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Collaborative Design of Fish Habitat Enhancement Projects in Streams and Rivers of Washington State

by

James Henry Dooley

A dissertation submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

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Abstract

Collaborative Design of Fish Habitat Enhancement Projects in Streams and Rivers of Washington State

by James Henry Dooley

Chairperson of the Supervisory Committee: Professor James L. Fridley

College of Forest Resources
Division of Forest Management and Engineering

A study was conducted of project-level design processes related to fish habitat enhancement projects across Washington state. Data was collected from 65 projects within 14 Water Resource Inventory Areas. Over 200 individuals and agencies were found to have participated in project-level decision making. Social network analysis was used to identify communication linkages between participants, and to identify likely sources of influence. Social networks were weak within and across projects, except in rural eastern Washington. Problem framing by sponsors and participants had a substantial influence on objectives and constraints; yet little impact on chosen solution features. Team structure appeared to take on the form of an informal collaborative network rather than a formal organizational structure. Engineers played various roles including analyst, designer, advisor and leader. Engineering roles were highly situational and not predictable from project to project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation. ABET: Accreditation Board for Engineering and Technology

Abbreviation. AHB: Area Habitat Biologist

Abbreviation. ASE: Analysis / Synthesis / Evaluate method of engineering design

Abbreviation. C: Constraint

Abbreviation. CFS: Cubic feet per second

Abbreviation. COE: U.S. Army Corps of Engineers

Abbreviation. DP: Design parameter

Abbreviation. FR: Functional Requirement

Abbreviation. GIS: Geographic information systems

Abbreviation. HPA: Hydraulic Project Approval

Abbreviation. IPS&S: Influencers, participants, stakeholders and surrogates

Abbreviation. JARPA: Joint Aquatic Resource Permits

Abbreviation. KCBSM: King County Bank Stabilization Manual

Abbreviation. MDS: Multidimensional Scaling

Abbreviation. Mgr: Manager

Abbreviation. NRCS: United States Department of Agriculture Natural Resources Conservation Service

Abbreviation. Prog: Program

Abbreviation. QFD: Quality Function Deployment

Abbreviation. RCW: Revised Code of Washington

Abbreviation. Std. Dev: Standard Deviation

Abbreviation. WAC: Washington Administrative Code

Abbreviation. WRIA: Water Resource Inventory Area

Abbreviation. WDFW: Washington State Department of Fish and Wildlife

PREFACE

Throughout my career as a practicing engineer, I have continuously sought better methods for identifying and accommodating the needs of project stakeholders. I have been a professional engineer for more than twenty years, with experience in tropical agriculture, horticulture, plant biotechnology, forestry and elsewhere in the natural resource arena. As a designer, design team leader and engineering process developer one would think that I had a good handle on how to do design. True, there are patents, successful products, industry-standard machines and improved work methods as evidence of at least modest success. However, at the conclusion of nearly every project, our design teams could look back and see missed opportunities due to imperfect design processes.

Hallmarks of the engineering development groups that I led were that we ran our projects 1) in a open environment with frequent visits to and by our clients, 2) such that physical models and artist drawings were produced early so non-engineers could "see and feel" what the engineers were thinking, and 3) with early field trials and experiments that were "media events" where clients and other stakeholders could learn along with us, as well as personally experience successes and inevitable failures. In essence, to the best of our ability and within the culture of the time we brought our clients and other stakeholders *inside* the design and development process. We adapted existing design methods (Dooley 1989) and developed new design tools (Dooley 1983) to better blend engineering rigor with group processes. Yet, there was need for more serious thought about how to "do design" in a more open and participative culture that was emerging.

By 1990, a crisis was brewing in the forest products industry due to the convergence of A) public review via the National Environmental Policy Act (NEPA), and B) computerization of forest planning and engineering design. Planning and design could be accomplished orders of magnitude faster than in the past, and computer routines could easily optimize for economics and logistics. Computerization made it even more difficult to factor stakeholder input into design decisions. NEPA and similar local policies required that plans and designs be subjected to public inspection and review before issuance of regulatory permits. An immediate disconnect was apparent between the values and coefficients used by industry's planners and engineers, and the values held by reviewers. Somehow, the timber industry needed to find ways to bring stakeholders to the front-end of design and planning activity rather than having to address their objections at the back end. Somehow, professionals in the industry had to find or develop more open and inclusive design processes that take advantage of information technologies, yet accommodate deep legacy, context, place and other values.

Companies such as Weyerhaeuser (my employer at the time) initiated Town Meetings and other large group processes to better understand the differences between company-held values and those of the neighbors and the general public. It was clear that if the timber industry did not change how it accommodated external stakeholder values, Congress and various state legislatures were likely to pass increasingly onerous legislation regulating the industry. Common ground between companies and citizenry included stewardship ethics, agrarian values, belief in local community development, among other points of agreement. Contention often focused on what planners erroneously considered "small stuff" like sense of place, local wildlife, traditional hunting and recreational access, locally significant view points along roads and the like. These issues might have been considered inconsequential to designers and planners, but they were game stoppers to the local populous. Again, the question to technical managers like myself was, "How do you change your methods to ensure these kinds of needs and requirements are met *during the design process* rather than as mitigation issues during regulatory review?"

Part of the response by industrial forestry concerns and public agencies was to create stakeholder councils to get as many interested parties together and visit prospective project sites and discuss collective and individual needs before the design was cast. In the forest industry, these "ID" teams substantially reduced end-of-process disputes and delays. Still, there were no effective and generally accepted processes for stakeholder and client involvement *during* design.

Professors Jim Fridley and Jens Jorgensen from the University of Washington, Professor Roger Garrett from U.C. Davis, Professor Tim Foutz and Professor Brahm Verma from The University of Georgia shared my interest in finding more participative and effective methods for doing engineering design in the new social environment we faced. Our conversations during the 1988 through 1993 period helped me develop a conviction that the area needed systematic research and that new design methods are likely to be needed.

I had always had a plan to go back to school and pursue a doctorate in engineering design. Drs. Fridley and Verma encouraged me to think seriously about working on my ideas about doing design in an increasing complex social environment. Finally, by 1994 opportunity and situation converged to make a dedicated Ph.D. effort possible.

The journey from matriculation to completion has been a seemingly eclectic exploration of traditional engineering methodologies with frequent sojourns into the worlds of society building, political sociology, policy design, chaos theory, decision philosophy, problem framing, and a host of other seemingly irrelevant non-engineering topics. Looking back, every stop has added richness and understanding of how the world works. The pieces of social science, behavioral psychology, mathematics, political science all contribute to development of better ways to incorporate diverse participants into design processes. This dissertation is but a way-point on the journey.

Jim Dooley, September 3, 1999

ACKNOWLEDGMENTS

The author wishes to thank all of those friends, family and professional peers who encouraged me to step out of a career in industry to pursue this research, education and dissertation program. I am grateful to my spouse, Kathryn, and children, James and Heather, who demonstrated patience during the difficult times and prodded when I needed to get back on track. A special thanks is due to Ms. Kari Paulson, who was a true professional when it came to conducting interviews, arranging site visits and critiquing data analysis. Justin Maschoff provided disciplined and expert data analysis to turn mountains of data into the informational tables and figures included in this dissertation.

We had a phenomenal response rate on requests for interviews and site visits. Over 100 persons took time from their busy schedules to talk to us on the phone, participate in site visits or respond to mailed surveys.

As the analysis and writing were winding up, there was a moment when a fear set in that no one really cares about the results and conclusions that come from four years of effort. Fortunately, Pat Trotter, Carl Menconi, Mike Nelson, Ken Bates and other professionals in the habitat field provided supportive words during the final months of the effort.

It is not often that a graduate student is allowed the freedom to explore across discipline boundaries. I owe each committee member a debt of gratitude for his support, advice and tolerance as I brought (with varying success) management, engineering design, social science and behavioral studies into this research effort. Thank you Professors Jim Fridley, Bob Lee, Chad Oliver, Peter Schiess and Rob Smith for the opportunity.

This work was conducted at Silverbrook Limited and at the Cooperative for Forest-Systems Engineering at the University of Washington. The University of Washington portion of the project was supported, in part, by the USDA Forest Service PNW Research Station Agreement No. PNW 93-0363.

DEDICATION

The author wishes to dedicate this dissertation to Kathryn, James and Heather

CHAPTER 1: INTRODUCTION AND RATIONALE

RATIONALE

One of the greatest challenges facing engineering and technical problem solvers is finding ways to fully integrate social complexity and diverse stakeholder viewpoints into their work. Modern engineering decision-making generally developed under a paradigm that assumed a single client and a single designer or "chief" engineer (Vincenti 1991). More recently, a number of public policy and sociopolitical changes have either allowed or encouraged direct public participation in the activities of engineers and scientists. Engineers and technical specialists working in the natural resources are facing ever-increasing external public, regulatory and special interest group participation in their daily work.

Direct involvement of stakeholders in the affairs of corporations, agencies and other natural resources entities is now about fifteen years old. During its short history, stakeholder involvement was primarily associated with major policy decisions, large group processes, stakeholder councils and the like. At the operational level, stakeholders continued to have little effect. Only recently have select stakeholders from outside an organization been invited to participate on cross-functional teams at the operating level (Ancona and Caldwell 1992).

In spite of an extensive literature base related to stakeholder involvement at the policy and macro level, there is little know about: 1) the extent to which stakeholders influence decisions at the operating level, and 2) processes used by project level designers to incorporate stakeholder input into their decisions. Missing from the literature is a serious study of how design teams actually involve and accommodate stakeholders. Since most professionals involved with the natural resources have experienced public participation and stakeholder involvement since its inception, it would be very informative to study and characterize how stakeholder involvement has been institutionalized.

The objects of this study are 1) to describe how stakeholders are involved in natural resources related design projects, and 2) how designers and design teams consider stakeholder input as they make decisions.

DESIGN PROBLEMS IN THE NATURAL RESOURCES

Design in the natural resources is rapidly evolving from a purely technical process conducted behind closed doors to a highly public and cross-agency participative process that involves a myriad of participants and reviewers (Pukkala and Kangas 1996). Historically, design problems were associated with transportation infrastructure and extraction of natural resources (Bryant 1913). While engineers and other designers might have felt a moral or ethical imperative to address the needs of various stakeholders, it was clear that their marching orders were to optimize designs for economics and logistics (Bryant 1913). Design tasks involved railroad grade design, road alignment, transportation network planning, design of bridges, etc. Harvest unit planning emphasized the technical aspects of efficient and safe wood extraction. While design tasks were often difficult and included many judgments in the decision making process, objectives and constraints were usually well defined and understood.

By the mid-1970's federal and state legislation began to encourage public participation in natural resource planning and design projects. Over time, this expectation has filtered down to the operational level. Today, almost all design solutions undergo public scrutiny prior to implementation. Moreover, engineers and other designers are encouraged or required to seek input from stakeholders inside and outside the firm during the design process. Stakeholder intensive design activities include:

- Forest harvest and transportation system planning
- Harvest unit layout
- Commercial thinning of production forests
- Stream rehabilitation and habitat enhancement
- Riparian buffer specification

Stakeholders in each of these design projects include regulators, contractors, various internal functional groups, public special interest groups and the employees directly involved in the project itself. The biggest change for designers has been the addition of external stakeholders to the participant lists. Successful designs not only must meet internal objectives, but must satisfy the needs of third parties (Ullman 1992) – in particular those parties that have the power or conviction and resources to block unwanted solutions.

For purposes of illustration, the design of stream rehabilitation and habitat enhancement projects will be described. Stream habitat improvement projects necessarily involve the collaborative efforts of landowners, agencies, contractors, regulators and various special interest groups. Many of the projects are initiated by agencies or interest groups other than the landowner. When someone other than the landowner initiates a project, the stream corridor landowners are recruited or otherwise brought into the project. In other cases landowners initiate habitat improvement projects for their own benefit, then bring agencies and other interests into the project to share costs, provide labor or provide political support favorable to gaining project approval by regulatory agencies.

Stream improvement projects are generally accepted as having competing interests of flood control, habitat enhancement, landowner uses, recreational demands, etc. Thousands of small projects have been executed across the United States in the past decade. At least several hundred small stream projects have been conducted in the state of Washington. Through the collective experience of many projects, it appears that identification of interest groups, development of communication linkages, and establishment of norms for involvement are showing signs of maturity. Social and communication networks involving project designers and stakeholders may be well established in some regions of the state.

Designers make a number of design decisions that are likely to be influenced by stakeholder input, including:

1. valuing competing objectives
2. overall stylistic approach to solution
3. specification of materials to be used,
4. specification of structure size and shape,
5. location and distribution of structures along the stream,
6. method of placement, and
7. method of anchoring.

Small streams are defined for our purposes as streams having normal summer flows of less than 100 cubic feet per second (cfs) or channel width less than ten meters. Common materials that are used for habitat enhancement and channel structures include concrete, steel, milled wood, automobile bodies, quarry rock, cobbles in gabions, placed logs and placed root wads. The choice of materials is a function of potentially conflicting needs such as cost, aesthetics, fisheries value, availability of materials, regulatory requirements and landowner preferences. Participants in the materials decision are likely to include the landowner, design firm, materials supply firms, regulatory agencies, environmental special interest groups, fisheries special interest groups, and installers.

Structure size and shape involves a trade-off of materials cost, placement difficulty, stream channel characteristics, hydrologic regime, and effectiveness for creation of fish habitat. The location and distribution of structures along a stream typically is affected by stream access issues, project budget versus technical optimal habitat creation, balancing of creating new pools versus reinforcing existing pool habitats, desire to modify the stream direction, etc. Method of placement ranges from hand labor to heavy equipment, cranes, logging skylines and helicopters. Tradeoffs include project budget, availability of labor, size of materials, environmental sensitivity and site accessibility. The method of anchoring can include choices to do nothing, drill and epoxy anchors into the streambed, tie cables from the structures to riparian trees, driving piles or structural elements into the stream bank and ballasting the structure with large rocks. In all of the above decisions there is the potential for dominance by value judgments, preferences of central stakeholders, and scientific/cultural norms that support one technical or analytical paradigm over another.

DESIGN AND PROBLEM SOLVING METHODS

The technical aspects of design are frequently supported by documents that act as surrogates for scientists, engineering specialists and others. For instance, a logging expert might be represented to a harvest planner by logging design engineering manuals, guidelines and analytic software packages already present in the planner's library. Logging equipment manufacturers are represented by catalogs and technical specifications. Technical foresters with site knowledge are represented by cruise reports, geographical information systems (GIS) maps and stand tables. Public policy is represented by published codes and regulations. In the past, it was deemed sufficient for engineers and other designers to confine their analyses to consideration of the aforementioned objective information (Hughes 1991). Designers were typically trained and managed to maintain objectivity by deferring preference, subjective judgment and political components of a problem to management and/or the client (Davis and Johnson 1987; Glegg 1971; Pahl and Beitz 1984).

A host of organizational, social and technical changes are working together to fundamentally change the nature of natural resources design and the roles of technical staff (Fisher 1993; Sladovich 1991). Designers are now expected to directly coordinate with other functional groups within the enterprise as well as with external stakeholders to address technical and non-technical aspects of design problems. The research community has responded with two kinds of support. One approach involves creating decision support tools that enable preference and other subjective data to be handled inside otherwise objective and repeatable technical decision processes, such as developed by Pukkala (1996). The other approach involves improved teaming and group processes that better enable diverse project participants to work effectively and in relative harmony (Babiuch and Farhar 1994).

