two further consequences: (1) "map wars" in which factions present differing maps; and (2) increased non-disclosure statements when corporations allow resource-specific data to be used to generate thematic-style maps.

The one consequence for which map makers and map users followed different trajectories pre- and post-test was the idea that GIS could create a technical elite that could influence natural resource decisions. Map users are still concerned about this outcome, and perhaps map makers remain in denial?!

One other area showing little significant change was the request to choose a best definition of a GIS map (Question 4). The greatest number of map makers (43%) still believed a GIS map is an idea. Map users gave almost their entire support, pre- and post-test, for the idea that any GIS map is just one of the many possible displays that could be produced from the same database.

Table 16 Question 8, Pre-test, post-test comparison
Numbers shown represent percentages within each professional affiliation. For map makers, n=7; for map users, n=9.

	MAP MAKERS		MAP USERS	
	PRE	*POST*	*PRE*	*POST*
Privacy issues	86	88	78	78
Anti-trust issues	71	57	67	78
Increased collaboration	100	86	100	78
Technical elite	29	14	56	75
Map-making accessible	100	100	100	89
Testing alternatives	100	100	67	78
Uncertainties look like truth	86	86	89	89

CHAPTER 5: DISCUSSION

The research for this project began with a specific focus on the use of GIS maps, in an attempt to identify areas in which mutual learning might emerge and prove fruitful for improving the long-term process of managing natural resources. GIS maps were proposed as a lens, even a magnifying glass, through which we could examine trends in communication and understanding of science among parties with highly varied training in the science arena.

The knowledge that has emerged, however, suggests that GIS maps may be more accurately conceived as a prism than a lens, scattering light across a larger and more colorful spectrum than a single lens will allow. Specifically, ideas on connections between the diffusion of technology, social change, story-making, and the management of transition, shed compelling light on the future of natural resource management in a thoughtful society.

Results from the five sources of data analyzed in this study offer a number of patterns which could help form tentative theory about where the CLAMS enterprise and its GIS maps are located in terms of supporting mutual learning in the natural resource arena. In general, the larger themes are change themes—both potential and actual change, as well as constraints upon change. They encompass trust, uncertainty, shifting power, and significant changes in story-making. Discussion of specific findings from each analysis in turn will precede discussion of these overarching themes and patterns.

I. WEB-SITE SURVEY

Overall, the initial survey of CLAMS web-site users revealed a prevailing uncertainty, even among technically-trained users, about usability and real applicability of GIS maps and databases. Questions about usability and expectations, taken together, suggest a map maker/map user relationship that remains to some degree in its infancy. The variability among answers could indicate both differing levels of expectations for how such maps and databases can be used, and differing levels of expertise in their use, or differing familiarity with their purposes and construction. However, among active users, expectations of how a map will be used, and its suitability for that use are quite well matched. Selected uses remain so far relatively general.

Questions of pursuing greater detail in maps and thinking at the landscape scale do not appear to be uppermost in many users' minds; perhaps having web access to this kind of database is not yet a widespread phenomenon, and it is arguable that landscape-scale thinking is not yet a widespread practice, being limited to those who practice it daily in their craft, such as whole-ecosystem ecologists, or geographers (Shindler 2000). It is not obvious from the results that the use of GIS per se helps us think at a landscape scale. Yet. While maps in general have always encouraged that approach, the change offered by GIS maps may be to encourage new and broader relationship-based questions, as well as more focused thinking across whole landscapes. Nonetheless, there is a clearly-stated willingness by users to use these maps for decision-making, particularly at the coarse scale.

Responses to specific questions about uncertainty suggest only a moderate level of comfort in dealing with the uncertainty contained in CLAMS GIS maps among this group of users. The heavy proportion of scientifically-trained respondents should bias the responses in favor of people already accustomed to thinking in terms of scientific uncertainty. However, their concept of "reality on the ground" suggests that their "map concept" is divided between those well-informed by understanding of the real-world constraints of GIS map production, and those who, despite technical backgrounds, may still be subject to some degree of "map tyranny." The one quarter of respondents claiming to "not know" about accuracy, and the one quarter who are unclear about whether the uncertainty contained in GIS maps renders them unusable, could well be quite different people. However, these responses suggest that significant questions remain among some users about the role these devices might play in natural resource management. Being used to dealing with uncertainty, it seems, does not necessarily equip either map makers or map users to be comfortable dealing with it, nor to understand its implications. It is also not clear whether GIS introduces more uncertainty than traditional maps into the tools we use to support natural resource management, or whether the very nature of inquiry peculiar to GIS will gradually help accustom users to the notion of uncertainty.

The overall level of trust is variable, but ranges to moderately high for a project using a technology without a long life-span in supporting decision-making. However, the high numbers for "uncertain" about the question of whether scientists involved in CLAMS make unbiased decisions about what the maps will analyze, suggests that opinions are at best unformed on the trustworthiness and hence the usability of GIS maps. Whether this is due to not having a clear opinion on the subject, or simply never having thought about it before, is not apparent.

The weak ranking for *awareness* of most of these assumptions suggests that the GIS maps and models do not speak for themselves, even amongst a relatively scientifically-trained audience. The need to make assumptions explicit once again invokes schema theory, acknowledging that we all carry our own referents that could interfere with understanding those of others. Awareness of assumptions about biodiversity and habitat condition, particularly for salmon, may be a by-product of greater public attention being paid to the associated issues; thus it is not clear that this level of awareness came from the CLAMS maps and databases themselves. The adjustment required by software bugs also limits how we can interpret these data.

The *agreement* with assumptions about salmon could also be positively skewed by the greater press and media coverage of salmon issues. Likewise harvest issues. Not surprisingly, respondents seem to doubt rather strongly that forest policy will remain steady in the long term: the last two decades have seen enough rapid change in social dynamics to convince most people in the age groups represented that change in the human component of forest management is inevitable. The idea that clear cuts can never return to their 1980s size may fit with this consciousness of change, and explain the higher level of "uncertain" responses.

Some of the stories revealed in CLAMS maps and models lend themselves more simply to visual rendering, such as the decline of oak woodland savanna through time, and to a lesser extent the reduction in acreage of young, diverse forests. This may explain the clearer understanding of these particular messages from the CLAMS maps. Others are more complex and multi-faceted ideas (effects of one ownership policy versus another, contribution of ownerships to biodiversity through time) which may have hampered delivery of the message. Visual clarity no doubt plays a role in how successfully specific stories came across to map users, and measuring effects of color choice or intensity of cover in this context is beyond the scope of this project. It is also possible that the naming of these findings may have made them clearer in respondents' minds and thus affected responses to the question, although the survey relied on recall rather than having the maps on hand, suggesting that the concepts had had their effect (ie. been retained by participants) from the time of first viewing the maps.

In general, these respondents appear to reflect a certain willingness to begin to use CLAMS GIS maps, but it is still strongly tempered by the known shortcomings and uncertainties inherent to their production. The emergence of this wariness from a group of users that is predominantly trained in the sciences could result from their cumulative awareness of uncertainty in many scientific endeavors, or simply from the novelty of the technology as a player in resource management. Whatever the cause, it is possible only to say that this survey suggests an openness to use and understanding of the new tools, but hardly yet a wholehearted embrace of them.

II. 2002 WORKSHOP

Findings from the 2002 workshop tend to cluster around data accuracy, a reflection on trust of both science as process, and technology as its chief handmaiden. Confidence Levels, and all its constituent ideas, here acts as a constraining variable on mutual learning opportunities. Analysis of input at this workshop suggests that the presence of concerns about accuracy and reliability could in certain settings offset sincere efforts to address complex natural resource questions and forge larger visions for inquiry.