Analytic tool sets have a driving objective to make it possible to treat non-technical aspects of design problems in similar deterministic, or at least by repeatable methods, as used for the purely technical and economic aspects of a problem. Berg (1995) demonstrated that conjoint factor analysis could be useful for characterizing logger preferences related to harvest unit layout. Lexical analysis was applied by Shaw and Manley (1991) to parse stakeholder opinions into objective decision-support data. Shaw and Manley's method included a mathematical framework for using the output of textual analysis for problem definition. McIntyre and Higgins (1989) developed a method to model stakeholders as "objects" within an object-oriented programming language. Structured interviews and directed brainstorming were used to identify stakeholder positions on issues, which were subsequently coded into optimization routines. Pukkala and Kangas (1996) developed a numerical method for integrating stakeholder attitudes towards risk into forest planning analysis.

The emphasis of teaming and group process development is on methods that might cause group decisions to be "better" than individual decisions absent team or group input. Social processes are emphasized in team handbooks (Scholtes 1988, among others) and stakeholder involvement guides (Babiuch and Farhar 1994; Mallak, Patzak, and Kurstedt 1991 and others). The premise of teaming and group processes is that decisions will be supported by scientifically sound data collection, objective analysis where appropriate and rigorous evaluation of alternatives. Where numerical methods are not available or appropriate the team will resort to group processes to generate and evaluate information. Eppinger et. al. (1994) addressed the problem of communication among participants in large design projects. Eppinger proposes a Design Structure Matrix of the form originally detailed by Steward (1981) that can be analytically rearranged such that communications sequences and dependencies are emphasized. Logical groupings of dependencies can then be used to specify those participants who need to be involved at different points in a design process.

A critical assumption of most technical problem solving processes is that there is an optimal or satisfactory solution for every design problem. What is missed is the fact that not all design problems have a technical solution due to competing values and interests of participants (Lindblom 1990). Lindblom asserts that solution of social problems is often confounded in that some participants benefit if the status quo is maintained and others benefit from continuation of a problem conflict. Lindblom further asserts that the very act of participating in a group problem solving effort frequently results in "mutual adjustment" of problem definition, constraints and solutions. Mutual adjustment may lead to a satisfactory resolution of a design problem without need for construction of a new technical product.

APPRECIATIVE DESIGN

Appreciative Design is an engineering and problem solving method that brings stakeholders, along with their beliefs, roles, needs and values, directly inside the design process (Dooley and Fridley 1996). The tool set for Appreciative Design provides a bridge between social systems and technical systems for problem solving. The method begins with problem framing (Tversky and Kahneman 1981) and continues through problem definition, structured decision making, and solution acceptance phases of an engineering project. Appreciative Design draws heavily from structured problem formulation and decision making tools of Suh (1990). While Appreciative Design builds upon familiar design process models, it is the approach to stakeholder involvement that sets it apart from other "technological" processes. Blending technical and social processes provides a higher probability that solutions will be accepted by the community of stakeholders surrounding a particular design problem (Wilson and Morren 1990 : 108).

The term *appreciative design* is adapted from the term "appreciative systems" as first used by Vickers (Checkland and Casar 1986). Vickers reportedly holds the view that a continuous flux of human events, comprises of an ongoing interplay between events and ideas, hold a dominating effect on decisions. This interplay continuously reframes the problem in the minds of participants and encourages mutual adjustment of what constitutes acceptable outcomes based on shared knowledge and insights. Laumann and Knoke (1987) suggest the same forces are at work in public policy development when they assert that policy problems are subject to "perpetual revision" during the course of policy making. The notion of appreciative design is that better solutions are developed if and when the designer(s) have open dialog with, and understand and embrace the interests, concerns and values of stakeholders associated with a design project.

The Appreciative Design method is detailed elsewhere (Dooley and Fridley 1996). The method has been successfully applied to a number of projects within the author's product development firm. The Appreciative Design process is a significant extension of the hierarchical axiomatic design methodology of Suh (1990; 1995a) and includes many features of the Soft Systems Methodology developed by Checkland (1990).

Suh's structure and optimization methods (Suh 1990) (Suh 1995b) are particularly well suited for addressing the messy problems that are common in industry and the natural resource fields. Suh's approach is based on a set of design rules. The Appreciative Design implementation of Suh's approach adds some important structure and detail, as well as provides an easily followed hierarchical tracking of information, alternatives and decisions. The hierarchical structure allows reviewers, decision-makers and others to easily follow the history of decisions made throughout a project.

Suh's design principles are expressed in terms of a decision logic that includes *functional requirements, design parameters* and *constraints* (Suh 1990). Functional requirements (FRs) are design objectives cast in solution-neutral and independent statements. There is general consensus that problems are best defined when the objectives are framed by what is to be achieved by the project rather than by how needs are to be met (Love 1980).

Design Parameters (DPs) are either brainstormed alternatives or calculated specifications that become features of a solution. Brainstorming, ideation and other methods of creating or searching for alternative solutions are well understood by engineering professionals, educators and students so did not need to be included in the model.

Constraints (Cs) are objective statements and mathematical relationships that set bounds on the range of DPs that are acceptable. Constraints provide limits on the how, what, when, where and why of the design solution. Constraints are most often used by designers as criteria to sort alternative DPs into those which are acceptable and those to be discarded or reworked. An initial set of constraints typically is drawn from conversations with the client and all relevant stakeholders. Constraints can also be found through exploration of the laws of nature (e.g., $f = ma$, $\sigma = mc/I$), laws of humankind (e.g. codes, laws and regulations), cultural norms of the organization (e.g., policy and design manuals), and norms of the community (e.g., codes of ethics). In all cases constraints must be linked to a "constraint owner" in order to make them relevant to the problem at hand (McIntyre and Higgins 1989). The constraint-owner linkage provides relevance to a constraint and its source.

DESIGN AS A SOCIAL PROCESS

In spite of its long history of creating artifacts to meet society's needs, engineering is believed by most people to be free of societal influence and "outside the checks and balances of social order" (Vincenti 1991). A proposition of this paper is that the profession of engineering is a social construction; therefore, it is logical that engineering design should be practiced in a broad societal context. There appears to be a general lack of awareness and appreciation that influences external to the firm and design team frequently dominate design decisions. Increasing external public, regulatory and special interest group participation in engineering design comes at a time when the current generation of design engineers is least prepared to appreciate and accept non-technical input (Hughes 1991; McNeill 1992).

Over the past forty years or so engineering has been positioned by educators and many practitioners as being necessarily independent of, and immune from, social influence (Morrison 1986; Vincenti 1991). In the mid-1950's engineering education in the United States was directed away from social-technical integration toward more scientific and mathematical content (ASEE 1954; ASEE 1955). At the same time that engineering education stepped away from problem definition and consideration of non-technical aspects of design, the new educational discipline of professional management provided specialists to assume the decision-making roles in society (Chandler 1977). Engineering students were subsequently taught that it was the role of engineering managers and other non-technologists to address politics, external interests and other non-technical design issues (Bennett 1996; Morrison 1986). However, since the early 1980's we have watched a major shift in the practices of engineering employers to place the burden of addressing non-technical design issues squarely back onto the design engineer. Design engineers are now challenged to directly participate in a broader social system more than at any time in the past four decades.

We have also seen over the last fifteen years an erosion of confidence in engineers by the general public (Ferguson 1992). Many of the attacks on engineering and other technological artifacts appear to arise from newly discovered risks or negative consequences of what was perceived to be highly beneficial technical advances in the past. The rate of change in societal values and expectations may be causing the public to lose sight of the social context within which a technical project was undertaken. The social construction view of technological systems holds that all technological artifacts "bear the imprint" of the social context surrounding their development (Hughes 1991; Pfaffenberger 1990). A few years after the construction of an engineering work or release of a new product there is little public recollection of the social context that stimulated or constrained its design. While the social construction view suggests that the design of an artifact and society are inseparable another view suggests that engineering methods are consciously or unconsciously disconnected from the processes for problem solving used by the non-engineering society at-large (Adams 1991). It may be that the community of engineers and engineering educators have not taken time to maintain their places in the social systems necessary for the survival of the profession (Bugliarello 1991).

Other forces of change are at work as well. The social institutions that support engineers and engineering employment are undergoing unprecedented change. Employment relationships are in turmoil, with engineering and other service positions bearing a full share of many organization's downsizing and outsourcing movements. Erosion of private property rights combined with increased acceptance of the stakeholder view of the corporation (Carroll 1993) has brought multitudes of stakeholders into the design process, either as participants or reviewers of proposed engineering works. Changes inside and outside the engineering community suggest that it is no longer clear just what the role and place of engineering is in our modern society.

There have been a number of recent studies of the social organization and dynamics within design firms and design teams (Bucciarelli 1988). Bucciarelli's recent work, *Designing Engineers,* explores the inner workings of a number of design teams and organizations (Bucciarelli 1994). Bucciarelli concludes that the practice of engineering is as much negotiation and compromise as it is analytic.

PREMISES AND ASSERTIONS

There are five key premises that underlie the author's perspective throughout this dissertation.

1. Design is a social enterprise
2. Design problems can be resolved into Functional Requirements, Design Parameters, Constraints space
3. Constraints are owned by stakeholders – they cannot come from thin air
4. Surrogates influence decisions in ways similar to natural stakeholders
5. Problem framing has an overarching influence on the final solution set

HYPOTHESES

The proposed research project is primarily descriptive in nature. However, the premises suggest a logical set of hypotheses.

Hypothesis 1. Design decisions made by project core teams are influenced by stakeholders who are not team members.

The study seeks systematic evidence that core team members have processes to identify stakeholders and consciously factor stakeholder input into their design decisions. Measures of centrality ((Freeman 1978) will provide important insight whether individual stakeholders are central to decision making or on the periphery. Cause maps (Nelson and Mathews 1991) will aid linkage of stakeholder input to design parameters and constraints.

If it is discovered that obvious stakeholders are on the periphery and not central to the social networks, then the validity of hypothesis 1 will be in question. If design parameters and constraints are found to be internally derived, and cannot be linked to stakeholders then the validity of the first hypothesis will also be in question. More likely, the study is expected to find that some teams and projects and/or design decisions have strong stakeholder influence and others have little or no stakeholder influence. Other factors such as team make-up, role definitions, decision making methods, etc. will then be explored to attempt to at least partially explain the differences.

Hypothesis 2. The level of stakeholder influence on design decisions is related to stakeholder position in the core team social network.

Social network analysis (Gartner and Wagner 1996; Knoke 1990; Marsden and Lin 1982; Wasserman and Faust 1994) will provide a map of the communication patterns between core team members and stakeholders. A social network is a set of actors who are connected to each other by membership, communication or other tie (Wasserman and

Faust 1994). Social network analysis is the characterization and exploration of relationships between members of a social network (Wasserman and Faust 1994). Social networks have three properties that provide insight into the centrality or periphery of network members. The *degree* property is an indication of the number of other stakeholders who have direct contact with any particular stakeholder. The property of *betweenness* is an indication of how a stakeholder is likely to be a conduit for communication between other stakeholders. The property of closeness indicates how spatially central any particular stakeholder is relative to all other stakeholders. Essentially *closenessness* measures how many times a message must be passed from one person to reach all others in the social network. In a spoked network the figure at the center would have a closeness value of one since all others on the network can be reached directly (Freeman 1978). Stakeholders who have frequent direct communication with members of the core team and problem owner are expected to exert higher levels of influence on design decisions than stakeholders who have indirect communication channels.

Hypothesis 3. Stakeholder surrogates influence design decisions in ways similar to "natural" stakeholders.

A point of departure for the current study is that stakeholder surrogates will be included as part of the social network. Surrogates are likely to include non-participating-stakeholder reputation, regulations, reference materials, and legacy effects of past direct involvement with non-participating stakeholders. Surrogates may have the same or stronger effect on design decisions than natural stakeholder connections. Surrogates are expected to drive perceptions and beliefs on the part of core team members and the problem owner that form an important basis for judgment of the utility for alternative design parameters (Checkland and Casar 1986; Checkland and Scholes 1990).

Inclusion of surrogate items in the social network matrix and analyses will allow testing of this hypothesis. Melding of social and other components is expected to give a more robust picture of factors driving design decisions than analysis that excludes surrogates. The results are expected to show that design decisions have a mix of natural and surrogate social actors at the central positions. If all surrogates are at the periphery then the validity of the hypothesis will be in question.

In any systems research project there is a question of how to define the system boundary, at least for the purposes of the current study. Social systems are essentially infinite and without bounds, making it impractical to bring closure to a research project unless there is some form of boundary definition (Churchman 1979). For the purposes of the current project, the systems boundary is set at the second tier of stakeholders - those entities and persons who are likely to influence design decisions through direct communication with the first tier of stakeholders. The first tier of stakeholders are those who are in direct communication with core team members or the problem owner thorough social contact or first-hand surrogates.

SELECTION OF EXEMPLARY DESIGN PROBLEM

Among the many design problems facing engineers in the natural resources, two appear to be particularly well suited for the current research study. Of particular interest would be problems that are common enough to allow a reasonable research population, yet emergent in that results would be of value to practitioners still seeking better ways to conduct design activities.

Across the Pacific Northwest there is a rapid increase in (1) design of salmonid habitat enhancement projects in small streams, and (2) design and layout of commercial forest thinning programs. Both problems are stakeholder intensive. Few standard design practices exist. Effective solutions are dependent upon satisfying the needs of stakeholders both within and external to the sponsoring organization. Either problem situation has the potential to provide adequate data sets for rigorous analysis.

After preliminary interviews with project leaders in each problem type, it was decided to concentrate on a broad study of in-stream salmonid habitat enhancement projects across Washington State. Almost all construction projects that have activities or impacts on fish-bearing waters must obtain a Hydraulic Project Approval (HPA) permit from the Washington Department of Fish and Wildlife (WDFW). Only projects on federal lands and tribal reservations are exempt from the HPA permit. During 1997, over 6,500 HPA permits were processed by the State of Washington (D. Rings, per. comm.). Of those issued, approximately 600 involved habitat enhancement either as a primary objective or as mitigation for project impacts.

Preliminary examination of HPA records was conducted in June of 1997. The number of projects varies widely across river basins of the state with some basins having no projects and others having more than 100. All permit records are filed in the by Water Resources Inventory Area (WRIA). The logical way to segment data is by WRIA and type of project proposed on permit applications. Sufficient textual and contact data is recorded on HPA permits to allow characterization of projects, the nature of the stream being modified, and a set of initial participants that could be used to seed a snowball sampling social network data collection strategy.

RESEARCH APPROACH

The present study is among the first attempts to systematically explore social organization and dynamics of design teams that are comprised of persons from many different organizations and professional interests. Such design teams are increasingly common in industry where regulators, vendors, outside fabricators, customers and others are all included in, and often numerically dominate, product design teams. In the natural resource industries, complex design teams are becoming the norm. The present project sets out to explore the social network surrounding the design of technical components of select design projects, and how the participants in the social network influenced the specification of design parameters.