"Ground-truthing" as a goal and ongoing practice arose many times, recognizing that some field data are too sparse to produce robust models, or are outdated, or second-hand. The need to validate models on the ground emerged repeatedly, and affects whether participants believe CLAMS tools are currently usable. It became clear that until sufficient agreement occurs between remotely-sensed and modeled data, and reality on the ground, skepticism and distrust will remain. This has been proven out over the course of the CLAMS project, as data have been refined, updated, and added to, and more land managers acknowledge a defensible level of accuracy.

However, trust took the form of skepticism rather than complete mistrust. In keeping with other studies, trust issues related for the most part to the specifics of research—the validity of the models, the trustworthiness of the data—rather than questioning the overall appropriateness of the scientific enterprise (Lach et al. 2003; Priest 1995).

In general, the levels of support dropped away and the levels of skepticism increased as the consideration of CLAMS research moved from the abstract and conceptual towards the concrete and particular, in other words, from research findings towards policy tool. Crudely put, this is great stuff, but can we safely use it in practice? Or, we love the maps, but don't make policy with them. The skepticism and trust balance is a key to understanding opportunities for mutual learning, as can be seen in findings from other data.

When combined with web-site survey data, these findings are in accord with Baskerville's concept of ecology as of limited use in the challenge that is environmental decision-making (Baskerville 1997). Shorter time frames, smaller areas, and higher precision than used in the CLAMS enterprise have been the traditional focus of ecological observations, experiments and models. While the CLAMS approach is thus a departure, it appears that the potential learning processes have as their first phase a period of learning how to learn from new tools. This finding meshes with the widely-accepted idea of phasing in new technology (Rogers 2003; Rohracher 2003).

Perhaps most central to the abstract/concrete issue is whether the many questions stakeholders raise about CLAMS tools can be satisfactorily addressed. This statement seems obvious on the surface, but the devil, as always, is in the details. How can confidence levels be actually expressed to the satisfaction of map makers and map users alike? Can universal confidence metrics be developed for the information of GIS map users? Should assumptions be, quite literally, spelled out on all GIS maps? Can measures of uncertainty be required and standardized as well? And then the true challenge: how might such a potentially unwieldy set of measures, if it were attached to GIS maps and databases, get imported usably and understandably into decision-making forums and structures?

Inferences from these questions point to the structures of decision-making, and the difficulty within both decision-making and public education of grappling with scientific uncertainty. The idea of negotiated meanings here combines appropriately with the need to identify conflicting epistemologies (Benda et al. 2002; Weber and Word 2001), and suggests that the interpretation of GIS maps and their role in natural resource management policy is destined to be a process of much longer deliberation than the standard scientific presentation suggests. Comments at the 2002 workshop suggested a relatively sophisticated understanding of some of the social and political challenges involved in bringing such an enterprise into the public policy arena.

Mutual learning as a goal is embedded in some of the observations and suggestions found in both the support and skepticism components of this database. Fear of "map tyranny" and the "oracle" are counterbalanced by suggestions of incorporating stakeholder assumptions in models and developing reliable methods for interpreting output to multiple audiences. Without their putting it directly into words, responses from workshop attendees could be characterized as making the transition from the default philosophy of the rightness of positivist science, to the emerging post-modern philosophy of grappling with multiple, often conflicting worldviews en route to making socially valid decisions about natural resource management.

A generalized sense of the presence of conflict in natural resource decisions can enhance the role of GIS maps in helping manage that conflict, according to some researchers (Jankowski and Nyerges 2001; Bojorquez-Tapia, Diaz-Mondragon, and Ezcurra 2001). For example, workshop participants recognized that agricultural lands, fire, and roads represent controversial issues, but their repeated suggestions to incorporate them in "the next round" suggest some level of faith in this kind of scientific undertaking's ability to help resolve them, even if the preliminary exchanges are hostile. The post-Enlightenment idea of science as a continuous, self-correcting enterprise is the theoretical backdrop here, a different concept from science as the sole arbiter of truth.

Comments about accuracy at the 2002 workshop also relate to the long tentacles of remote-sensing as a data-gathering technology: as high-tech as it is, it is not 100% accurate, although it is currently "the best we got." That it can reach with impunity across private property lines is a matter to be confronted by property owners and land managers of all stripes. This aspect of GIS development could in the future have some perceptible impact upon private property rights, and thus in its way contributes directly to social change. Legal anti-trust issues will also arise around any attempts to manage whole watersheds across ownership boundaries, where it involves bringing together representatives of corporations to discuss management practices, for the specter of being accused of price-fixing or associated skullduggery looms large in the minds of their lawyers (Thompson, Anderson, and Johnson 2004).

III. MENTAL MAPS

Across the seven interviews that led to construction of four mental maps, we can see similarities along with significant differences, between perspectives on the production and use of GIS maps. The differences appear graphically in the structure of the mental maps, the emphasis, the language, and the resultant selection of map components.

Similarities among mental maps are revealed most clearly in their emergent properties. Consistently, the emerging properties identified in the mapping process relate either to the power of institutionalized traditional science and its privileged knowledge, or to social issues, in particular to social change. These properties seem to reflect the currently shifting paradigms carrying different understandings of science, along with improved comprehension of the environmental and natural resource issues we face as a society.

The emergent property of privileged knowledge has its roots in logical positivism and its promotion of science as the sole reliable source of true knowledge, but reflects more than this in the current context. Institutional privilege, access to funding and technology, professional training, all play into the position in which CLAMS map makers and other professional scientists find themselves. CLAMS map users and other non-scientists are to some extent left out in the cold by these arrangements, but as mental maps and other data in this study reveal, are beginning to reject that position. In particular, map users do not see themselves as any less capable than map makers of comprehending and utilizing technical information (Fischer 2000).

Leading theorists in conflict studies would portray the frustration expressed by non-scientists, in this case our map users, over access to the technology and the privileged knowledge it supports, as a component of the classic conflict between imbalanced power structures (Freire 1998; Lazega 1992; Lyotard 1979). Taking both composite maps together, we can safely conclude that the power structure continues to leave scientists in decision-making positions with regard to the content and usability of GIS maps.

What may be happening here is that diffusion has carried scientists-as-map-producers along more quickly, with the result that non-scientists have been excluded completely from the first cycle of user involvement in developing the technology. Rohracher has concluded that the unsystematic nature of user-developer interactions can impede uptake of technology:

> "Learning was often restricted to a patchwork of small networks of one or two producers, some intermediaries and a small group of users, and only very slowly spilled over to other actors" (Rohracher 2003).

Other research has emphasized that the shaping of a map, including its assumptions, uncertainty, and fuzziness, naturally involves human decisions and is thus a locus of social power, even if the individuals involved are essentially blind to or uninterested in that power (Rohracher 2003; Rappert 2001).

This observation conforms with Rohracher's idea of technology introducing a potential shift of power relations and dependencies that new actor networks can bring with them (Rohracher 2003). Rohracher notes that end users are less likely to create the "actor networks" that would more definitively embed the new technology into their social systems. As one non-scientist interviewee noted:

> "It's not a functional relationship unless we have access. On the other hand, how are we supposed to do the business of watershed restoration without it? It will sever us at some point if we can't stay up with the technology."

In the case of CLAMS, scientists and non-scientists are both end users of GIS technology. In general, because of training and job requirements, scientists have become more rapid adopters than non-scientists, becoming producers of maps sooner and more efficiently than non-scientists, in general. Each group clearly traverses the boundaries between introduction and diffusion of technology at different paces.

The emergent property of social change agents is present in all maps, and quite comprehensive, including both deliberate motivation for change as well as tentative trends in that direction. In general this property is suggestive of systemic change.

There are clear implications, supported by both these common emergent properties, for story-making, specifically the transition from unilateral to collaborative forms of it. Story-making begins to emerge here as a central component of producing and using GIS maps for natural resource management, no matter whose hands are on the keyboard to run the actual software, or whose schemata inform the choice of inquiry (Anderson, Spiro, and Anderson 1978; Fiske and Linville 1980).

Here there are implications for the ongoing communication challenges between those trained and experienced in the technical world of scientific endeavor, and those outside that world. Communication between scientists as map makers and non-scientists as map users is easily skewed by language, experience, and worldview (Weber and Word 2001; Lach et al. 2003), but when the purpose of communication is turned to the simplicity of story-making, the challenges of crossing a technical divide are greatly reduced. Rather than the attempt simply to present complex biophysical principles for an uninvolved audience (unilateral story-making), the attempt is to describe a perceived world, in a relatively personal way, and try to determine if that image is understood and shared. Language differences tend to dissipate in this changed context, and there are fewer barriers to collaboration. The potential is increased for changed understanding to travel system-wide.

Mental maps very strongly support the hypothesis that technology is socially constructed; the invention or implementation of a tool in the belief that its use has no consequences is an incomplete process, as numerous investigations about phasing of technology diffusion reveal (Brunn, Dahlman, and Taylor 1998; Rohracher 2003; Rogers 2003). In an iterative manner, we make our tools, then respond to them, and then respond to the changes they inevitably introduce.

IV. 2004 WORKSHOP: FOCUS GROUPS

In the focus group (data gathering) portion of the 2004 workshop, a number of elements identified in earlier data began to coalesce. Used as codes in analysis of focus group data, they offer the outline of theory relating to CLAMS' stage of development as a learning enterprise.

Both complexity (including uncertainty) and scale are issues that have emerged from the traditional scientific process with new importance as a broad spectrum of non-scientists has become engaged in natural resource management dialogue. One of the combined effects of the scientific method and approach, and the necessity of grappling on technical terms with complexity and scale, is that access to full understanding of maps and models can become yet more constrained. Some researchers have even suggested that ecologists don't sufficiently understand scale issues themselves to be discussing them with any authority (Norton 1998; Baskerville 1997); others note that non-scientists are poorly prepared to look at system-level entities and effects (Shindler 2000; Costanza 2001).

Clearly, the development of technologies that are increasingly capable of wrestling with complexity on our behalf, is going to bring the issue of complexity to the foreground as we try to comprehend how those technologies might best approach it, or even what our analyses and answers might mean. What appeared more cogently as concerns about how uncertainty affects use of CLAMS maps in the web-site survey and the 2002 workshop has been subsumed two years later in explicit efforts to comprehend uncertainty and complexity, a more proactive perspective.

How does the leap of faith from scientific abstraction in a model to its use in policy get addressed in the face of uncertainty and complexity? In tune with questions raised by other theorists (Fischer 2000; Priest 1995), does technocratic expertise handle complexity any more confidently, or expertly, than citizen expertise? As seen in the pre-test/post-test survey results, the concept of uncertainty is unevenly approached by map makers and map users. In general, it is less of a concern to map makers, who are accustomed to making allowances for it in their research, but they perceive it to be more of a barrier to trust for map users, perhaps because they are not certain non-technical audiences fully understand its potential implications.

In a sense issues of scale are a subset of complexity. Scale, as we emerge into the changing demands of looking across whole landscapes to formulate natural resource policy, is a crucial issue for both analysis by map makers and understanding by map users. The study of whole ecosystems has raised scale to a primary position in ecosystem research, particularly as interconnections and "cascading" of system elements come clearer (Franklin 1993). As noted in the literature, ecologists themselves are not coming easily to terms with scale questions (Baskerville 1997), which go both up and down the size spectrum, and non-technical map users may not be quite ready yet to "see" landscapes in their totality (Shindler 2000). Nonetheless, discussions about scale issues became more informed on the part of map users, and more frank in admitting the difficulties, from the 2002 to the 2004 workshop.

The possibility of interactive maps—allowing users to investigate different outcomes with different variables, or mapmakers to embed assumptions in GIS data layers—recognizes an attempt to breach an ongoing communication barrier with an existing technology. Other studies have identified an urge to reveal the questions and uncertainties concealed in map construction (Aerts, Clarke, and Keuper 2003).

Many of the codes of the Epistemology cluster in focus group analysis—Scientific Method, Complexity, Information Control, Limited Access, and Map Tyranny—could be interpreted as producing the "lock-in effects" that work against innovations and change (Pahl-Wostl 2002). These effects have co-evolved through long periods of time, producing a stabilizing absence of flexibility in how "business" (in this case scientific inquiry) is done. Where these factors continue to operate in a manner unchanged by either social learning or new modes of thinking about science, they represent a system balance—a brake, in effect—that has yet to be released to a new phase of transition (Rotmans, Kemp, and van Asselt 2001).

If other factors found in the **Tools of Change** and **Shifting Learning Goals** clusters, such as Communication, Trust, Improved Access, and Technology Diffusion begin to take effect, the lock-in phenomenon could be reduced and ultimately eliminated, allowing anything from small to dramatic changes in the system balance. For CLAMS it could be argued that that balance began to shift some time between the 2002 and 2004 workshops.

The idea of addressing social values in a more robust way within the maps, so that they can become part of the analysis and have trackable effects on the future, has been raised by a number of people. One of the repeated criticisms of the CLAMS project, revealed also in other data, is the central assumption in projections that policy will not change in the next 100 years. It is a simple, and yet profound, argument, that we have not created, and maybe cannot create, a credible trajectory of social value change through time. Even incorporating landowner intentions into the models—an innovation with CLAMS—is subject to the frailty of all human intentions when confronted with the conditions of real life. In the maps showing changed environmental protections through time, we may be as close as CLAMS can yet come to addressing changing social values: in a historical view. Projected land use change also attempts to address this issue; principal investigators believe the link between population and land use is one indicator of social values (K.N. Johnson, pers.comm.).

Other researchers have noted the importance of linking ecological projections and findings to their social foundations, in order to give them true value (Pielke jr., Sarewitz, and Byerly 2000). This consideration is behind the challenge of reflexively understanding the social values—including those of the principal investigators—driving the kinds of maps and the types of inquiries taking place today. For here we are dealing with the "mental worlds" we have all created as we craft our sense of place (Tuan 1974). This observation is borne out by researchers investigating the nature of environmental controversy, and finding, often, that it is less about science than social and political values (Priest 1995; Pouyat 1999; Fischer 2000).

Of course, the expectations of science are likely to be changing as criticisms of its monotheistic hold on society gain strength. Ironically, those changing expectations might be pushing the bar yet higher for what science can achieve: can we truly expect the tools of science to reach beyond our current knowledge and report back with neat and usable answers, as in projecting social values through time?

Trust as a recurring theme takes a new turn at the 2004 workshop. Compared with the workshop two years before, where its characterization was more negative—barrier, rather than bridge—trust seems in the 2004 workshop to be perceived explicitly as a matter that needs to be worked on, to be built. This time, peer review, sensitivity analysis, and ground truthing were discussed in more practical, less defensive terms, as the suite of necessary though perhaps not sufficient tools required to build trust between and among data, technology, map makers, and map users.

V. PRE-TEST/POST-TEST SURVEY

It is important to remember that this survey received responses, necessarily in the case of the workshop group, from only very small numbers of people: 17 in the workgroup for both tests, and 19 and 13 in the control group for pre- and post-tests respectively. While the sample size undermines any opportunity to extrapolate to larger populations, the data do provide useful insights into the experiences and thoughts of the population under study, particularly the highly-engaged workgroup.