Since the project is somewhat exploratory in nature, it was deemed to be more effective to sample a broad selection of projects rather than intensively study just a few projects. A broad sampling strategy is expected to bring the research team in contact with diverse perspectives, a variety of project motives and different sponsoring organizations. It is acknowledged that a broad study that provides a richer understanding of social processes and decision making precludes certain types of rigorous statistical analyses. There probably will not be enough observations to allow stratification of data by landowner type, profession of the project leader, stream hydraulic classification, etc.

A variety of research tools are used in the current study. Quantitative and graphical social network analysis (Scott 1991; Wasserman and Faust 1994) enables rigorous characterization of communication linkages among project participants. Snowball sampling (Biernacki and Waldorf 1981) enables tracking out from a few known project participants as listed on the HPA to others involved in or influencing project design. Structured and semi-structured telephone and mail surveys (Dillman 1975) enable consistent capture of participant insight and recollections. On-site visits with unstructured interviews allows direct observation of project results as well as enables a richer understanding of project environments. Data analysis seeks systematic support for or in opposition to the hypotheses. Data analysis also seeks to create a rich understanding of how projects are executed and design decisions are made.

AUDIENCES AND INTERESTS

There are a number of audiences for the information and knowledge developed during the course of the present study. Presentation of early results has attracted attention from:

1. Habitat Restoration Specialists – Habitat restoration specialists are seeking to make sense of the social side of how projects are conducted. They seek insight into how other groups approach project planning and execution.
2. Grant Givers and Policy Mangers – Grant givers and policy managers seek to better understand the nature of salmonid habitat projects and how they are organized, including

who is involved. They also want to know if there are "best practices" and other insights that could lead to more effective and efficient projects.

3. Engineers and other Resource Professionals – Practicing engineers and other resource professionals seek insights into how to better contribute to team processes and appropriately contribute their knowledge and skills to successful projects.
4. Senior Managers – Senior managers who oversee technical services, agency departments, habitat enhancement programs and other related groups seek to better comprehend the situation their staffs work under. In particular, they are seeking insights that would allow them to better coach their subordinates and better allocate resources.
5. Engineering and other Professional Program Educators – Educators of engineers, scientists and other professionals who are likely to become involved in stakeholder-intensive projects seek knowledge and insight that can be passed along to students so they can be better prepared to fulfill their professional roles.
6. Extension and Outreach Specialists – Extension and outreach specialists are seeking better ways to deliver training, new knowledge and other educational programs to participants in habitat enhancement projects. They particularly are interested in better understanding participant tenure and timing of when they are most receptive for educational programs.

ORGANIZATION OF DISSERTATION

The general approach to this dissertation is a compilation of working papers that feature questions and/or insight that is important to a specific audience. Due to the nature of the compilation there will be a minor amount of repetition that may show across chapters. However, when the same data is used in multiple chapters, the analysis and interpretation will be from the different perspectives of the chapters.

Chapter 2 describes the methods, data collection and primary analysis. This chapter establishes the data and information used in subsequent chapters.

Chapter 3 presents a characterization of how salmonid fish habitat enhancement projects are conducted across Washington State. The chapter describes the nature of projects, motives for the habitat elements within projects, design processes used by project teams, the roles of various participants and surrogates, and how design decisions are made.

Chapter 4 focuses attention on engineers involved in the projects. The chapter explores the roles played by engineers, how central engineers are to design teams, whether direct engineering input is supplanted by design guides and other surrogates, and the prevalence of formal design processes.

Chapter 5 establishes that fish habitat projects fit well with Roberts' (1991) description of collaborative processes. Participation and roles are voluntary. Decision making is predominantly by social processes, Design teams have little membership continuity from project to project. Project teams are temporal in that they form to design and execute a project, then disband.

Chapter 6 investigates the influence of problem framing on project objectives and outcomes. Consistency of problem framing across project participants is explored to determine 1) if collaborators share a common technical or outcomes goal, and 2) how alternative framing affects project design.

Chapter 7 provides a critical analysis of the utility of using social network analysis tools when exploring engineering or other technical team decision making activities. Experience in the present study is compared with literature on case study, ethnographic and statistical approaches. Particular attention is paid to any apparent limitations of social network analysis in projects such as included in the present study set.

Chapter 8 provides an integration of insights and conclusions made in the prior chapters. Emergent questions stimulated by the present study are raised and discussed. Relevant topics for future research are suggested along with proposed approaches for their pursuit.

The chapter concludes with a discussion of how the results of the present study contribute to society, policy makers, educators and practitioners in the field.

CHAPTER 2: ANALYSIS OF PROJECT PARTICIPATION AND DESIGN RELATED TO FISH HABITAT PROJECTS

INTRODUCTION

Over the past 100 years we have witnessed dramatic declines in salmonid populations in the Pacific Northwest. Although hatchery influences, dams, and overfishing have also played significant roles, freshwater habitat loss and degradation is acknowledged to have contributed to the decline of virtually every species of Pacific salmon in western North America (National Research Council 1996; Nehlsen, Williams, and Lichatowich 1991). Continued loss of degradation of freshwater spawning and rearing habitat in the Pacific Northwest has serious implications for a $140 million dollar commercial salmon fishery (National Marine Fisheries Service 1990-1992 data).

Twenty-five years of research has documented the connection between forest practices and salmonid habitat loss in the Pacific Northwest (Beschta 1997; Bryant 1983; Roper, Dose, and Williams 1997). Other land uses, such as agriculture, urban, and suburban development have also caused substantial habitat loss in low elevation portions of Pacific Northwest watersheds (Beechie, Beamer, and Wasserman 1994). In response, there has been growing commitment on the part of government agencies, public interest groups, the forestry industry, and commercial and recreational fishing organizations to restore degraded habitat to benefit salmonid populations and the watershed ecosystem as a whole.

Millions of dollars per year are being spent on habitat restoration and improvement projects in streams and rivers across the United States. Extensive research by geologists, aquatic biologists, hydrologists and others is providing important insight into the requirements for habitat restoration projects (Beechie and Sibley 1997; Bisson et al. 1997). City and municipal governments are including habitat projects in their capital budgets to offset the effects of development, road projects or stream channelization (Bitter and Bowers 1993). Developers are often required to create wetlands or habitat features as part of mitigation for environmental impacts (Goldberg 1997).

Efforts at restoration range from expansive programs to restore natural function to an entire watershed to very narrow projects such as attempting to stop erosion at one location within a local stream network. While not always possible, an important first step of restoration is the removal or elimination of activities that are causing degradation (National Research Council 1996).

Governmental regulations provide an important element vehicle for reducing human impacts on fish-bearing streams. One of the most powerful regulations in Washington State is Washington Administrative Code (WAC) section 220-110. This particular code regulates all construction activities below the ordinary high water level of lakes and streams of the state to minimize the loss of habitat due to human induced changes. One element of WAC 220-110 is a requirement that all projects affecting lakes, streams and shorelines must be subjected to a permitting process called the Hydraulic Project Approval (HPA). The HPA permit process is supervised by the Washington State Department of Fish and Wildlife (WDFW).

Other state laws encourage active restoration through establishment of watershed councils, habitat enhancement groups and other non-governmental organizations. Many environmental, neighborhood and special interest volunteer organizations are also actively involved in stream habitat restoration. Counties and cities have active habitat programs to improve the quality of life for their citizens or to mitigate impacts of public works projects. There are tribal and federal programs as well. A preliminary survey of HPA records at the Washington Department of Fish and Wildlife offices in Olympia indicates that over 600 fish habitat projects are conducted in Washington State each year.

Habitat improvement projects are generally accepted to have competing interests of bank protection, flood control, civil structures protection, landowner uses, recreational demands, etc. Thousands of small projects have been executed across the United States in the past decade. At least several hundred small stream projects have been conducted in the state of Washington. Through the collective experience of many projects, one would expect that identification of interest groups, development of communication linkages, and establishment of norms for involvement are showing signs of maturity. One could also expect that social and communication networks involving project designers and stakeholders may be well established in most regions of the state.

STUDY OVERVIEW

The present study is among the first attempts to systematically explore social organization and dynamics of multi-agency design teams working in the natural resources. Of particular interest is how stakeholders and other project participants interact to arrive at design decisions. The current study focuses on participants and design decisions related to fish habitat improvement programs involving smaller streams.

Each design decision is likely to involve technical as well as well as subjective analysis. Both the technical and subjective analyses are likely to be further influenced by beliefs and values held by various project participants and stakeholders associated with any particular project. Stream habitat improvement projects necessarily involve collaborative efforts of landowners, agencies, contractors and various special interest groups. Many of the projects are initiated by agencies or interest groups other than the landowner. When someone other than the landowner initiates a project, the stream corridor landowners are recruited or otherwise brought into the project. In other cases, landowners initiate habitat improvement projects for their own benefit, then bring agencies and other interests into the project to share costs, provide labor or provide political support favorable to gaining project approval by regulatory agencies.

Fish habitat improvement projects typically involve the design and placement of structures within the riparian area and stream channel. Design decisions include:

- specification of materials,
- structure size and shape,
- location and distribution along a stream,
- method of placement,
- method of anchoring, and
- scope of project.

Common habitat materials include concrete, steel, milled wood, automobile bodies, quarry rock, cobbles in gabions, placed logs and placed root wads. The choice of materials is a product of potentially conflicting needs such as cost, aesthetics, fisheries value, availability of materials, regulatory requirements, agency bias and landowner preferences. Participants in the materials decision are likely to include the landowner, design firm, materials supply firms, regulatory agencies, environmental special interest groups, fisheries special interest groups, and installers.

Structure size and shape involves a trade-off of materials cost, placement difficulty, stream channel characteristics, hydrologic regime, and effectiveness for creation of fish habitat. The location and distribution of structures along a stream typically is affected by stream access issues, project budget versus technical optimal habitat creation, balancing of creating new pools versus reinforcing existing pool habitats, desire to modify the stream direction, etc. Method of placement ranges from hand labor to heavy equipment, cranes, logging skylines and helicopters. Tradeoffs include project budget, availability of labor, size of materials, environmental sensitivity and site accessibility. The method of anchoring can include choices to do nothing, drill and epoxy anchors into the streambed, tie cables from the structures to riparian trees, driving piles or structural elements into the stream bank and weighting the structure with large rocks.

In all of the above decisions there is the potential for dominance by value judgments, preferences of central stakeholders, and scientific/cultural norms that support one technical or analytical paradigm over another.

METHODS

The research was retrospective and covered projects conducted within Washington State for which HPA permits were issued in 1997. All field work was conducted within the first six months of 1998 so that project details would still be fresh in the minds of project participants.

The primary research method was a combination of semi-structured telephone interviews, site visits and mailed surveys. Additional detail was collected from HPA permit applications and documentary evidence provided by project participants. Data collection revolved around the following questions:

1. What was the design objective (functional requirement) that you were striving to achieve through ... (specification of material, choosing method of placement, etc.)
2. Who contributed to or influenced the design process and decision?
3. What were the constraints on how you achieved the objective?
4. Where did the constraints come from?
5. What was the range of alternatives you considered?
6. Where did the alternatives come from?
7. What constraints and alternatives were consciously kept off the table?
8. What was the social network that surrounded the design phase of the project?

UNIT OF ANALYSIS

The primary unit of analysis is an individual in-stream project which involves one or more habitat elements. By using projects as the focal point, identification of participants and their social networks *vis-à-vis* the project can be bounded. Data from individual projects can then be merged into larger data sets based on watersheds, geopolitical boundaries, design team attributes, sponsor type, project characteristics or other identifiable attributes. This choice of unit of analysis is also consistent with the principles of social network analysis, where the set of related actors is the unit of analysis rather than individuals (Wasserman and Faust 1994). In the present study, the primary tie that binds actors is common participation in an identifiable habitat project.

SELECTION OF RESEARCH SAMPLE

Projects to include in the research sample were identified through inspection of Hydraulic Project Approval (HPA) files at the Washington State Department of Fish and Wildlife (WDFW) offices in Olympia. HPA permits are filed by waterbody identifier numbers called Watershed Resource Inventory Areas (WRIA) and the year the permit was issued. All permits submitted to WDFW in a calendar year for a particular WRIA are filled in a common folder or series of folders. HPA permits for past years are maintained in off-site storage. In order to reduce recall errors on the part of project participants, only projects which were active during the 1997 calendar year were considered.

WRIA are real number codes for every watershed in Washington State. WRIA begin with a two digit integer that identifies a river system. The integer is followed by a four digit decimal that identifies particular tributaries. For example, WRIA 07.0012 identifies the South Fork of the Stillaguamish River. The main-stem Stillaguamish River is designated WRIA 07.0000.

A goal of the present project was to identify a set of at least 60 projects that represent a cross-section of habitat enhancement activities in state. Since the HPA permits were filed by WRIA number it was practical to choose two-digit identifiers that would ensure geographic representation. In order to reserve unbiased samples for future research, or follow-on research within the present study, WRIA in at least three geographically separate areas of the state were excluded from the study No watersheds were selected on the Olympic Peninsula, the interior of southwest Washington or in eastern Washington north of Interstate 90. Thereafter, integer-level WRIA were chosen across the balance of western and southeastern Washington for inclusion in the study set.

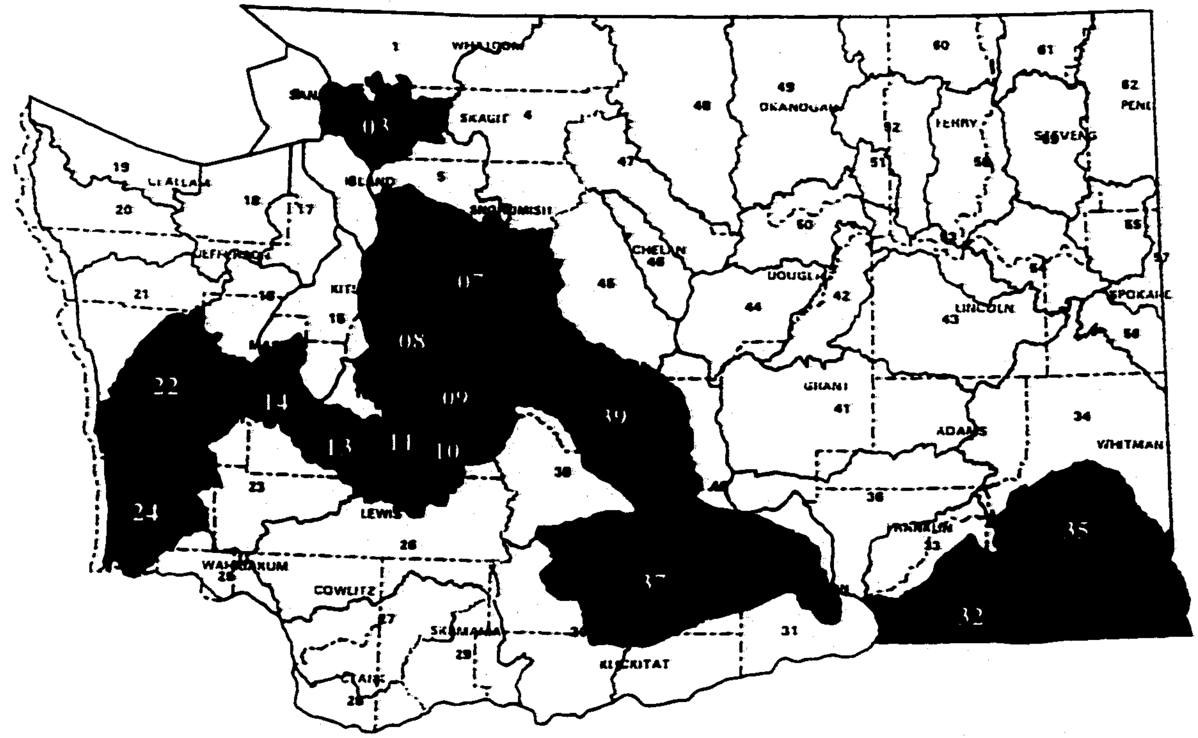

Figure 2-1. Map with shaded areas indicating distribution of Washington State Watershed Resources Inventory Areas (WRIA) included in the research project.