To begin with, workshop discussions did not change the basic view of map makers about what GIS maps are; strongest support was shown in both tests for map as idea. Map users barely changed their overwhelming preference for the "definition" suggesting a single GIS database can produce a large number of different maps. This is conceivably a reflection of their direct experience working with conflicting maps, or from witnessing "map wars" among parties interested in specific policy outcomes. This finding conflicts somewhat with the hypothesis that map users are more likely than map makers to accept "map tyranny." Perhaps instead we can infer a clearer sense among map users that GIS maps can tell many different stories; the corollary would be that they have a desire for being involved themselves in more collaborative story-making.

In general, it can be concluded that the concentrated discussions of GIS technology during the workshop had discernible effects on the workshop group, supporting the hypothesis that guided and thoughtful dialogue is more likely to change minds (affect learning) than a single presentation. Change was not seen across the board on all questions and issues, but it was apparent in small trends in many areas, a result in keeping with the features of managing transition, the power of collaborative story-making, and the potential for lock-in effects to stymie social change.

The most significant changes after the workshop emerged in the acceptance or rejection of mutual learning potentials, and barriers to communication, questions 6 and 7. A slight increase in appreciation among map makers for the sophistication of map users' understanding of the technology can be discerned in the post-test changes. Notably, map users themselves lost a little confidence in this area, possibly reflecting their own improved understanding of just how complex is the technology required to create GIS maps.

There also appears to have been some eye-opening among map makers about how much power they indeed have as the producers of GIS maps, who make decisions about what will and will not be included in each map. This concept was a subject of some discussion at the workshop, and suggests that map makers had not fully appreciated just how much power their position as producers of maps can give them, whether they have sought it intentionally or not. The concurrence of both groups in this area may outline a growing awareness of the idea that technology is not only socially constructed, but can affect the people using it as well as their audiences in turn in unforeseen ways (Postman 1992; Rappert 2001; Rohracher 2003). These findings, chiefly the change after the workshop in map makers' responses, also support the hypothesis that map users are more likely than map makers to comprehend the power of access to data and/or technology.

Map makers, familiar with and appreciative of the complexity of scientific uncertainty, actually reduced their belief that increased GIS use would address the ongoing challenge of understanding and dealing with uncertainty. However, their optimism increased for mutual learning's being helped by analysis from multiple viewpoints, along with their increased support for the idea of GIS maps as a productive starting point for dialogue, a not surprising outcome of prolonged and challenging discussions at the workshop. Again not surprisingly, map users' consistently strong support for the idea of analyzing data from multiple viewpoints is most likely a simple reflection of their continued wariness about data and their interpretation by map maker/scientists alone. These findings suggest only weak support for the hypothesis that scientists are more likely than non-scientists to recognize the potential analytical power of GIS databases. Content analysis of focus groups likewise undermined this hypothesis, emphasizing the idea that map users yearn to tap into that very analytical power in their efforts to better understand and convey to their own constituents the complex realities of Coast Range socio-ecological dynamics.

None of these differences alters the fact of considerable optimism for mutual learning outcomes from both map makers and map users, who have in the CLAMS case been progressing together through many stages of identifying best data sources, correction, and interpretation. Thus the hypothesis that mutual learning will be more familiar and appealing to map users is not strongly supported by the data, although map makers did "travel the greatest distance" in the degree to which their minds were changed by workshop interaction. Ultimately, differences between map makers and map users across the five postulates essentially balance the appeal of mutual learning to both groups.

The somewhat mixed results for considering what contributes to widened communication barriers (question 7) suggest several possibilities. In seeing the presentation of subjective viewpoints as more likely to raise communication barriers, scientists as map makers may have been voicing their goal of remaining objective (Lach et al. 2003), regardless of the claims of post-modernism about their inability to do so! In addition, the map makers' lesser support for the idea of GIS placing more decision-making power in the hands of a technical elite could be influenced by the long-standing one-way communication model to which they are accustomed, along with influence from the relatively fixed belief that scientists must not be advocates (Lubchenco 1998; Mills and Clark 2001; Rykiel 2001). Very strong evidence for the power of these latter two influences appears again in the listing of consequences, in which map makers gave only one-fifth of the support of map users after the workshop to the consequence of creating a technical elite which would influence natural resource decisions.

The list of five additional consequences generated by map users in pre- and post-tests reflect lingering concerns over *how* the CLAMS maps and databases could be used in the future. These concerns emerged from the start of this study, and have shadowed it throughout. However, in the final context of noticeably increasing support for mutual learning and story-making, in effect for collaborative inquiry, such concerns have to be seen as having reduced effects on dialogue and shared thought around GIS maps.

VI. PATTERNS

i. Trajectories of change

For each of the five sources of data informing this study, it is possible to designate one overarching change theme that captures the essence of findings from that database. Recognizing that generalizations can be instructive at the same time as they are misleading, these singular themes nonetheless are presented to help clarify their combined and interacting implications. In the sense used here, change themes are defined as elements emerging from the database which can be actual or potential agents of change, or can be constraints upon change.

From the CLAMS web-site survey, the most pervasive change theme was uncertainty, tending to act as a constraint on use and understandability of CLAMS maps and databases. From the 2002 workshop the key change theme centered on trust, in this case skepticism about the usability of CLAMS maps and databases. This theme also tended to act as a constraint. For mental maps, the overarching change theme was an uncertain, dynamic balance between the emerging properties of potentials for social change and the property of power and privileged knowledge. Thus for mental maps there is a mixed balance of support for and constraint of change. In the case of 2004 workshop focus groups, the perceived agent of positive change appeared as a drumbeat during discussions: re-framing the debate. Finally, results from pre-test/post-test surveys support the idea that deliberative interactions can act as potential positive change agents, as proposed by various scholars (Fischer 2000; Freire 1998; Funtowicz & Ravetz 2001; Gethman 2001). These latter two themes of re-framing the debate and deliberative interactions are story-making by other names.

Taken as a spectrum through time, these themes reveal a transition from a predominance of constraints on change to a predominance on active agencies of change. Thus it is possible to contrast the role of trust as discussed in the respective workshops, just two years apart, and see how mistrust acted as a constraint in 2002, and yet in 2004 was characterized as an element that needed to be minimized in order to make the most of the opportunity offered by the overall CLAMS enterprise. This change over a period of two years naturally reflects an increase in familiarity among workshop attendees, but could also reflect the kind of accelerated change that occurs during transition, to be discussed further below.

Table 17 (p.180) depicts the five databases as progenitors of dominant characteristics in terms of how each one, taken as a whole, reflected either support for agents of social change, or constraints on agents for social change.

Table 17 Database characteristics.
Relationship of each database, overall, to agents of change or constraints on change.

	ACTUAL/POTENTIAL AGENTS OF CHANGE	CONSTRAINTS ON CHANGE
WEB-SITE SURVEY		Uncertainty about usability of maps and data causes varied levels of trust and understanding
2002 WORKSHOP		Mistrust of data, sources, models affect motivation to interact; concern persists about nature of inquiry and its effects on decision making
MENTAL MAPS	Recognition of potential social changes affects power balance; divergent views of technological solutions emerge	Persistence of the privileged knowledge property of power affects views on access to and use of data and technology
2004 WORKSHOP	Re-framing the debate improves quality of argumentation; shifting learning goals help story-making and epistemologies coalesce	
PRE-/POST-TEST	Deliberative interactions support collaborative story-making; learning goals contribute to system adjustment	

ii. Story-making

Story-making deserves closer attention in the context of these change themes. Recognizing that science is first and foremost a story-telling enterprise helps us see that unilateral story-making by map makers has significant ramifications for public involvement, trust, confidence, and decision-making. Story-making requires trust in the elements of the story, both by teller and by listener, and surely also requires mutual trust between story-teller and listener.

However, if we take the view that a level of mistrust can act as an agent of regime change (Slovic 1993), then the expanded view of trust over a two-year period in the current study could represent just such a development. In other words, the mistrust identified two years ago may have been replaced not simply by broader trust, but by small and large change actions in both groups: greater efforts at communication, greater familiarity with the data, clearer recognition of the existence of multiple valid stories, understanding of the need for better questions. The potential of scenario-building, which some researchers have proposed as a viable approach to complex environmental decision-making (Carpenter 2002), may be best realized by its engagement of multiple parties in scenario design and selection, in an effort to honor the collaborative story-making process.

Also a strong contributor to story-making is the gradual transition in understanding of GIS technology, from a technical understanding of its production capabilities, to a social understanding of its communication capabilities. This has profound implications for how GIS maps might be co-opted for story-making by interested parties other than the scientists who are to date the only mapmakers in CLAMS.

iii. Clashing epistemologies

Another aspect of this change reveals itself rather surprisingly in what might be early hints that the clashing epistemologies issue is fading from prominence. This statement will seem contradictory to findings from most data used in this study, but it appears that the evolution of perspectives on trust, and on the importance of story-making, could symbolize a shift in acceptance of differing epistemologies as part of the landscape. This does not at all suggest that they will cease to operate as potential barriers to communication, rather that they will become a "wallpaper" issue—somewhat akin to statements that gender differences exist and are to be valued, or that all environmental decisions are made in political contexts. The evidence in CLAMS suggests that multiple or collaborative story-making will in the long-term become more important than the now-obvious fact that scientists and non-scientists carry different schemata, and report them with different language.

The frequent repetition of the phrase "re-framing the debate" during focus group discussions highlighted this progression. The exact nature of the re-framed debate was never spelled out, but its outline included making assumptions explicit, using new technologies to examine new questions, assessing values when science is not really in conflict, and taking responsibility for new kinds of learning. The idea of story-making as a collaborative effort begins to take shape.

The difference from earlier data is that clashing epistemologies are not ignored, but nor are they given as much power. The thrust is towards changing the sideboards of dialogue, making sure it is no longer monologue, and seeking inclusiveness in multiple ways.

iv. Learning about learning

If we subscribe to the idea that we all operate from our own thematically-founded schemata or frames, it is arguable that exposure to themes as opposed to raw information (GIS maps as opposed to data tables, for example) will resonate more with the way we naturally process new material. Can this development be helping to level the learning field productively? Can spatial representation change the kinds of questions we can ask?

While tools such as GIS maps can be used to communicate information of selected kinds, they can also serve to teach us about information itself, to suggest how we think about information as we absorb it and turn it into knowledge. It is important to keep in mind that GIS has allowed improved questioning by ecologists themselves; a key factor in understanding communication problems is recognizing that no one group has a corner on asking the best questions, or formulating the most incisive hypotheses.

Indeed, recent research has confirmed, in line with communication theory on information exchange, that sharing and communicating new information unveiled by GIS maps is what will lead to actual learning (Hendriks 2000). Thus the very process of verbal interaction, often through story-making, drives and shapes diffusion of technology and innovation.

What effects do the questions we ask during GIS inquiries have on the resultant stories about our landscapes? In other words, how does our framing of questions reflect our worldview, and in turn influence the stories emerging from the maps? GIS technology has the capacity to enhance the thematic nature of our thinking, and thus to improve our ability to frame questions, especially larger system questions, both for scientific research and for the subsequent policy-making to which non-scientists can contribute through public interaction.

The question of whether GIS will eventually be used in more settings is less important than the question of how it will change the way we think about landscapes. Intelligence, here as elsewhere, is less about knowing than about methods of thought. In this respect CLAMS may be at a turning point, with choices of several trajectories for its potential evolution.

v. Responsibility and knowledge

The stage of diffusion of a technology also affects its relationship with societal values, and with the issues of dependence and dominance raised with the "privileged knowledge" identified by mental mapping as an emergent property. Rohracher has observed the complexity inherent to embedding a new technology, with different kinds and layers of discourse acting simultaneously to shape the direction of technical solutions (Rohracher 2003). For example in our case, at the same time as watershed councils are decrying their lack of resources for fully investing in GIS, they are craving higher levels of reliability in data, and engaging in conversations about problems of scale. They are not, in fact, allowing their lack of facility with the technology to keep them out of the game.

Transforming or negotiating meanings are each lengthy processes central to social change, and impossible to ignore as a technology such as GIS disperses via the adoption process (Sieber 2000; Weber and Word 2001). Given that other technologies are available to improve the communicative abilities of GIS (eg. multimedia, decision support, spread sheets), does any one entity or group have the sole responsibility to engage those technologies and improve the decision-making environment? If the goal is to develop inquiring minds in the pursuit of natural resource management—a new goal compared with the objectivist, solution orientation—then what science brings to the negotiating table looks more like puzzle pieces than fully-formed answers.

Nonetheless, given that emotion plays a central role in decision-making, it is likely that apparent disagreements over science will continue regardless of what tools are on offer. Certainly disagreements over values will.

vi. Balance points

In the lead-up to genesis of the CLAMS project, numerous factors were operating in the natural resource management arena that could have brought about changes in approach. There were the environmental upheavals in the region in the early 1990s, culminating in FEMAT. There was funding and opportunity for bioregional assessments, with interest from state and federal agencies for forward planning. There was growing awareness of the importance of landscape-scale ecosystem management, and with it the importance of watershed health and restoration, and the establishment of watershed councils. There was particular interest in salmon restoration, watershed health, and concomitant funding. There was the rapid involvement of non-governmental organizations, and the sometimes slow, sometimes rapid spread of ideas about public involvement in policy decisions, and then in the science that in theory underpinned them. At the same time, the shift in perceptions of science to favor post-modern views of knowing continued, as did the development of tools such as GIS as learning media, with web-based technologies for sharing information.

All of these factors were capable of playing a role in balancing the scales in favor of dynamic change in approaches to natural resource management, but there came as well a suite of factors within CLAMS that could also assist in various ways.

As the originally outlined science of the endeavor neared semi-completion, CLAMS team members continued to learn from and respond to the idea that public interaction was a growing force which required a planned and thoughtful response. While public engagement is not always rewarding, rarely easy, and has too frequently been unpleasant in the environmental arena, some successes could be named, leading to requests from users for more information, and the gradual easing of tensions through improved relationships. The engagement of social scientists in the project, and in the communication process, helped underline the importance of grappling with uncertainty, complexity, and coherence in ways with which public and lay audiences could identify. The recognition of the power of GIS in developing tools for public involvement, particularly in concert with other emerging communication technologies, is a key parallel step.

Transition theory suggests that, in general, small changes can generate large effects (Rotmans, Kemp, and van Asselt 2001). Any one of the plethora listed above could have contained the capacity to shift the balance, just as "lock-in" effects along the way, such as mistrust, clashing epistemologies, power struggles, and institutional stasis, could stall any attempts to change approaches to natural resource management (Pahl-Wostl 2002). To develop this theory further, we might ask at what point does a lock-in effect become a balance point? Remember the idea of mistrust (surely a potential lock-in effect) as an agent of regime change. Are there particular factors that can effect such a transformation? Possible causes could include social will or social permission, extra-institutional events, personnel types, adjustments to current policy, anticipatory mindsets of key players, anticipatory tools, exploration of alternatives through learning approaches.

vii. Interrupting the scientific method

Ultimately, the presence of such factors adds up to gradually increasing pressure on the current system to make room for innovation. Timing for the take-off phase of transition may never be well-understood, since the actors are mostly human. Rotmans et al. do note that guidance during the subsequent acceleration phase is most difficult, because "the direction of development in this phase is mainly determined by reactions which reinforce (or weaken) each other and which cause autonomous dynamics, so that processes become more rapid" (2001, p.184).