Within each WRIA the goal was to pull at least three projects that included habitat elements and no more than fifteen from any one WRIA. In some WRIA the entire file had to be reviewed to identify three projects. In a few WRIA there were no habitat projects during the 1997 year. In others there were many projects involving habitat features. In those cases the reviewers pulled the first habitat permits they came across in the file.

Two people independently reviewed the permit files. Questions of interpretation of selection criteria or uncertainties about whether or not a particular HPA met the selection criteria were discussed between the reviewers. At the end of each day of file review, the number of HPAs selected from each watershed were tallied and checked against balance of regional representation. Ultimately, sixty-eight HPA permits were selected to include in the candidate project set. Two were removed when it was discovered that they involved lake habitat rather than in-stream habitat. One project was found to have been abandoned prior to any design activity. The remaining data set represents sixty-five in-stream habitat projects.

Criteria used to select HPA permits for inclusion were:

1. Any use of the words "*habitat*" or "*fish*" with the additional words of *wood, rootwad, stump, logs, rock, create, enhance, improve restore or augment*. Ignore words such as *culvert, bridge, riprap, dam, flow control structure*.
2. Objectives that suggest habitat enhancement as a motive for the project even if the key words were not present.

The hope was that at least thirty projects would yield complete data sets to be included in rigorous analysis for the present project. It was expected that some projects would have been issued permits but not executed, some key project participants or sponsors would refuse to participate in the study, and other key participants might not be located.

The HPA files at WDFW headquarters in Olympia contained a complete copy of the HPA application, the issued permit, and often included additional background notes, design documents or letters. Additional information on projects is often maintained at regional WDFW offices. That documentary information was not included in this project's data set. However, it was often cited by Regional Habitat Biologists during their phone interviews.

For each project in the initial set the following information was captured from the WDFW files.

- Applicant contact information
- Other contact information
- Regional WDFW habitat manager
- Applicant relationship to property owner
- Property owner contact information
- Project location
- Waterbody
- Description of materials planned to be used
- Description of purpose
- Specification of methods to be used
- Permitted start date
- Description of structures to be placed
- Project cost

Data collected from the HPA permit file was entered onto paper data sheets and then transferred to a computer database for sorting and analysis.

POTENTIAL SOURCES OF BIAS

Prior to undertaking the present study the researcher conducted a detailed analysis of potential sources of bias in sampling, data collection and analysis.

WRIA choice was not purely random. WRIAs were selected to cover regions of the State. However, WRIA selection was done without regard to the number of habitat projects in any particular WRIA. Although the data set is representative of geography it may not be a true statistical sampling of the number of projects conducted. For that to happen the reviewers would have had to review and classify all 6,000 plus HPAs processed by WDFW in 1997 and then randomly sampled from the approximately ten percent that included habitat features.

Samples were chosen without regard to the agency or landowner which sponsored the project. It might be interesting to ensure that the sample was representative of the number of projects undertaken by each sponsoring agency; however, such analysis would add unnecessary degrees of freedom to the experimental design. It could be possible that different types of sponsors tend to file their permit applications early or late in the year thusly be over represented or underrepresented in the data. Anecdotal discussion with the records manager at WDFW suggests such a bias is not present (Rings 1998).

Since all the projects included in present study were executed in 1997, it is possible that all projects were influenced by some temporal anomaly that either fostered or challenged cooperation and collaboration among designers. During the site visits and informal conversations with project participants the researchers probed to compare the project climate of 1997 with that of 1996 and the early stages of 1998. Projects conducted in 1997 were deemed to be substantially similar to those of 1996 and earlier. Projects being undertaken in 1998 (the year of the interviews) were judged to be somewhat different due to procedural changes within the WDFW that affected HPA permit processing and the political climate surrounding potential Endangered Species Act listing of salmonids in western Washington. However, once a project was fully approved and permits were received, project coordinators perceived that design and installation was typical of prior years.

The completeness of data was variable across projects included in the study. Of the sixty-five projects that were studied, structured phone interviews were conducted with participants of forty-two projects. Additionally, thirty-five projects of those with phone interviews were visited subsequent to the phone interview. Within projects where phone interviews occurred, the number of persons who participated in interviews ranged from one to four. A total of ninety-seven phone interviews were conducted. There is an opportunity for bias from non-respondents. Non-response or refusal to participate in an interview is a form of self-selection bias. However, a majority of those persons contacted did agree to be interviewed and permission was granted for the research team to visit nearly all of the project sites. Self-selection bias and non-participation bias do not appear to impact the richness, depth or breadth of the data collected. Projects that had neither telephone interviews nor site visits have the potential to introduce a bias if those projects had a systematic difference from those that remained in the data set. To evaluate this potential source of bias a number of metrics were evaluated to compare "dropped" and "kept" projects. Comparative metrics for dropped vs. kept projects are drawn from the HPA permit documentary records.

Table 2-1: Applicant types and their inclusion in analysis of participant data.

Applicant	Number w/no participant data	Number with participant data	Number total	% Without participant data
City	6	7	13	46
Consultant	2	0	2	100
County	8	10	18	44
Developer	0	1	1	0
Non-Governmental Organization	0	5	5	0
Federal	0	2	2	0
Private Landowner	6	11	17	35
State	0	3	3	0
Timber Company	0	3	3	0
Tribal	1	0	1	100
Totals	23	42	65	35

For the dominant applicant types, the percentage of projects where participant data was collected is similar to the percentage of projects where no participant data was collected.

Table 2-2: Summary of stated project purpose from the HPA permit versus inclusion in analysis of participant data.

Project Purpose	Number w/no participant data	Number with participant data	Number total	% Without participant data
Bank Protection	10	20	30	33
Bank Repair	1	4	5	20
Bridge Construction	1	1	2	50
Culvert Work	3	2	5	60
Dredging	0	1	1	0
Habitat	6	9	15	40
Mitigation	0	2	2	0
Protect Public Works	0	2	2	0
Restoration	1	0	1	100
Sediment Storage	1	1	2	50
Totals	23	42	65	35

For the dominant project purposes the percentage of projects where participant data was obtained is similar to the percentage of projects where no participant data was collected.

Rater bias is a concern when the words printed on an HPA or spoken in an interview are restated during the process of data capture or analysis. In this study, rater bias was minimized by capturing responses in the words used by the respondent, and then the two raters checking on and discussing any restatement or consolidation made by the other. Restatement was most necessary with regards to project purpose and participant roles. Project purpose was most often stated in the HPA permit and in the interviews as a narrative answer. Affinity processes were used to group responses into similar categories and then assign meaningful labels for each category. Participant roles were rated and categorized using an affinity process that involved two raters.

METHODS OF DATA COLLECTION AND ANALYSIS

Data collected about habitat design projects was to be used more broadly than a straightforward test of the hypotheses. In addition to hypothesis testing, it was hoped that a rich picture could be developed about how habitat projects are designed. The research team had interests in such subjects as 1) how problem framing influenced the design process, 2) the range of methods and materials used in projects, and 3) the utility of social network tools for exploring communication patterns in complex design teams.

TEXTUAL ANALYSIS

Documents in the HPA files for each selected project were reviewed by two raters who followed a standard data collection format. The two raters acted generally independently, except that each sought review by the other for text that was particularly obtuse or otherwise unclear.

Wherever practical, the words captured on the data sheets were verbatim statements from the HPA or supporting documents. Verbatim capture preserves the integrity of raw data, as well as minimizes the risk of rater errors during restatement.

Data was entered into a computerized database (Microsoft Access, Microsoft Corporation) for aggregation and reporting. Database reports were created for methods and materials specified within the permit, participants, distribution of projects by WRIA, and other useful summary information.

SURVEY TECHNIQUES

Telephone interviews and mail surveys were designed according to generally accepted methods (Dillman 1975). A long list of potential questions was developed and then pared or revised to focus on those most likely to yield information relevant to the stated hypotheses and establishing a context for data analysis. The survey strategy was to send an introductory letter to identified project participants followed by a telephone interview. Both the introductory letter and draft interview script were tested with four knowledgeable persons, and revised to address their concerns.

The telephone interview was scripted as a semi-structured interview. Each question was read as scripted. Clarification was offered in response to questions from the research subject, or when it was obvious from a response that the respondent did not understand the question. The surveyor was encouraged to ask follow-on questions that built on responses in order to develop a richer understanding of responses. Follow-on questions and answers were noted on each survey data sheet.

The telephone interview included a series of questions that were arranged in priority order so that a respondent who opted out after just a few minutes would still provide useful data. Because the survey depended on respondent recall of events that occurred six – twelve months prior to the interview, the identification of participants was requested in three different contexts. Research subjects were first asked to identify all participants that were involved in the project and their roles. Following a question about materials and methods used in the project, another question was asked about who participated in design decisions. In addition to identification of a subset of those first identified, this question often elicited additional participants who were not identified earlier. Another question asked who was involve in preparing the HPA permit and the language used on the HPA to describe project purpose, materials to be placed and methods to be used. In a few cases, this question elicited even more participants and designers.

Closing questions asked if the research subject wanted to add anything else to their statement, and whether the respondent desired to participate in a project visit.

PROJECT INSPECTION

More than half of the projects included in the study received a site visit by one or both of the members of the research team. Site visits allowed confirmation of the methods and materials cited during phone interviews or listed on the HPA permit application. Site visits also helped to establish a context for each project. The setting vis-à-vis neighbors, access, public works, channel conditions, geology, etc. contributes to an appreciation of non-verbalized constraints on the design process. Most site visits were hosted by a project participant. In some cases, particularly in Eastern Washington, site visits attracted an entourage of participants from multiple projects within a watershed.

Data collection during site visits included photographs of the project, detailed semi-structured and unstructured discussion about design methods, participant involvement, critical constraints, problem framing, etc. The site visit also offered an opportunity to review the list of identified project participants and their roles with the host, and to solicit clarifications or names and roles of yet-unidentified participants.

During the arrangement of site visits, potential hosts were told that the research team was not going to judge the success or failure of a project, nor was the team planning to comment on the merits of any particular project versus any other project. Such evaluations were outside the scope of the present project, and perceived to be highly subjective at best.

Each host was asked to provide a one-to-four hour tour of the projects in the present study that they were involved in. They were told that they could show the researchers additional projects as well, but it was critical to visit each project on the research set. Most hosts added project stops to the visit list. By the end of the field studies, 35 study projects were inspected and over fifty additional projects were informally visited. The additional projects were documented by location, photographs were taken and field notes were recorded. While not included in the data analysis for the present study, the additional site visits greatly added to the richness of understanding on the part of the researchers.

SOCIAL NETWORK ANALYSIS

Social network analysis (Gartner and Wagner 1996; Knoke 1990; Marsden and Lin 1982; Wasserman and Faust 1994) provides a useful and established method to characterize relationships between core team members and stakeholders. A social network is a set of actors who are linked by membership, communication or other social relationship (Wasserman and Faust 1994). Social network analysis is the systematic evaluation of the linkages between individuals in a social network (Wasserman and Faust 1994).

Stakeholders who have frequent direct communication with members of the core team and project/problem owner would be expected to exert higher levels of influence on design decisions than stakeholders who have indirect communication channels (Ronchetto, Hutt, and Reingen 1989).

A point of departure from conventional social network analysis for our study is that stakeholder surrogates are considered to be part of the social network. Surrogates are likely to include non-participating-stakeholder reputation, regulations, reference materials, and legacy effects of past direct involvement with non-participating stakeholders. Surrogates may have the same or stronger effect on design decisions than direct personal stakeholder connections. Surrogates are expected to drive perceptions and beliefs on the part of core team members and the project owner that form an important basis for judgment of the utility for alternative design parameters (Checkland and Casar 1986; Checkland and Scholes 1990).

Each member of the core design team and the project sponsor (collectively called "research subjects") are asked to list all of the people they are aware of who either participated in, influenced or otherwise contributed to design decisions. Research subjects are also be asked to list key references and other surrogates. A compiled listing is reviewed with each research subject to prompt addition of missing individuals, entities and surrogates. Additionally, an attempt is made to contact all participants with a telephone call and/or mail survey instrument that solicits their identification of communication linkages. In the present study, follow-up mailings intended to complete social network maps had a poor response rate, except in one watershed where over 90% of the follow-up surveys were returned.

The data is summarized in an adjacency matrix (Wasserman and Faust 1994) of the form shown in Table 2-3. All research subjects plus all influencers, participants, stakeholders and surrogates (IPS&S) are listed along both axes of the matrix. Where no acknowledgment of participation existed, a "0" is entered in the corresponding cell. Where acknowledged participation existed between pairs of participants a "1" is entered in the corresponding cell. The diagonal a-a ... n-n represents communication between a participant and itself so a "1" will be entered in the corresponding cell.

Table 2-3. Hypothetical Communication Matrix for Design Team

Actor	a	b	c	d	e	f	g
a	1	1	1	0	0	0	0
b	1	1	1	0	1	0	1
c	1	1	1	0	1	1	1
d	0	0	0	1	1	1	0
e	0	1	1	1	1	1	0
f	0	0	1	1	1	1	1
g	0	1	1	0	0	1	1

In the above hypothetical communication matrix the core design team and sponsor are actors a, b, and c. Stakeholders, influencers and others are represented by actors d, e, f and g. Careful study of the matrix shows that the core team members are well connected with each other. Actor a is not connected to anyone outside the core team. Actor d is indirectly connected to the design team through actors e and f.

An easier-to-follow portrait of the same data would be to draw a sociograph (Wasserman and Faust 1994) of the form shown in Figure 2-2. Each actor is assigned a node and links between nodes represent lines of communication.

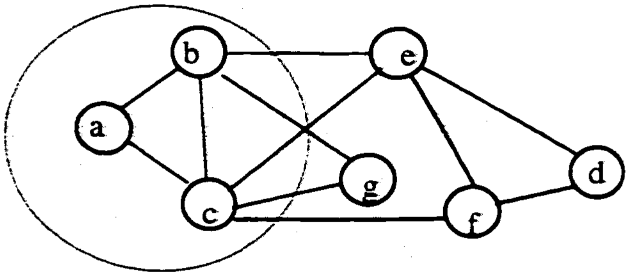

Figure 2-2. Sociograph of the data presented in Table 2-3.

The sociograph makes it more apparent that actor d is not as isolated as might be concluded from the communication matrix. Actors d, e and f form a triad and potential coalition with two lines of communication into the design team.

Social network analysis is readily executed with the assistance of two specialized software packages. UCINET (Borgatti, Everett, and Freeman 1992; Borgatti, Everett, and Freeman 1999) (Analytic Technologies) appears to be the social network analysis tool of choice for determining the centrality of participants in a social network. UCINET has the capability to measure centrality, connectivity and positions of subgroups. The software also has statistical routines to do network hypothesis testing, conduct multivariate analysis and do matrix algebra. UCINET is capable of smallest space analysis (Takane, Young, and de Leeuw 1977) and plotting the results using multidimensional scaling. KrakPlot (Krakhardt et al. 1995) (Analytic Technologies) is a social network visualization program that reads UCINET files to produce corresponding network diagrams. KrakPlot automatically organizes network nodes based on multi-dimensional scaling and simulated annealing techniques.

SNOWBALL SAMPLING

An initial set of project participants could be readily identified from the HPA documents on file at the Washington Department of Fish and Wildlife. Snowball sampling (Biernacki and Waldorf 1981) was then used to identify other participants, surrogates and influencers. Snowball, or referral, sampling goes beyond simple reliance on the limited set of participants identified in HPA documents. Each of the identified participants were asked to identify and provide a phone number or other contact information for others involved in the project under study. The second-level participants were contacted and asked to identify others they worked with on the subject study. For the purposes of the present broad study, no more than two layers of snowball sampling were appropriate. In a deeper study of a few projects, more layers of snowball sampling might uncover yet-undiscovered important communication ties.

Carpenter (1998) found that weak ties are important in policy networks because they provide for information diffusion over long distances and time frames. If we find that habitat project teams are isolated from each other and have weak internal communication networks, further study of weak ties may help explain how information is shared over space and time.

AFFINITY PROCESSES

Affinity processes are widely used in design and other problem solving settings to consolidate long lists of items into logical labeled subsets. Labeled subsets often provide a level of clarity for communication and understanding. The premise of affinity processes is that individuals with different cultures, education and experience often use different words to describe essentially the same thing. Long lists are shuffled, sorted and aggregated under mutually understood heading labels. Heading labels serve to simplify further discussion and analysis of the raw data. Typical label strategies include:

- the root synonym for all items in an aggregation

- terms that all items relate to (e.g., safety, operations, sales, etc.)

The major challenges within affinity processes are 1) developing an common understanding of selected root synonyms, and 2) ensuring that resulting consolidations do not result in major errors of understanding. The following example was developed by the author in 1986 to illustrate problems of affinity processes.

> *Sort the following list of eight items into to subsets based on important characteristics. Carrot, Chicken, Gopher, Pine Tree, Potato, Rose Bush, Steer (Cow), Worm.*

The obvious answer (at least to scientists and engineers) is that four of the items are plants and four are animals. However, in more than ten years of using this exercise to help groups appreciate divergent perspectives, at least six logically defensible sets of labels have been used to sort the above eight items into just two categories. Other commonly used affinity labels include 1) four are associated with foods and four are not foods in Western culture, and 2) four are thought to "live" above ground and four live below ground. Affinity processes are potentially subject to context, cultural, experiential, and other biases.

In the present study, affinity processes are used to consolidate stated project purposes, participant roles, decision processes and agencies into root synonyms. In each data set, the words used by participants and on documents varied widely so as to be of little value for communication of research results. A long list of terms used by participants was developed for each data set of interest. The two raters independently created contextually logical groupings with an objective to reduce the number of different labels to a manageable set relevant. The two raters then compared their results and agreed upon a set to be used for final analysis. They then reviewed every participant response in the context it was provided and assigned it to one of the final affinity labels. For example, project purposes such as *bank protection, bank hardening, slope stabilization, erosion control,* and similar phrases were consolidated under the label "Bank Stabilization" in the final analysis.

DATA COLLECTION

Method Followed to Conduct Interviews on Design Decisions

Participants identified from the HPA permit files were sent a one page introductory letter in the mail. The letter briefly explained the goals of the dissertation and described the motivation for the study. The criteria for participant selection was detailed so the recipient could understand how they were chosen. The letter stated that an interviewer would be calling within a couple of weeks to conduct a phone survey about the project with which each project participant was involved. The letter stated that responses would be kept confidential.

For the phone interviews, a script was followed by the interviewer to introduce herself to the respondent and describe the research project. The introductory script states "we are trying to understand how design decisions are made in fish habitat projects across Washington state." This was the extent of the explanation provided initially. If a respondent asked for more details, they were freely provided. The introductory script stresses the fact that the projects were randomly selected and reaffirmed that answers to the questions would be coded and confidential.

Telephone Survey Responses

Once a respondent agreed to be interviewed, the questions were asked in order. Suggestive language was added to two questions so to lead the respondent in the direction we wanted: (1) Who else was involved in the project - planning, writing, implementation; and (2) What reference materials influenced the design - WAC codes, design manuals, standard drawings, etc?

Questions about how the decisions were made were sometimes misunderstood and answered with a listing of persons "who made the decisions." The interviewer attempted to elicit a response that provided information on what methods and scientific criteria were behind a given decision, but she did not pursue this very aggressively. In some cases, the interviewer sensed the respondent either did not know what the criteria had been or was trying to hide the fact that no clear criteria had been used.

Interview Length

The average time of interview (from phone logs) was 17 minutes. In most cases, a conscious effort was made to keep the interview length at a minimum. However, when a respondent was inclined to describe at-length details related to his or her project, he or she was encouraged to do so, and as many notes as possible were recorded.

Following Leads (Snowball Sampling)

The interviewer first tried to contact the applicant listed on the permit. From this initial contact she was generally able to get at least one or two names to call next. In several cases, the Area Habitat Biologists' responses provided the first lead to other key participants. The interviewer focused follow-up calls on participants who had been named as contributing to design aspects of the project.

Dropping Projects

Projects were dropped from the telephone survey list if repeated attempts to contact participants were unsuccessful. Projects were also dropped in a few cases because contacts refused to participate. Although about 20 projects were ultimately dropped from telephone surveys, the data from HPA files and site visits was retained and pooled with similar data from other projects.

Exceptions to Telephone Surveys

Washington Department of Fish and Wildlife Area Habitat Biologists (AHBs) who were involved in more than two projects were sent survey forms in the mail. These responses probably differ slightly from what they would have been had the interview been conducted over the phone. Typically, the written responses from AHBs were brief, with many similarities between different projects. Only two of the eight AHBs that were sent surveys neglected to return the forms. Of these two, one offered a summary statement on the phone of how he handles projects in general and the other agreed to be interviewed over the phone.

Not all respondents were asked the following questions:

1. Is there any other information that may be useful to our research?
2. Would you be interested in visiting the project site with us?
3. Do you have any questions for me?
4. Would you like a copy of our results and published papers that come from this project?

These questions were omitted in some cases if the respondent seemed pressed for time or did not seem very interested in the research.

DATA

Throughout data collection and preliminary analysis, identification of projects, watersheds, agencies and participants was maintained. Maintenance of identification was necessary to allow re-evaluation of photographic records and facilitate follow-up with participants in subsequent surveys and contacts to clarify information. Prior to final analysis all data was coded such that individual watersheds, projects and participants became anonymous. Watersheds were assigned a letter code (a, b, c...) based on random letters generated in an Excel (Microsoft Corporation) spreadsheet. The four Eastern Washington watersheds are designated *d, t, w* and *z*. Western Washington watersheds received designations *a, b, c, k, m, p, r,* and *s*. Individual agency identification was lost through aggregation during the affinity process. Hence, the data presented here is coded. All original records and uncoded computer files are maintained in secure storage by the researcher.

HPA Document Review

Data was collected from HPA permit files at the Washington Department of Fish and Wildlife offices in Olympia. Access to WDFW files was obtained via a "Request for

Public Record" that was accepted by the WDFW on June 19, 1997. All documents were inspected in the files for each of the 65 projects included in the present study. Documents typically included the Hydraulic Projects Approval form and a sketch or drawing of the project. Description of a project varied from a pencil sketch on the reverse side of the HPA form, to multi-page large format blue-line prints from engineering firms. In some cases the documents included completed Joint Aquatic Resource Permits Application (JARPA) forms, correspondence and other documents.

All Hydraulic Project Approval permits identify the applicant and provide contact information, including the name and phone number of a person. The applicant may be anyone, not necessarily the lead agency, landowner or other key participant. The applicant is, however, the entity that the WDFW considers to be in responsible charge of the project. Table 2-4 is a compilation of the applicant types that are represented across the 65 projects included in the present study. Applicant types are artificial classifications developed by the research team to allow differences between applicant types to be visible. In most cases the classification was evident from the entity listed as applicant on the HPA. In the remainder of the cases there were no affiliations listed for the applicant, so the applicant affiliation was determined during subsequent phone interviews with the applicant.

Table 2-4. Distribution of Projects by HPA Applicant Type (n = 65)

Applicant	Frequency	Percentage
City	13	20
Consultant	2	3
County	18	28
Developer	1	2
Non-Governmental Organization	5	8
Federal	2	3
Private Landowner	17	26
State	3	5
Timber Company	3	5
Tribal	1	2

City applicants included public works departments, school districts, and parks departments, among others. Consultants included environmental and engineering firms. County applicants included public works departments, parks districts, natural resources divisions among others. Developers were private developers of residential or commercial property. Non-governmental organizations included regional fisheries habitat enhancement groups, conservation districts and resource conservation and development groups. Federal agencies included natural resource agencies such as the Natural Resources Conservation Service, the U.S. Army Corps of Engineers and others. Private landowners include individual landowners and non-industrial private businesses. State agencies included transportation, fish and wildlife, parks and other agencies. Timber companies include major timber landowners of projects that were within working forests. Tribal applicants were Native American Tribes.

The second key piece of data on the HPA form is a detailed description of the location of the project, including waterbody, WRIA and street address or Range/Township/Section.

The location description allowed the research team to plot each project on a map to efficiently arrange site visits. The number of projects studied by coded two-digit WRIA is shown in Table 2-5. More detailed listing of projects is not done to protect the confidentiality of associated subsequent survey and interview data.

Table 2-5. Number of Projects by Watershed

WRIA	Number of Projects Included in Study	Percentage
Western Washington		78
a	2	3
b	4	6
c	3	5
e	1	2
k	1	2
m	7	11
n	3	5
p	10	15
r	16	25
s	4	6
Eastern Washington		22
d	1	2
t	2	3
w	6	9
z	5	8

The responsible Area Habitat Biologist (AHB) from the WDFW regional office was listed on each HPA permit along with a contact phone number. Project owners are required to contact the AHB prior to any site work. The AHB has primary responsibility for negotiating terms of the HPA and for enforcing WDFW regulations during the subsequent field work by an applicant.

The HPA form requests a textual project description, including purpose. In most cases the description was cryptic at best. The two raters who were reviewing HPA files were instructed to look for key words that suggest a project purpose if none was listed. Table 2-6 shows the distribution of project purposes as stated on or gleaned from the HPA application files. The listing shown in Table 2-6 has received one level of consolidation via an affinity process. In later analysis, it is subjected to further consolidation to be consistent with categorization of project purposes stated by project participants.

Table 2-6. Distribution of Projects by Purpose from HPA Application Files (n = 65)

Project Purpose	Frequency	Percentage
Bank Protection	30	46
Bank Repair	5	8
Bridge Construction	2	3
Culvert Work	5	8
Dredging	1	2
Habitat	15	23
Mitigation	1	2
Protect Public Works	2	3
Restoration	1	2
Sediment Storage	2	3

Bank protection includes activities that are intended to prevent bank erosion and channel meander. Bank repair typically involves bank reshaping or repair of previously placed hardening materials to fix storm damage. Bridge construction involves the placement of a new bridge as a stream crossing. Culvert work includes new culvert placement or significant culvert cleanout excavation. Dredging is the removal of gravel from a stream channel. Habitat is the construction of hydraulic works or placement of materials for the purpose of creating fish habitat. Mitigation is the construction of habitat to offset human-caused damage to the environment. Protect public works means to place structures in the channel to route hydraulic flows away from bridges, road embankments and other public works. Restoration means projects that are meant to return instream habitat to some previous condition. Sediment storage projects are those which change channel shape or hydraulics with the intention to trap additional sediment within a project area, or delay routing of sediment further downstream.

Interview, Survey and Site Visit Data

Data from interviews, mailed surveys and site visits was merged as it was collected in order to provide a rich picture of each study project and its participants. In general, additional data was pursued until either the research team achieved a high comfort level that a reasonably complete picture was in-hand or that continued pursuit of incomplete data was futile.

Interviewees were asked to state their view of the project's objective or purpose. In many cases, both a primary and secondary objective were provided. In such cases both were recorded in the order presented. As additional interviews were conducted relevant to a particular project, a fairly clear sense of the primary and secondary purposes relevant for design decisions emerged, even when their was disagreement among participants as to the overall project purpose. In 21 of the projects there was clear consensus of a single project purpose, and no indication of a secondary objective. In Table 2-7, data from the HPA inspection and interviews are brought together to show the distribution of project purpose as gleaned from the HPA files along with the distribution of the primary and secondary purposes as stated by participants. To provide completeness, a combined column of data provides a distribution of percentage of projects where the indicated purpose was stated in participant interviews as factor that affected design decisions, regardless of whether the purpose was primary or secondary.

Table 2-7. Distribution of Project Purpose by HPA and Participant Interviews.

	Percentage of Projects			
Data Source	HPA Permit	Participant Interviews		
Purpose of Project	Stated Purpose	Primary Purpose	Secondary Purpose	Factor in Design Decisions
Conveyance	0	2	0	1
Develop Public & Private Works	11	6	3	7
Education	0	0	2	1
Fish Passage	0	3	0	2
Flood Control	0	2	0	1
Habitat	23	15	23	31
Mitigation	2	3	3	5
Modify Channel	2	3	0	2
Protect Private Property	0	8	2	6
Protect Public Works	0	8	0	5
Repair / Maintain	8	11	0	6
Stabilize Bank	46	17	11	20
Unknown	9	23	25	14
None	-	-	32	-

The *conveyance* category includes projects intended to speed the flow of flood waters through the project area. *Develop public and private works* combines activities by public agencies, developers and private land owners who are doing instream work incidental to other construction projects. *Education* objectives included public education about natural resources, stream processes and the like. *Fish passage* projects attempted to remove barriers to migration for salmonids. *Flood control* projects include protection of nearby property by dikes or preventing channel meander. *Habitat projects* generally involve the construction of hydraulic works or placement of materials for the purpose of creating fish habitat. *Mitigation* is the construction of habitat to offset human-caused damage to the environment. *Protect public works* objectives are indicative of projects meant to protect roads and bridges, well sites or other public infrastructure. *Repair/maintain* includes projects to repair storm damage to previously installed projects or to conduct routing maintenance to such projects. The *stabilize bank* category was assigned to projects meant to prevent bank erosion, sediment delivery, etc. Projects were assigned to the "unknown" category when it was impossible to discern one or more project objectives. The "none" category is used only for projects were participants did not identify a secondary objective.

Among participants who were interviewed there was the following distribution of agreement as to the primary objective for the project. The participants may have used different words, but generally agreed on the primary objective for 25 of the 32 projects for which multiple interviews occurred. Participant descriptions of project objectives diverged substantially for the remaining seven projects.

The data also allowed a project-by-project comparison of how well the participant's description of project objectives matched those stated on the HPA documents. A total of 47 projects could be compared. For 37 of the projects, the descriptions of objectives generally agreed and for ten of the projects the descriptions were divergent.