These researchers have a number of questions pertaining to taking action under transition conditions, of which the two most important for this study are: Do the actions and experiments taken contain potential for learning? And, are other actors stimulated to become joint owners of a problem?

Specifically, then, with an entity like CLAMS at our disposal, it may be possible to interrupt the scientific method in order to frame research questions that are more comprehensive of differing values, and thus that are more likely to involve mutual learning. Without seeking to alter a set of methodological rules that have served society well for three centuries, establishing a mode of incorporating new perspectives at the beginning of an applied science research effort, then returning again to the public quest for understanding once science findings are available, appears to be a useful pathway for future natural resource management.

GIS maps do appear to be one technological innovation offering assistance in such a revised approach to inquiry, but not without deliberate planning. The idea of using scenarios to create and encourage stories about future possibilities here emerges as one of the greatest untested potentials of a science-based platform such as CLAMS (Carpenter 2002).

We can surmise that the opportunities for mutual learning will only emerge if they are actively and intentionally sought out. Similarly, the system changes that might come from unintended consequences of GIS development, as revealed by analysis of mental mapping and focus groups, will not automatically generate that change without human assistance. Such changes can best arise in settings where GIS is recognized not only as a technology, but as a very useful social tool, representing a symbolic sea change in the way we can inquire about and analyze the world around us, in this case using spatial data (Jankowski and Nyerges 2001; Bojorquez-Tapia, Diaz-Mondragon, and Ezcurra 2001).

viii. Unintended consequences

As with any newly-introduced technology, there are multiple and multi-faceted consequences, many of them unintended. Nonetheless, as Wejnert's review and model suggest, these consequences have a direct effect on diffusion and adoption of new technologies (Wejnert 2002). Many of the unintended consequences which emerged in the current study's data related to system adjustment.

The interaction between the three categories of unintended consequence and the themes revealed by content analysis (Table 4, p.151) appears to show a definite progression in these consequence clusters from structural matters of organization to symbolic matters of meaning. Thus the unintended consequences of GIS use in natural resource management decision-making collectively represent some of the same factors revealed in the main body of research for this study. These are factors that other research has established as necessary for the success of transition: diffusion, learning processes, and processes of embedding in the form of acceptance and mutual adaptation (Rotmans, Kemp, and van Asselt 2001; Rohracher 2003).

The primary focus of these unintended consequences is system adjustment, suggesting that transition takes on a life, and a velocity, of its own once a sufficient or critical mass of change factors is in place. Such a development provides additional evidence that the general theory of transition in population dynamics may indeed be applicable to social change, as Rotmans et al. suggest. Further, if we concur with Pahl-Wostl (2002) that social transformation processes are not currently well understood, the system adjustment trajectory of the consequences identified here suggests at least one possible pathway that is generated by the marriage of technology with a dynamic social condition.

CHAPTER 6: CONCLUSIONS

As a case study, this project's findings cannot be generalized statistically across larger populations. However, there are clear implications and lessons for the interaction of science and scientists with attentive publics and natural resource management. Reference to theory from multiple fields allows some theoretical generalization, many concepts are transferable, and the study can help flesh out constructs and models for other cases.

A number of trends and ideas emerge from this research, some directly related to the learning potentials of GIS map use, others relating to associated social change factors.

1. Fading of espistemological problem.

The differences in both training and worldview between scientists and non-scientists, in this case represented by our map makers and map users, respectively, is not about to go away. However, it does appear to have been receding in perceived importance. Whether this is because it is now more widely understood and acknowledged, or because the particular players in the CLAMS arena are getting to know each other better, is not immediately clear. There seems to be a greater focus now on commonalities and the potential for progress in understanding. What is clear from the findings, particularly the focus groups and pre-test/post-rest survey, is that time taken to explore meaning together can only help to adjust the critical balance between skepticism (or even hostility), and trust.

In light of repeated findings that map users want assumptions to be made explicit in order for them to be understood, we can conclude that map users are more likely now to view map makers and their work as a puzzle to be tackled and understood, than as a plot to be uncovered. GIS maps can continue to play a crucial role in this transition.

2. New knowledge communities.

The very process of looking at large landscapes as CLAMS does in the effort to understand natural resource management issues becomes its own trigger for change. In turn, the process of utilizing the impressive power of GIS maps to aid in that endeavor catalyzes further system change. Not only do such maps tend to reflect large landscapes, but they combine that with the ability to sort and combine information thematically, to thereby re-frame debates, refine questions, and challenge static ideas. The task of understanding the power of the technology, not just the complex content it displays, has helped map makers think in terms of a new ethics of presentation, and all players to begin to discuss a "shared responsibility" in grappling with the issues. Map users are hungering for further application of technology to continue to improve the exchange of ideas. The call to arms is coming from both sides now.

The question of whether mutual learning approaches, collaborative inquiry, and understanding scientific assumptions places new responsibility on the heads of both map users and map makers was raised explicitly in the focus group conversations for the first time in this study. Could it be possible to *create* an attentive public, to *require* it even? Building a new kind of knowledge community to address complex environmental problems would call upon broader bases of knowledge than currently operate in this arena. Exchange of ideas and knowledge would likely have direct effects on story-making about the environment, with potential influences on decision-making. In such a scenario we might be mapping ideas as much as landscapes with GIS.

3. Potential system adjustments.

Every technology has both intended and unintended consequences. Some are important, others not, some are constructive, others devastating. Simultaneously, networks of events or factors can coalesce to form dynamic conditions that activate balance points within systems. In the case of CLAMS, a series of both external and internal factors have primed the project for adopting some level of change in how both inquiry and subsequent communication of findings take place. Specific to GIS use, the various unintended consequences suggest the development of a support network for adjustments both large and small to current systems. In turn, change in the way CLAMS supports public interaction has ample potential to change the way natural resource management is conducted and supported by scientific research in the Oregon Coast Range. If the consequences of adoption of the technology trend in a direction away from yet more privileged knowledge, the likelihood of technology diffusion is increased

(Wejnert 2000), as is the likelihood of transformation of traditional decision-making structures.

4. A new phasing stage in technology diffusion.

Following from the unintended consequences, as well as the intended ones of grappling more efficiently with huge amounts of spatial data, a new phase, or sub-phase, might be added to the currently accepted lists of phasing in technology diffusion. Somewhere between trial and adoption (Brunn, Dahlman, and Taylor 1998), or between implementation and confirmation (Rogers 2003), might come a process called the development of faith. Simply put, it is an optimistic, forward-looking view of the possibility of change, shared by enough actors to make a difference in how technology-assisted problem-solving is approached. In addition, it may be a period in which the social and technical understandings of technology begin to coalesce to some extent. The result is that dialogue about the technology itself, and about subjects for which it is used in the discovery process, improves in breadth and depth. If the development of faith is combined with the pre-existence or simultaneous emergence of balance points, the use of the technology is more likely to stick, even to spread in creative ways.

In the present case, it is conceivable that the CLAMS project, and possibly others like it, is at a critical balance point chiefly involving trust and learning, and the ongoing commitment of individuals and institutions. In theory, primary actors representing both scientists and non-scientists could collaborate to shift that balance intentionally to a permanently improved condition of public interaction in natural resource management. The final phase—adoption or confirmation—is then more likely to be achieved.

5. Retrieving the power of story-making.

GIS maps provide a highly suitable backdrop to the collaborative development of stories about landscapes. When an impersonal database can be queried and the results seen by stakeholders of many stripes, often literally standing around a map together, something important happens to any adversarial dynamic. The more space there is to build stories together or tell individual stories to each other, the more space there is for the kind of mutual learning that keeps minds open to new possibilities. Closer understanding of place, via stories, contributes in turn to the development of faith in the social and technical value of the technology.