Each interviewee was asked whether a formal or documented design process was followed. Of the 97 persons interviewed, no one acknowledged that any kind of formal or structured process was followed during the design of a project under consideration.

Interviewees were also asked to describe the social processes used to arrive at a final design for each project under consideration. Sufficient data to make a determination was collected for 46 projects. Interviewee statements were assessed against common decision processes and a tally was created. Table 2-8 shows the frequency of use for different decision-making methods.

Table 2-8. Distribution of Design Decision-Making Methods

Decision Method	All Projects (N=50)		WIRA R (N=14)		WIRA Z (N=4)	
Collaborative	**# of Projects**	**% of Projects**	**#of Projects**	**% of Projects**	**# of Projects**	**% of Projects**
Negotiation	29	58	8	57	4	100
Consensus	1	2	0	0	0	0
Collaboration	8	16	2	14	0	0
Goal Driven	1	2	1	7	0	0
Noncollaborative	sum = 39	% = 78	sum = 11	% = 79	sum = 4	% = 100
Experience	7	14	2	14	0	0
Deference	1	2	0	0	0	0
Consultants	3	6	1	7	0	0
	sum = 11	% = 22	sum = 2	% = 21	sum = 0	% = 0

The table is organized so that collaborative, or inclusive processes are grouped in one section and non-collaborative processes are grouped below. *Collaborative* processes mean that participants work together with mutual respect and mutual learning, and includes deference to those with more expertise in particular aspects of the project design. *Consensus* processes are those where participants work toward decisions that can be agreed to, if not supported by all participants. *Consultative* processes are generally those where the project leaders seek input from other participants, but are free to make decisions. *Delegated* processes are where subsets of the participants assign some or all decisions to other parties. *Experience* processes are those where a decision-maker makes a design decision based on personal experience and does not seek input from others. *Goal driven* was described by participants in the one project where it was cited as meaning that all alternative decisions were tested against the project goals and the alternative perceived to best achieve a goal was chosen.

Interviewees were asked to list the reference materials that influenced the design of the projects they were associated with. Reference materials generally stand as surrogates for experts or stakeholders who are not physically participating in a project. The materials that were cited by more than one participant are listed in Table 2-9.

Table 2-9. Reference Materials that Influenced Project Design (Design Surrogates)

Surrogate	Frequency
Washington Administrative Code Section 220-110	22
King County Bank Stabilization Manual	11
Natural Resource Conservation Service Bioengineering Standards	7
Washington Department of Fish and Wildlife Habitat Enhancement Manual	5
Rosgen's Stream Classification Guide	4
Watershed Management Plan (for the watershed under consideration)	2
U.S. Army Corps of Engineers Manual	2

The Washington Administrative Code Section 220-110, better known as "WAC 220-110," is the state law that regulates construction activities within the ordinary high water line of rivers and lakes of the state. The Watershed Management Plan for the watershed under consideration is typically a policy document that was developed through public and agency processes that is intended to guide development, restoration and enhancement activities within a watershed. The Natural Resource Conservation Service Bioengineering Standards is a collection of issued and draft design drawings and guidelines published by the Natural Resource Conservation Service within the U.S. Department of Agriculture. Many of the standard cited by participants are from the NRCS Engineering Field Handbook (NRCS 1996); however, some were acknowledged to be *de facto* standards from the local NRCS offices. The "King County Bank Stabilization Manual" is actually the Guidelines for Bank Stabilization Projects in the Riverine Environments of King County (Johnson and Stypula 1993). The guidelines were cited by participants from watersheds across the state, not just in central Puget Sound. As with the NRCS bioengineering standards, the "US Army Corps of Engineers standards" cited by project participants also appeared to be an aggregation of various documents. However, it appears that the Fisheries Handbook of Engineering Requirements and Biological Criteria (Bell 1986) was at the root of most citations. Many project participants from rural portions of the state had attended one of Charles Rosgen's workshops and were influenced by his published works, most often Applied River Morphology (Rosgen 1996), which includes a chapter on habitat restoration. Although five interviewees cited the "Washington Department of Fish and Wildlife Habitat Enhancement Manual" or some derivative of that title, no such document exists (R. Barnard, per. comm.). The WDFW does publish a series of pamphlets, e.g., (Washington Department of Fish and Wildlife 1995).

Participant Data

During the course of 97 telephone interviews and follow-up mail surveys, a total of 250 participants were identified as having participated in the 65 projects under study. Each participant was assigned a three digit identifier. The identifier was linked to the type of organization (agency) they represented, project role(s), and projects they were associated with. During the assignment of participant identifiers, no distinction was made between participants who were natural persons, documentary surrogates or anonymous persons associated with a participating entity or agency.

For purposes of social network analysis, several types of data were collected.

1. Participant by participant data connects all of the persons who were interviewed to other identified participants. Participant by participant data allows exploration of the centrality of individuals within and across projects. The data also allows determination of communication path lengths from central participants to more distant participants.

2. Participant by project data allows exploration of the centrality of individuals and surrogates within and across projects and watersheds. The data also allows determination of how well connected or isolated project teams are across the state.

3. Participant by influencer data allows exploration of the centrality of influencers within and across projects and watersheds.

4. Agency by project data allows exploration of the centrality of agencies within and across projects and watersheds.

5. Role by project data allows exploration of the centrality of various participant roles within and across projects and watersheds.

Known Limitations to Data

The data included in the present study represents a small fraction of all the habitat related design projects in Washington State. The data does not include representation from the northeast and interior southwest portions of the state. It is possible that projects in under-represented areas have different decision making and social processes.

Fisheries habitat projects are conducted in most other states of the United States and throughout Canada and other parts of the world. No attempt was made to document design and decision methods used outside the state of Washington.

Although the present data set is quite extensive, completeness of records is highly variable. Participation rates in surveys and interviews varied from almost none to almost unity. The problem of missing data confounds traditional statistical analysis.

Identification of participants, surrogates, and decision making methods depended on recall on the part of interviewees and survey participants. Although the experimental focus was on recent projects, recall errors could affect the data through errors of addition or omission.

DISCUSSION OF DATA

Project Design

The technical design of projects can best be explored by fitting data into the Axiomatic Design methods (Suh 1990) as further developed into Appreciative Design (Dooley and Fridley 1996). Candidate functional requirements are readily discerned from objectives stated on the HPA permit or synthesized from participant interviews. Suh's *independence axiom* can be applied when multiple functional objectives are stated for a project. How habitat entered a project is telling about whether habitat creation is an element of functional requirements or is a constraint on methods allowable for achieving non-habitat objectives. Consideration of the context of each project allows allocation of stated objectives to the functional requirements and constraints columns of the design matrix.

Design parameters appear to be related to whether or not habitat is a functional requirement or a constraint. When habitat is a functional requirement then the amount of wood, rock or other habitat features in a project appear to be driven by the "more is better" maximization function. When habitat is in a project as mitigation or a constraint on unrelated in-stream construction then a minimization function appears to be at play. Since the actual number of habitat elements was not numerated during site visits, and no as-built documentation was uncovered for any project included in the study, The observation of a maximization / minimization function is based on observation and anecdotal comments of participants.

Project Decision Making

The data allows exploration of how the framing of habitat as enhancement versus mitigation affects how decisions are made by design teams. Table 2-10 extracts the data on decision making methods according to how habitat entered projects. Of the 65 projects studied, sufficient data was collected on 58 projects to include them in the data set.

Table 2-10. Decision Making Methods vs. How Habitat Entered Projects

Decision Method	Frequency				Percentage		
	Enhancement	Mitigation	Unknown	Total	Enhancement	Mitigation	Unknown
Collaboration	1	5	0	6	17	83	0
Consensus	0	1	0	1	0	100	0
Consultative	0	1	0	1	0	100	0
Delegated	2	0	0	2	100	0	0
Experience	5	2	1	8	63	25	13
Goal Driven	1	0	0	1	100	0	0
Negotiation	6	21	0	27	22	78	0
NA	1	2	1	4	25	50	25
Unknown	1	9	5	15	7	60	33
Total	17	41	7	65	26	63	11

Habitat entered 26 percent of the projects as an enhancement activity and 63 percent of the projects as mitigation for other activities. Where sufficient data exists to make observations, the only anomaly as to how decisions are made is that *designer experience* accounts for a disproportionate fraction of the methods used when habitat is enhancement driven. All other decision making methods appear to be independent of whether habitat is framed as enhancement or mitigation.

Of the decision making methods, negotiation was the method used for more than half of the projects where a method was identified. Collaboration and deference to experience accounted for most of the rest of the methods used. Collaboration and negotiation are generally accepted to be highly social activities, requiring strong social skills among participants for the methods to be effective. The two asocial decision making methods (delegation and deference to experience) were the dominant methods used in 22 percent of the projects where a method was identified.

CONCLUSIONS AND CARRY-FORWARD MESSAGES

- Habitat entered 26 percent of the projects as an enhancement activity and 63 percent of the projects as mitigation for other activities. There were no obvious differences in project teams and design due to how habitat entered the project objectives.

- Social techniques, principally negotiation and collaboration are the decision making methods used in 72 percent of the projects where a determination could be made. Non-collaborative methods, including deference to experience and delegation, were used in 22 percent of the projects where a determination could be made.

- Surrogates were present in 67 percent (33/49) of the projects where participant data was collected. Surrogates primarily influenced design decisions and had no role in setting objectives.

- The average number of participants in projects was 7.0. For eastern Washington the average was 7.4 and for western Washington the average was 6.8. There are no significant differences between the number of participants or number of organizations involved in projects across the state.

- Engineering roles, including engineer/project manager, engineering design, engineer and engineering technical specialist were present in 23 of the 58 projects for which a determination could be made. Engineering is a minor component of both participant networks and project activities. Intentional design is obvious across projects, yet there is little engineering activity or perceived value from engineer participation.

- Regulator roles are central to almost all projects included in the study. Of the surrogates, the Washington Administrative Code 220-110 regulatory document was the most commonly cited surrogate.

Hopefully, the resulting characterizations of similarities and differences will stimulate future research into 1) how stakeholders are involved in other design problem types; 2) other employer types; other geographical regions; and other natural resource industries such as agriculture.

CHAPTER 3: DESIGN OF SALMONID HABITAT ENHANCEMENT PROJECTS IN STREAMS AND RIVERS OF WASHINGTON STATE

Over the past 100 years we have witnessed dramatic declines in salmonid populations in the Pacific Northwest. Although hatchery influences, dams, and overfishing have also played significant roles, freshwater habitat loss and degradation is acknowledged to have contributed to the decline of virtually every species of Pacific salmon in western North America (National Research Council 1996; Nehlsen, Williams, and Lichatowich 1991). Continued loss of degradation of freshwater spawning and rearing habitat in the Pacific Northwest has serious implications for a $140 million dollar commercial salmon fishery (National Marine Fisheries Service 1990-1992 data).

Twenty-five years of research has documented the connection between forest practices and salmonid habitat loss in the Pacific Northwest (Beschta 1997; Bryant 1983; Roper, Dose, and Williams 1997). Other land uses, such as agriculture, urban, and suburban development have also caused substantial habitat loss in low elevation portions of Pacific Northwest watersheds (Beechie, Beamer, and Wasserman 1994). In response, there has been growing commitment on the part of government agencies, public interest groups, the forestry industry, and commercial and recreational fishing organizations to protect remaining aquatic habitat, and restore degraded habitat in order to benefit salmonid populations and watershed ecosystems as a whole.

Millions of dollars per year are being spent on habitat restoration and improvement projects in streams and rivers across the United States. Extensive research by geologists, aquatic biologists, hydrologists and others is providing important insight into the requirements for habitat restoration projects (Beechie and Sibley 1997; Bisson et al. 1997). Efforts at habitat restoration range from trying to restore natural function to an entire watershed to attempting to stop erosion at one location within many kilometers of the stream network. While not always possible, an important first step of restoration is the removal or elimination of activities that are causing degradation (National Research Council 1996). City and municipal governments are including habitat projects in their capital budgets to offset the effects of development, road projects or stream channelization (Bitter and Bowers 1993). Developers are often required to create wetlands or habitat features as part of mitigation for environmental impacts (Goldberg 1997).

NATURE OF HABITAT-AS- ENHANCEMENT PROJECTS

There are three distinct stages of doing habitat protection, enhancement or mitigation. Policy-level activities are ongoing in most watersheds of the state through Watershed Councils, neighborhood special interest groups and regional planning agencies. Policy activities tend to focus on macro-issues of watershed priority habitats, relative ranking of potential enhancement efforts within or across watersheds, and generally guiding whether to spend resources on one basin or another.

The second stage is related to project selection and macro design. This level is often tasked to local fisheries enhancement groups, conservation districts, neighborhood coalitions and the like. Program coordinators seek willing landowners to allow fisheries enhancement activities to occur on stretches of fish-bearing water that flow through the landowner's private property. Landowners typically must sign a binding agreement that involves 1) allowing access across their property to do enhancement construction, 2) providing some cost sharing in the form of cash or in-kind services, and 3) accepting responsibility for project maintenance for a multi-year period of time. Frequently, landowner agreements also require that a riparian buffer be created within which the landowner gives up the right to make economic use of the buffer strip. It is not surprising that many landowners offset their contribution by insisting that property protection or other personally motivated goals be added to an enhancement project on their land.

The third stage of project development is the actual design and construction of individual projects. Once a decision is made to proceed with a habitat enhancement project, and the general scope is defined, then design and construction can proceed. Design involves creating a project plan that achieves objectives set by various sponsors while satisfying constraints placed by regulators and other stakeholders.

When a project is cast in the frame of habitat enhancement, the project is given special treatment in the permitting and regulatory review process. Exemption from most regulations provides designers with a nearly constraint-free design space. The low level of administrative and regulatory scrutiny is reflected in the observation that design outcomes are very much a product of the ideas and needs of those persons who are active on the design team.

The Revised Code of Washington, Section 75.20.350, (RCW) provides the legislative authority for streamlined permit review and approval of "fish habitat enhancement projects." The RCW specifically defines three types of projects as being primarily fish habitat enhancement:

1. "elimination of human-made fish passage barriers, including culvert repair and replacement;
2. restoration of an eroded or unstable stream bank employing the principle of bioengineering, including limited use of rock as a stabilization only at the toe of the bank…; or
3. placement of woody debris or other instream structures that benefit naturally reproducing fish stocks."

Sponsors of fish habitat enhancement projects may request Hydraulic Project Approval from the Washington Department of Fish and Wildlife, and must meet Hydraulic Code Rules set by the Department of Fish and Wildlife (WAC Chapter 220-110). A copy of the application for approval is provided to the local county development agency, and is subject to a fifteen day comment period. However, paragraph (4) of the RCW specifically prohibits local government entities from requiring permits or charging fees for fish habitat enhancement projects that otherwise meet the provisions of the state code.

Anecdotal evidence suggests that local agencies place low priority on review and comment for such applications since such review is unfunded.

In 1998, the Washington State Legislature reaffirmed the streamlined permit process with three primary justifications:

1. "habitat enhancement projects play a key role in the state's salmon and steelhead recovery efforts;"
2. projects should be done in a cost-effective manner, which includes "minimizing the expense and delays of various permitting processes;"
3. streamlined processes "improve the speed with which fish habitat enhancement projects are put into place."

The broad exemption from regulatory constraints and scrutiny granted by RCW 75.20.350 leaves the area habitat biologists from WDFW with primary responsibility for governmental oversight of habitat enhancement projects. The area habitat biologists are guided by the Hydraulic Code Rules which are included in the Washington Administrative code at Chapter 220-110.

The foregoing is not to say that projects are free of all constraints other than those of the Hydraulic Code. Project designs are constrained by needs of the sponsoring organization, funding agency guidelines, landowner-imposed constraints, and more practical constraints related to site conditions and materials availability. Such constraints are internal to the project and its direct participants rather than societal or governmental constraints.

NATURE OF HABITAT-AS-MITIGATION PROJECTS

Fisheries habitat projects also begin through a regulatory process rather than a policy process. The citizens of the State , through their elected legislators, enacted a body of law intended to stop the loss of aquatic habitat in the state (1998). All construction activities within stream channels or within the ordinary high water line of waterbodies must go through a permitting process that includes, among other jurisdictional requirements, application to the Washington Department of Fish and Wildlife for a Hydraulics Project Approval, better known as an HPA permit. For habitat-as-enhancement projects the HPA regulatory review often focuses on ensuring that projects do not cause unintended net loss of habitat during enhancement activities. For habitat-as-mitigation projects, the HPA regulatory review seeks to ensure that habitat is protected where possible, and new habitat is created sufficient to offset losses that result from construction activities that are the primary objective of an applicant.

One might expect that enhancement versus mitigation habitat projects would follow different decision making processes and have different design characteristics. A famous University of Washington design professor would likely assert that habitat-as-enhancement projects are "Ah Ha!" projects since they tend to be self-motivated; whereas, habitat-as-mitigation projects are "Hey You!" projects since they are only undertaken upon the demands of a regulatory agency. It is the "doing habitat" operational stage of projects that is of interest to the present study.

In this paper the author explores how habitat enhancement and mitigation projects are conducted in Washington State. The study is based on retrospective data from a cross-section of projects that were active in 1997.

HABITAT IMPROVEMENT

Efforts to improve stream habitat date from the early 1900's (Hubbs, Greeley, and Tarzwell 1932; White 1996). The most common methods to improve or manage in-stream habitat and/or hydrology include current deflectors, low-head dams, weirs, planted vegetation and boulder placement (Gore and Hamilton 1996). Over seventy design handbooks, manuals and guides have been identified by the author (Dooley 1999). A number of the available guides to habitat restoration and/or enhancement appear to be appropriate for use in rivers and streams of the Pacific Northwest (American Fisheries

Society Western Division 1982; Flosi et al. 1998; Slaney and Zaldokas 1997 and many others).

DESIGN AS A SOCIAL PROCESS

In spite of its long history of creating artifacts to meet society's needs, engineering design is believed by most people to be free of societal influence (Morrison 1986) and "outside the checks and balances of social order" (Vincenti 1991). There appears to be a general lack of awareness and appreciation that influences external to the firm and design team frequently dominate design decisions. However, since the early 1980's we have watched a major shift in the practices of engineering employers to place the burden of addressing non-technical design issues squarely back onto the designer. Designers are now challenged to directly participate in a broader social system more than at any time in the past four decades.

The social construction view of technological systems holds that all technological artifacts "bear the imprint" of the social context surrounding their development (Pfaffenberger 1990) (Hughes 1991). A few years after the construction of an technical work there is little public recollection of the social context that stimulated or constrained its design. Yet, stylistic elements of the design, choice of materials and technical arrangements can often be traced by researchers to their temporal social context.

The present study is among the first attempts to systematically explore social organization and dynamics of design teams that are comprised of persons from many different organizations and professional interests. Such design teams are increasingly common in industry where regulators, vendors, outside fabricators, customers and others are all included in, and often numerically dominate, product design teams. In the natural resource industries, complex design teams are becoming the norm. In our project we set out to explore the social network surrounding the design of technical components of select design projects, and how the participants in the social network influenced the specification of design parameters.

METHODS

An ongoing empirical study is exploring how stakeholders influence decision-making by design teams in the natural resources. The current study focuses on design decisions related to fish habitat improvement projects involving small streams. Fish habitat improvement projects typically involve the design and placement of structures within the riparian area and stream channel. Design decisions include specification of material, specification of structure size and shape, location and distribution of structures along the stream, method of placement, and method of anchoring. Each of these design decisions is likely to involve technical as well as subjective analysis. Both the technical and subjective analyses are likely to be further influenced by beliefs and values held by various stakeholders associated with a particular project.

The research is retrospective and covers Washington state projects which were issued permits by the regulatory agencies during 1997. The primary research method was a combination of semi-structured interviews, surveys and direct project inspection. Additional detail was collected from permit applications and documentary evidence provided by project sponsors. Data collection revolved around the following questions:

What was the design objective (functional requirement) that project sponsors were striving to achieve through ... (specification of material, choosing method of placement, etc.)

- Who contributed to or influenced the design process and decision?
- What were the constraints on how you achieved the objective?
- Where did the constraints come from?
- What was the range of alternatives that were considered?
- Where did the alternatives come from?
- What constraints and alternatives were consciously kept off the table?
- What was the social network that surrounded the design phase of the project?

The study sample was drawn from project sponsors who recently received Washington State Department of Fish and Wildlife Hydraulic Project Approval (HPA) permits for small stream habitat improvement projects. Researchers were looking for systematic evidence that core team members had processes to identify stakeholders and consciously factor stakeholder input into their design decisions.

DESIGN OF FISH HABITAT IMPROVEMENT PROJECTS

Stream habitat improvement projects necessarily involve collaborative efforts of landowners, agencies, contractors and various special interest groups. Many of the projects are initiated by agencies or interest groups other than the landowner. When someone other than the landowner initiates a project, the stream corridor landowners are recruited or otherwise brought into the project. In other cases landowners initiate habitat improvement projects for their own benefit, then bring agencies and other interests into the project to share costs, provide labor or provide political support favorable to gaining project approval by regulatory agencies.

Habitat improvement projects are generally accepted as having competing interests of bank protection, flood control, civil structures protection, landowner uses, recreational demands, etc. Thousands of small projects have been executed across the United States in the past decade. At least several hundred small stream projects have been conducted in the state of Washington. Through the collective experience of many projects, one would expect that identification of interest groups, development of communication linkages, and establishment of norms for involvement are showing signs of maturity. Affiliation and communication networks involving project designers and stakeholders should be well established in some regions of the state.

Small streams are defined for our purposes as streams having normal summer flows of less than 100 cfs. or channel width less than ten meters. Common habitat materials include concrete, steel, milled wood, automobile bodies, quarry rock, cobbles in gabions, placed logs and placed root wads. The choice of materials is a product of potentially conflicting needs such as cost, aesthetics, fisheries value, availability of materials, regulatory requirements and landowner preferences. Participants in the materials decision are likely to include the landowner, design firm, materials supply firms, regulatory agencies, environmental special interest groups, fisheries special interest groups, and installers.

Structure size and shape involves a trade-off of materials cost, placement difficulty, stream channel characteristics, hydrologic regime, and effectiveness for creation of fish habitat. The location and distribution of structures along a stream typically is affected by stream access issues, project budget versus technical optimal habitat creation, balancing of creating new pools versus reinforcing existing pool habitats, desire to modify the stream direction, etc. Method of placement ranges from hand labor to heavy equipment, cranes, logging skylines and helicopters. Tradeoffs include project budget, availability of labor, size of materials, environmental sensitivity and site accessibility. The method of anchoring can include choices to do nothing, drill and epoxy anchors into the streambed, tie cables from the structures to riparian trees, driving piles or structural elements into the stream bank and weighting the structure with large rocks.

In all of the above decisions there is the potential for dominance by value judgments, preferences of central stakeholders, and scientific/cultural norms that support one technical or analytical paradigm over another. We are attempting to identify the source of influence on design decisions during the course of the study.

Observations are being compared and contrasted across projects within a sponsor type and between sponsor types. We expect to find wide variation in stakeholder involvement practices within and between sponsor types. We will be able to describe and draw conclusions about how a limited number of designers and design teams practice stakeholder involvement. Exploration of the source of differences may lead to new understanding and ideas about how to improve stakeholder involvement training or processes. Hopefully, the resulting characterizations of similarities and differences will stimulate future research into 1) how stakeholders are involved in other design problem types; 2) other employer types; other geographical regions; and other natural resource industries such as agriculture.

RESULTS

The study covered fifty-one in-stream habitat projects on twelve watersheds in Washington State. Project size ranged from very small landowner initiated projects to multi-million dollar construction projects. Over ninety individuals associated with the projects were interviewed by phone or in person. More than thirty-five project sites were visited so materials and methods could be assessed. Most site visits were guided by one or more project participants. Their presence allowed unstructured exploration of reasoning behind many of the design decisions made by the project designers.

We were able to identify most project participants through snowball sampling (Biernacki and Waldorf 1981) starting with project sponsors and others listed on the HPA permit application filed with the Washington Department of Fish and Wildlife (WDFW). The number of project participants ranged from three to seventeen, with 5 - 7 participants most typical. Not all project participants were directly involved in design decisions. However, most projects had at least three persons identified as influencing design decisions. A few projects followed the traditional model of an arm's length relationship between designers and other project participants. However, this was rare in our sample.

The roles most often identified with project participants include:

- Landowner / Project Sponsor
- Funding Agency – FEMA, Conservation District, etc.
- Project Manager / Coordinator
- Designer
- Technical Participants – Engineer, biologist, ecologist, hydrologist, geomorphologist
- Regulator(s) – WDFW, Dept. of Ecology, US Army Corps of Engr., etc.
- Contractor / Work Crew

In many projects an individual might be associated with multiple roles. For example, the project manager might also be the lead designer and the landowner may also be the contractor. One finding that is relevant about roles is that participant roles were fairly easy to identify and were apparently well understood by other participants. The clarity of roles was a bit perplexing since most project "teams" were ad hoc and virtual. By that we mean that project teams tended to come together through a poorly structured affinity process, execute a project and then disband. Team membership changed dramatically from project to project within a watershed (except for rural eastern Washington). Snowball sampling was necessary to discover project and design participants because no one, including the project manager, was able to identify all project participants in a majority of the projects studied. Participants knew those persons they interacted with to do their part of the effort, but did not know or attend meetings with other participants. The virtual team notion is supported in that the team structure exists only as an artifact of our investigation and mapping of relationships.

We expected to find that stakeholders who did not have personal ties to project team members would participate via public involvement processes such as SEPA reviews or letters to permit agencies. We found no evidence of project design influence by special interest groups and private citizens. In effect, influence was via direct participation, negotiation and personal relationships. When we probed into the reasons behind the lack of participation and influence by indirect means, we found that most project managers encouraged it, but no response was received.

We expected to find that stream restoration and habitat practitioners would have well-established networking mechanisms. Although we identified over 200 participants in our study sample, we found that only a few had any contact with practitioners, engineers or technical specialists from outside their own watershed. The only technology and design ideas transfer agents we could identify were the WDFW Area Habitat Biologists and USDA –NRCS specialists. Both of these professional jobs entail participation in multiple projects within a region, and the individuals who hold these positions tend to be transferred around the state during their careers. Although we identified these two positions as central to the social networks and the only available explanation for idea dissemination, the individuals we interviewed in those positions tended to downplay or disavow their technology transfer role.

We asked all project designers to list the reference works an experts who influence how they approached design decisions. We found that only about ten percent of those involved in design decisions had ever read one or more of the design guides on the market or ever attended a training workshop. It was very clear that design expertise was developed through experience within the watershed.

We probed to discover the level of influence that the Washington Administrative Code that covers habitat projects (WAC 220-110) exerts on design decisions. Outside of the regulatory agents, we found little familiarity with the code and its' prescriptions with respect to design.

The subset of roles most often identified as influencing design decisions (in decreasing order of frequency) include:

1. Funding Agency
2. Project Manager/Coordinator
3. Regulator(s)
4. Designer
5. Contractor / Work Crew

The funding agency has a huge influence on design. If the funding agency is FEMA then the project goals and constraints are dominated by flood and public works protection. If the funding agency is a conservation district then we found that the NRCS field guide and standard drawings controlled most design decisions. If the funding agency was a county surface water management agency then bank protection or conveyance tended to dominate the project design. In most of the projects funded by such agencies habitat features were introduced as mitigation or secondary objectives. When the funding agency was devoted to habitat creation or enhancement, then the projects took on a decidedly different flavor. The habitat objectives took center stage, and bank protection, property protection and other objectives were added to satisfy landowners, neighbors and other influential stakeholders.

The influence of the project manager is to be expected. From the earlier discussion about the ad hoc and virtual nature of the project teams, it should be apparent that the project manager is in a central position for control of information and decisions. We found that the project manager usually had the most experience with organizing and designing habitat projects. The combination of leader-authority and relevant experience was borne out in influence level. However, the project manger was very sensitive to the needs and biases of other key participants. Projects were often framed in ways to garner approval from potentially blocking stakeholders or support from funding agencies.

The regulator's influence on design was most often exerted through enforcement or interpretation of the state codes (WAC 220-110) covering in-stream habitat projects. Some regulators also perceived their role to include coaching and advising inexperienced project managers and designers or effective design of projects.

The designer's influence was marginal in most cases where the designer's task was plan preparation for permit approval. However, when the designer was a consultant, engineering specialist or project manager, then the level of influence was high, but not absolute. Designers had to be sensitive to and incorporate features necessary to satisfy other stakeholders.

Contractors and work crews had fundamental control over how the projects were executed. In many cases the design simply specified that X number of logs or root wads or rock barbs should be installed along Y feet of stream. Drawings were of typical sections and left the actual methods of placement, anchoring and arrangement to the work crews. We frequently heard that the experience and creativity of contractors or work crews can make or break a project.

We probed to discover what sort of design processes were followed by engineers, designers and project managers. We found that none of the design participants were comfortable characterizing their design process as procedural, rational, or standard. None of the designers we interviewed were familiar with Quality Function Deployment (Guinta and Praizler 1993) (Ullman 1992) or Suh's principles of design (Suh 1990). We were unable to discover a coherent design process for any of the projects we studied. This is not to suggest that projects were not successful. All of the projects we visited appeared to be functional and delivering on the objectives described in either the HPA permit or as framed by participants during our interviews.

DISCUSSION

From a classical engineering design and team process viewpoint, it is not apparent how very many of the projects we studied could possibly be successful. There were no formal design processes and design optimization algorithms. There was no formal team building. It was rare that all project participants even knew one another. Yet, the designs we saw were adequate to receive landowner, funding agency and regulatory approval as well as meet stated project objectives. We were left with a number of questions about how doing design in the natural resources really works.

1. Would we expect procedural design methods to produce better designs with respect to cost, logistics and goal satisfaction?
2. How do ad hoc, virtual teams organize and achieve their goals?
3. What are the mechanisms for mutual learning and technology transfer across projects?

One explanation for why formal design processes were not followed is the observation that few projects were led by a trained engineer. Only engineers receive education in procedural design methods. Other professional disciplines tend to follow problem solving or participatory decision making processes when faced with "design" problems. In order for processes like QFD and Suh's principles to have much effect on how habitat projects are executed, the methods would need to be delivered to and accepted by the majority of project participants who have other technical or non-technical backgrounds.