6. Implications for studying science and society.

It is clear from the findings that, without fanfare, science in this case has an altered status, from arbiter of truth for a privileged group, producing privileged knowledge, to tool of inquiry with broad potential social applications. Once meanings are explored by attentive parties, there is less likelihood of adversarial declarations of bias, and a greater chance that communities of interested people will change their focus from conflict to interaction, from content to idea. Such a seedbed nurtures suggestions for collaboration, for directed uses of technology, and for improved understanding on multiple levels and subjects—post-normal science in action (Funtowicz and Ravetz 2001). With the development of new, informal knowledge communities, the idea that scientists can learn from non-scientists has room to grow.

Science, then, has moved from its Enlightenment role at the pinnacle of knowledge-gaining activities, through turbulent periods of adverse reaction to its inbuilt power and apparent arrogance, to a currently visible condition in this arena in which it is regarded as a highly respected contributor to ongoing dialogue about complex subjects such as natural resource management. While it cannot be claimed that the CLAMS work group, or its extended connections, has absolutely arrived at such a destination, there are clear signs that the journey is well under way, and the destination clearly perceived. Hence the view of science and scientists as partners with interested non-scientists—rather than as oracles, owners of knowledge, or philosopher-kings—might now be explored as an important sea-change in the continuing evolution of the relationship between this type of scientific endeavor and society.

7. The movement from structure to meaning.

The long view of the findings from this study can be described as capturing a movement away from the structured perception of society and its components that was at the center of structural-functionalist studies, wherein scientists and their institutions produced knowledge in a relatively unchallenged manner. Instead, we see now the beginnings of a practice of recognizing that meanings will vary among groups, and that meanings are crucial to understanding. As symbolic interactionists insist, the business of exchanging knowledge involves altering meanings, this being surely the most fundamental definition of mutual learning.

Thus we can propose that in the absence of the real and perceived walls of a structured community or society, sustained interaction between scientists and non-scientists over natural resource management provides freer rein for developing trust, addressing complexities and uncertainties, and nurturing faith in the learning process.

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APPENDIX A: CLAMS WEB-SITE SURVEY

Welcome to the CLAMS Maps Survey site. Thank you for giving us the short time it will take you to complete the questions below. We are interested in finding our how useful and understandable these important CLAMS tools are. Because you have requested CLAMS maps in the past, your input will be of significant help. All your answers will be kept confidential.

1. **Please tell us which of the following statements best describes your familiarity with CLAMS at the time you requested material from the CLAMS web site.**

I had heard several presentations about the CLAMS project	**25%**
I had heard one presentation about CLAMS	**4%**
I had encountered several references to CLAMS (web/colleague/journal)	**49%**
I had encountered only one reference to CLAMS before I went to the web site	**12%**
I had never heard of CLAMS before I found the web site	**10%**

2. **For what purpose did you request CLAMS maps/databases from the web site? Select all that apply.**

Agency planning	**40%**
Class assignment	**12%**
Site selection for research	**17%**
Graduate research	**19%**
Post-graduate research	**17%**
Development of data display techniques	**16%**
Other (watershed assessment)	**9%**

3. **Please indicate which of these descriptions best fits your use of the CLAMS maps/databases that you requested. Select all that apply.**

Coarse-scale (large watershed/basin) planning or assessment	**61%**
Fine-scale (small watershed, local) planning or assessment	**47%**
Assessing general trends in bioregional landscapes	**26%**
Getting specific answers to questions about bioregional landscapes	**12%**
Other (aquatic, general comparison)	**11%**

4. **Please read the statements below and indicate how much you agree with each based on a scale where "1" is strongly agree, "2" is agree, "3" is uncertain, "4" is disagree, and "5" is strongly disagree.**

	Agree	**Uncertain**	**Disagree**
The CLAMS maps/databases served the purpose for which I downloaded them.	**79%**	**9%**	**12%**

The maps/databases were more technical than I expected	**17%**	**19%**	**65%**
The maps/databases would be more helpful if they provided greater detail	**54%**	**19%**	**28%**
The maps/databases helped me better understand regional-scale land management challenges	**55%**	**32%**	**13%**

5. **Please indicate how likely you would be to use CLAMS maps/databases in the ways listed below on a scale where "1" is highly likely, "2" is likely, "3" is uncertain, "4" is unlikely, and "5" is highly unlikely, and 6 indicates you would never have cause to use CLAMS maps/databases in this way.**

	Likely	**Uncertain**	**Unlikely/ Never**
Small watershed restoration projects	**44%**	**23%**	**33%**
Riparian management planning	**39%**	**20%**	**41%%**
Forest management planning	**46%**	**18%**	**36%**
Stakeholder/policy dialogue	**51%**	**16%**	**33%**
Public outreach and education	**58%**	**18%**	**24%**

~~6.~~ **Uncertainty in GIS-based maps such as CLAMS produces can come from many sources, from lack of comprehensive field data to untested models. Note that uncertainty does not mean outright error in the maps. Please indicate how much you agree with the following statements on a scale from 1 to 4, where 1 is "strongly agree," 2 is "agree," 3 is "disagree," 4 is "strongly disagree," and 5 is "don't know."**

	~~**Agree**~~	~~**Disagree**~~	~~**Don't Know**~~
The CLAMS GIS maps contain a high degree of uncertainty	**43%**	**36%**	**21%**
I am comfortable with the level of uncertainty contained in the CLAMS GIS maps	**77%**	**18%**	**5%**
I understand that all scientific models, such as CLAMS GIS maps represent, contain uncertainty	**98%**	**0%**	**2%**
The level of uncertainty in the CLAMS GIS maps makes them unusable for			

many purposes	**39%**	**43%**	**18%**
The CLAMS GIS maps closely represent reality on the ground	**23%**	**50%**	**27%**

7. **One of the questions that arises about use of model-based maps such as CLAMS offers is the level of trust which users have for them. Please indicate which of the following components of trustworthiness is most important to you with respect to CLAMS.**

The maps/databases come from a legitimate source.	**30%**
The maps/databases provide a high degree of surface accuracy.	**23%**
The scientists have no hidden agendas.	**7%**
The scientists have used a peer-reviewed process for developing the maps.	**40%**

8. **Please indicate to what extent you agree with each of the following statements on a scale of 1 to 5, where 1 is "strongly agree," 2 is "agree,", 3 is "uncertain," 4 is "disagree," and 5 is "strongly disagree."**

	Agree	Uncertain	Disagree
You would trust CLAMS maps and models enough to use them in your decision-making	**72%**	**21%**	**7%**
CLAMS maps and models would be more reliable if stakeholders were fully included in ground-truthing (accuracy checks)	**46%**	**35%**	**19%**
CLAMS scientists make unbiased decisions about what GIS maps will show and not show	**43%**	**46%**	**11%**

9. **Please skip to Question 11 if you did not review CLAMS vegetation and habitat maps while you were visiting the CLAMS web site. If you did review the vegetation and habitat maps, please indicate on a scale of 1 to 3, to what extent you were AWARE the following assumptions were included in developing these maps, where 1 is "fully aware," 2 is "uncertain," and 3 is "not at all aware."**

	Aware	Uncertain	Unaware
Forest management policy will remain the same under all ownerships for the next 100 years	**15%**	**31%**	**54%**
Habitat condition is a reliable indicator of biodiversity	**19%**	**50%**	**15%**
Private timber harvest can continue at or near historical levels in the CLAMS			

area	**0%**	**27%**	**12%**
Clearcuts will never return to their 1980s size or frequency	**8%**	**50%**	**31%**
Land management has contributed to habitat loss of salmon populations in the CLAMS region	**62%**	**23%**	**15%**

10. Please skip to Question 11 if you did not review CLAMS vegetation and habitat maps while you were visiting the CLAMS web site. For the same set of assumptions used to develop the CLAMS vegetation and habitat maps, and listed in the last question (9), please indicate on a scale of 1 to 5 to what extent you AGREE with the assumption, where 1 is "strongly agree," 2 is "agree," 3 is "uncertain," 4 is "disagree," and 5 is "strongly disagree."

	Agree	Uncertain	Disagree
Forest management policy will remain the same under all ownerships for the next 100 years	**4%**	**16%**	**80%**
Habitat condition is a reliable indicator of biodiversity	**69%**	**15%**	**15%**
Private timber harvest can continue at or near historical levels in the CLAMS area	**27%**	**12%**	**62%**
Clearcuts will never return to their 1980s size or frequency	**58%**	**31%**	**12%**
Land management has contributed to habitat loss of salmon populations in the CLAMS region	**85%**	**15%**	**0%**

11. Several findings about the Coastal landscape that have emerged through the CLAMS projects are described below. We are interested in whether the CLAMS maps have been helpful to you in understanding the findings. Please indicate for each statement below how helpful the maps/databases have been to you on a scale where 1 is "very helpful in understanding," 2 is "somewhat helpful in understanding," 3 is "somewhat unhelpful in understanding," 4 is "very unhelpful in understanding," and N/A means "does not apply to the maps I used."

	Helpful	Unhelpful	N/A
Oak woodland savanna is declining through time in the Coast Range	**81%**	**17%**	**2%**

Ownership strongly affects future vegetation development and habitat condition	**67%**	**30%**	**4%**
Habitat for anadromous fish will not be "saved" by reduced timber harvest on federal lands	**63%**	**28%**	**9%**
Young, structurally diverse forests are rare on all ownerships	**57%**	**35%**	**7%**
All ownerships in the CLAMS region contribute to biodiversity through time	**59%**	**37%**	**4%**

12. What is the single best description of your affiliation?

Public land manager/agency	**23%**
Private industrial land manager	**5%**
Watershed council member	**2%**
Non-governmental organization	**11%**
Student	**16%**
Academic researcher	**32%**
Other (consultant)	**13%**

13. What is the highest level of education you have completed?

Some college	**4%**
Bachelor's degree	**19%**
Some graduate school	**19%**
Master's degree	**40%**
PhD/equivalent	**18%**

14. If appropriate, what was your major for your highest degree?

Natural science	**72%**
Social science	**28%**

15. What is your age group?

25-34	**47%**
35-49	**42%**
50-64	**11%**

APPENDIX B: PRE-TEST, POST-TEST SURVEY

Thank you for participating in this CLAMS web-based survey. It should take you 10 minutes or less to complete the survey. Your participation in the CLAMS workshop at Oregon State University in June 2002 provided invaluable information to the project. One set of questions emerging from that workshop addressed the use of maps to display data. The purpose of this short questionnaire is to elicit your views of maps in general and GIS maps in particular.

1. **Which of the following statements corresponds with your understanding of the traditional, non-GIS map? Check all that apply.**
    i. A map is an idea
    ii. A map closely represents reality on the ground
    iii. A map omits more data than it includes
    iv. A map represents an objective viewpoint
    v. A map represents a subjective viewpoint
    vi. A map encourages inquiry by its users

2. **Which single statement from question 1 do you feel BEST defines "map" for you?**
    i. A map is an idea
    ii. A map closely represents reality on the ground
    iii. A map omits more data than it includes
    iv. A map represents an objective viewpoint
    v. A map represents a subjective viewpoint
    vi. A map encourages inquiry by its users

3. **Which of the following statements corresponds to your understanding of GIS (Geographic Information Systems) maps? Check all that apply.**
    i. A GIS map is an idea
    ii. A GIS map closely represents reality on the ground
    iii. A GIS map conceals far more data than it displays
    iv. A GIS map represents an objective viewpoint
    v. A GIS map represents a subjective viewpoint
    vi. A GIS map encourages inquiry by its users
    vii. Any GIS map is just one of many possible displays that could be produced from the same database

4. **Which of the statements from question 3 do you feel BEST defines "GIS map" for you?**
    i. A GIS map is an idea
    ii. A GIS map closely represents reality on the ground
    iii. A GIS map conceals far more data than it displays
    iv. A GIS map represents an objective viewpoint

v. A GIS map represents a subjective viewpoint
vi. A GIS map encourages inquiry by its users
vii. Any GIS map is just one of many possible displays that could be produced from the same database

5. Some people have ongoing concerns about GIS maps and their use. How much does each of the following attributes of GIS maps concern you, where 1 is "no concern at all," and 5 is "a great deal of concern"?

	AVG.RANK Pre / Post
i. GIS technology is too complex for most people to use.	**2.4 / 3.3**
ii. The ability to produce GIS maps is in the hands of too few people.	**2.5 / 2.6**
iii. Producers of GIS maps have more decision-making power than users of GIS maps.	**2.3 / 2.8**
iv. GIS maps display only a tiny fraction of the available data, from one viewpoint.	**2.8 / 2.5**
v. Many people do not realize that GIS maps may not be highly credible.	**3.6 / 3.5**

6. Some people believe that GIS maps may make it possible for people to learn together. How likely is each of the following attributes of GIS maps to lead to mutual learning, where 1 is "highly likely," and 5 is "highly unlikely"?

	AVG.RANK Pre / Post
i. GIS maps integrate data across ownerships.	**1.8 / 1.7**
ii. Many people can explore databases and contribute to problem-framing dialogues.	**2.1 / 2.1**
iii. As GIS maps become more commonly used in management, their inherent uncertainty will become better understood.	**2.2 / 2.1**
iv. GIS maps represent powerful opportunities for analyzing data from multiple points of view.	**1.8 / 1.5**
v. GIS maps offer a valuable starting point for dialogue.	**1.6 / 1.6**

7. Some people believe that GIS maps set up communication barriers between technical and non-technical people. How likely is each of the following attributes of GIS maps to widen that communication gap, where 1 is "highly likely," and 5 is "highly unlikely"?

		AVG.RANK Pre / Post
i.	Many GIS maps are developed from databases that are too technical to articulate in public settings.	**2.9 / 2.8**
ii.	GIS maps seem like truth to most non-scientists.	**2.6 /2.2**
iii.	GIS maps are based on data with varying levels of quality.	**2.3 / 2.2**
iv.	GIS maps present subjective viewpoints.	**3.1 / 2.7**
v.	Limited access to technology will move decision-making power into the hands of a small minority of technical people.	**3.3 / 2.9**

8. Like other emerging technologies, GIS maps have both positive and negative unintended consequences. On the list below, check all of the potential of the use of GIS maps that you think may occur.

i. Emerging privacy issues (remote sensing data "sees all")
ii. Emerging anti-trust issues (ecosystem management across industrial ownership boundaries)
iii. Increased collaboration in natural resource decision-making.
iv. The creation of a technical elite who can influence natural resource decisions.
v. Advances in GIS technology that make map-making more accessible.
vi. Efficiency and speed in testing alternative natural resource futures.
vii. The ability to make uncertainties and untested assumptions look like the truth.
viii. Other.

9. What is the single best description of your professional affiliation?

i. Public land manager/agency
ii. Industrial land manager
iii. Academic researcher, CLAMS project
iv. Academic researcher, non-CLAMS
v. Watershed council member
vi. NGO member
vii. Non-industrial private landowner
viii. Attentive public
ix. Other