Another explanation is that project quantity is preferable over design-process derived improvements in project quality. As noted earlier, the Washington State Legislature provides a clear mandate in support of "faster, cheaper" habitat enhancement projects. Some project participants strongly believed that imposition of formal design processes or engineering discipline on project teams would unnecessarily increase the cost of projects, and substantially reduce the number of projects that could be completed per year.

It appears that multi-disciplinary, cross agency projects adopt a team model that is only just now being recognized. The basis for team membership, conflict avoidance, and role clarity appears to be professional respect and shared goals. The goals of a habitat project are clear from the outset. Only those skills, competencies and stakeholders necessary to achieve the goal appear to be brought into the project. Project participants, including the project manager, trust other project participants to do their job well and link to resource specialists they need to support them. This form of organization was recently characterized as an "intellectual web" or "spider's web" (Quinn, Anderson, and Finkelstein 1996). The notion of a spider's web form of organization is based on networking rather than organizational matrices. The project manager knows three or four key persons who need to be involved in the project. Each of those persons knows others who are needed for more niche roles, and so on.

Another apparent key to success in this unstructured approach to design is the ability of key participants to rapidly identify who the key stakeholders are and figure out how to weight their conflicting needs during decision making. Mitchell, Angle and Wood (1997) called this "the principle of who and what really counts." This notion is supported in our finding that most project teams had an efficient 4-7 participants, yet the list of potential participants could easily top a dozen or more. If critical stakeholders were excluded from project decision making we would have expected to see written testimony in the public comment files, or heard tales of threatened legal actions, etc. Such evidence was not present in our study sample.

Weighting of the conflicting needs of various participating stakeholders was almost universally characterized as a process of mutual learning, negotiation, brinksmanship and/or accommodation. The processes used were all social processes. In several projects there was concern about engineers and other technical specialists not being sensitive to the give and take of negotiated decision making and uncomfortable with the notion of design as a social process.

FITTING DATA TO APPRECIATIVE DESIGN METHOD

The Appreciative Design method for design of technical works (Dooley and Fridley 1996) is a structured process to search for a best-set solution to technical and organizational problems. The Appreciative Design method is a significant extension of the hierarchical axiomatic design methodology of Suh (1990; 1995a) and includes many features of the Soft Systems Methodology developed by Checkland (1990).

Suh's structure and optimization methods (Suh 1990) (Suh 1995b) are particularly well suited for addressing the messy problems that are common in industry and the natural resource fields. Suh's approach is based on a set of design rules. Our implementation of Suh's approach adds some important structure and detail, as well as provides an easily followed hierarchical tracking of information, alternatives and decisions. The hierarchical structure allows reviewers, decision-makers and others to easily follow the history of decisions made throughout a project.

Suh's design principles are expressed in terms of a decision logic that includes *functional requirements, design parameters* and *constraints* (Suh 1990). Functional requirements (FRs) are design objectives cast in solution-neutral and independent statements. There is general consensus that problems are best defined when the objectives are framed by what is to be achieved by the project rather than by how needs are to be met (Love 1980).

Design Parameters (DPs) are either brainstormed alternatives or calculated specifications that become features of a solution. Brainstorming, ideation and other methods of creating or searching for alternative solutions are well understood by engineering professionals, educators and students so did not need to be included in the model.

Constraints (Cs) are objective statements and mathematical relationships that set bounds on the range of DPs that are acceptable. Constraints provide limits on the how, what, when, where and why of the design solution. Constraints are most often used by designers as criteria to sort alternative DPs into those which are acceptable and those to be discarded or reworked. An initial set of constraints typically is drawn from conversations with the client and all relevant stakeholders. Constraints can also be found through exploration of the laws of nature (e.g., $f = ma$, $\sigma = mc/I$), laws of humankind (e.g. codes, laws and regulations), cultural norms of the organization (e.g., policy and design manuals), and norms of the community (e.g., codes of ethics). In all cases constraints must be linked to a "constraint owner" in order to make them relevant to the problem at hand (McIntyre and Higgins 1989). The constraint-owner linkage provides relevance to a constraint and its source.

One method to visualize the interplay of Functional Requirements and Constraints is to draw a decision tracking matrix of the form shown in Table 3-1. In the table we illustrate a hypothetical habitat enhancement project that is framed as a bank stabilization project. Hence, we can state the functional requirement with the action phrase "provide bank stabilization." The functional requirement for bank stabilization is likely to have resulted from policy and strategic planning at the watershed level. A typical policy / strategy statement might identify a waterbody and suggest that water quality, spawning success and other public goals would best be achieved by initiating bank stabilization projects along the stream.

If a designer is to provide bank stabilization in small streams, there are a limited number of proven / accepted methods (design parameters) for achieving the functional requirement, including adding rip-rap to the slope, building bulkheads or crib-walls, and lining the unstable bank with concrete, among other techniques. The choice of design parameter is constrained by requirements placed on the designers by a number of constraint owners.

In the illustration we show typical constraints from four common constraint owners. The Washington Department of Fish and Wildlife has a regulatory role to ensure that public interests are protected. Principle constraints owned by the WDFW and represented through the Area Habitat Biologist (AHB) are compliance with relevant sections of the Washington Administrative Code that require protection of aquatic life during the construction phase of the project and mitigate any loss of habitat due to project elements. The property owner is another obvious constraint owner. In the hypothetical case, the property owner desires to protect a barn from damage if the stream meanders in the barn's direction. The landowner probably is paying at least a portion of the cost of the project, so is sensitive to project costs. The local conservation district is a participant in many rural in-stream projects to pursue national soil & water quality programs, as well as to assist financially through cost-sharing programs. Participation by conservation districts and other governmental agencies brings additional constraints to the project related to program mandates and agency design standards. The final constraint owner in our hypothetical project is a contractor who will actually build the project. The contractor brings a perspective to the designers related to such constraints as site access problems or limitations on availability of materials. The first row of the decision matrix illustrates an initial round of discussions by the designers, problem owner and constraint owners.

Table 3-1. Appreciative Design Decision Tracking Matrix (with hypothetical data)

Functional Requirements	Design Parameters	Constraints
FR1.0 Provide Bank Stabilization • Improve water quality • Reduce sedimentation • Protect spawning beds	DP1 Method of stabilizing bank DP 1.1 Riprap DP 1.1 Wood Crib Wall DP 1.2 Concrete Channel	WDFW • Comply with WAC • Mitigate loss of habitat due to project Property Owner • Protect Barn • Minimize cost Conservation District • Meets funding guidelines • Complies with federal design standards Contractor • Ease of access • Available materials
FR 2.0 Protect Barn	DP 2.0 Method of compliance with WDFW Constraints DP 2.1 Add stumps DP 2.2 Add brush bundles DP 3.0 Method of addressing access limits DP 3.1 Use helicopters DP 3.2 Use hand crews DP 3.3 Build access road DP 4.0 Method to protect barn DP 4.1 Move channel DP 4.2 Move barn	

Continuing with the hypothetical case, the initial discussions raise a number of important issues that must be resolved during the design of the bank stabilization project. Buried in the constraint discussion is a hint that an additional functional requirement may be present in that the property owner desires to protect a barn. This additional FR is shown in the second row of the matrix as FR 2.0. High level constraints may spawn new design parameters as well as functional requirements. Design Parameters 2, 3 and 4 are shown to illustrate how features and design elements arise to address constraints.

Had we continued with the illustration through successively more detailed levels of design, we would eventually arrive at a complete set of design parameters that fully achieve the functional requirement(s) and satisfy or mitigate the constraints.

Data on design processes from the present study is conclusive that formal tracking of objectives, constraints and alternative design parameters did not occur in any of the projects. In a few cases, we mapped our interview and inspection data for project participants who joined in site visits. In all cases those who saw our maps agreed that such mapping would have helped communication during negotiations and design discussions. They universally expressed concern that any documentation requirement, including that of Appreciative Design, would be difficult to implement. Concerns ranged from the fact that design teams form for single projects then disband to beliefs that no team member has sufficient incentive to assume the role of scribe. Therefore, although there is belief that better design processes would result in more efficient and effective design decision making, there is concern that design processes would not be implemented.

CONCLUSIONS

We found compelling evidence that design of fish habitat projects in Washington State is a highly social process. Project participants represent a wide range of disciplines and agencies, each with a different culture and set of objectives / constraints to be satisfied during the project. The average number of persons who participated in project planning and execution was 6.0 (sd=3.5). Of those, an average of 3.3 (sd=2.3) were involved in design decisions. Design teams typically included persons with non-technical roles in the project. Although all projects included modification of stream channels, anchoring of placed materials and other activities that classically would be considered engineering, engineers participated in the design of only 15 of the 42 projects for which role data was available. In only two cases did a person hold both engineering and project management roles.

Decision making with respect to design elements (materials, placement, anchoring, etc.) was either through social processes such as negotiation, or deference to past successful experience. We found no evidence of analytic optimization, systematic exploration of alternatives, or other formal design methods. Data was not collected that would allow determination if socially based design and decision processes were a result of project management by non-technical leaders, or a logical response to the nature of the projects.

We found that project teams tend to operate in isolation from one another both within a watershed and across watersheds. The regulators and conservation district staffs appeared to be the only participants who were likely to aid communication across projects within a watershed. The high number of participants within projects and low overlap of participation across projects is a challenge for technologists, educators and others who wish to disseminate improved methods for habitat enhancement.

This project stimulates a need to further explore:

1. how unstructured collaborative project teams form, develop norms and roles and organize for communication,
2. what design methods are best applied to "engineering" projects in the natural resources where the team is numerically dominated and/or led by non-engineers, and
3. effective methods to disseminate technical and project management knowledge across isolated project teams.

CHAPTER 4: ENGINEERING CONTENT AND PARTICIPATION IN DESIGN OF FISH HABITAT ENHANCEMENT PROJECTS

INTRODUCTION

One of the greatest challenges facing engineering and scientific problem solvers is finding ways to fully integrate social complexity and diverse viewpoints of interested publics into their work. Modern engineering decision-making generally developed under a paradigm that included a singular decision-maker or client and single engineer. Only recently has engineering education embraced team and participative approaches to design. Literature on stakeholder involvement and multiple decision-makers is just beginning to emerge. During the last fifteen years a number of public policy and sociopolitical changes have either allowed or encouraged direct public participation in the activities of engineers and scientists. Discipline-based design approaches are being replaced with multidisciplinary and cross-functional team approaches to design and problem solving (Bucciarelli 1994). Task teams and cross-functional or concurrent engineering teams are frequently assigned rather than self-selected, making society-building a necessary concurrent activity for team members. Technical professionals are generally unprepared to understand or participate in social role and norm development that is critical to team success (Bugliarello 1991). Additionally, the technical professions are struggling to discover and develop sensitivity to, and appreciation of, the societal context of their work as well as develop new operating paradigms that are consistent with engineering being as much a social process as it is a technical process (Konda et al. 1992).

A study of fish habitat improvement projects across Washington State provides important insight into stakeholder involvement in natural resource engineering projects. This paper reports on the knowledge gained about who the stakeholders are that participate in the design process and how they exert their influence on design decisions.

ENGINEERING DESIGN AS A SOCIAL PROCESS

In spite of its long history of creating artifacts to meet society's needs, engineering is believed by most people to be free of societal influence and "outside the checks and balances of social order" (Vincenti 1991). A proposition of this paper is that the profession of engineering is a social construction; therefore, it is logical that engineering design should be practiced in a broad societal context. There appears to be a general lack of awareness and appreciation that influences external to the firm and design team frequently dominate design decisions. Increasing external public, regulatory and special interest group participation in engineering design comes at a time when the current generation of design engineers is least prepared to appreciate and accept non-technical input (McNeill 1992) (Hughes 1991).

Over the past forty years or so engineering has been positioned by educators and many practitioners as being necessarily independent of, and immune from, social influence (Morrison 1986) (Vincenti 1991). In the mid-1950's engineering education in the United States was directed away from social-technical integration toward more scientific and mathematical content (ASEE 1954; ASEE 1955). At the same time that engineering education stepped away from problem definition and consideration of non-technical aspects of design, the new educational discipline of professional management provided specialists to assume the decision-making roles in society (Chandler 1977). Engineering students were subsequently taught that it was the role of engineering managers and other non-technologists to address politics, external interests and other non-technical design issues (Morrison 1986) (Bennett 1996). However, since the early 1980's we have watched a major shift in the practices of engineering employers to place the burden of addressing non-technical design issues squarely back onto the design engineer. Design engineers are now challenged to directly participate in a broader social system more than at any time in the past four decades.

We have also seen over the last fifteen years an erosion of confidence in engineers by the general public (Ferguson 1992). Many of the attacks on engineering and other technological artifacts appear to arise from newly discovered risks or negative consequences of what was perceived to be highly beneficial technical advances in the past. The rate of change in societal values and expectations may be causing the public to lose sight of the social context within which a technical project was undertaken. The social construction view of technological systems holds that all technological artifacts "bear the imprint" of the social context surrounding their development (Pfaffenberger 1990) (Hughes 1991). A few years after the construction of an engineering work or release of a new product there is little public recollection of the social context that stimulated or constrained its design. While the social construction view suggests that the design of an artifact and society are inseparable another view suggests that engineering methods are consciously or unconsciously disconnected from the processes for problem solving used by the non-engineering society at-large (Adams 1991). It may be that the community of engineers and engineering educators have not taken time to maintain their places in the social systems necessary for the survival of the profession (Bugliarello 1991).

Other forces of change are at work as well. The social institutions that support engineers and engineering employment are undergoing unprecedented change. Employment relationships are in turmoil, with engineering and other service positions bearing a full share of many organization's downsizing and outsourcing movements. Erosion of private property rights combined with increased acceptance of the stakeholder view of the corporation (Carroll 1993) has brought multitudes of stakeholders into the design process, either as participants or reviewers of proposed engineering works. Changes inside and outside the engineering community suggest that it is no longer clear just what the role and place of engineering is in our modern society.

There have been a number of recent studies of the social organization and dynamics within design firms and design teams (Bucciarelli 1988). Bucciarelli's recent work, *Designing Engineers*, explores the inner workings of a number of design teams and organizations (1994). Bucciarelli concludes that the inner workings of engineering firms demonstrate that the practice of engineering is a social enterprise. Bucciarelli noted that the firms he studied were part of a larger system including the financial community, universities, and others, but his focus was internal processes, not the social dynamics of external relationships.

The present study is among the first attempts to systematically explore social organization and dynamics of design teams that are comprised of persons from many different organizations and professional interests. Such design teams are increasingly common in industry where regulators, vendors, outside fabricators, customers and others are all included in, and often numerically dominate, product design teams. In the natural resource industries, complex design teams are becoming the norm. In our project we set out to explore the social network surrounding the design of technical components of select design projects, and how the participants in the social network influenced the specification of design parameters.

METHODS

An ongoing empirical study is exploring how stakeholders influence decision-making by design teams in the natural resources. The current study focuses on design decisions related to fish habitat improvement projects involving small streams. Fish habitat improvement projects typically involve the design and placement of structures within the riparian area and stream channel. Design decisions include specification of material, specification of structure size and shape, location and distribution of structures along the stream, method of placement, and method of anchoring. Each of these design decisions is likely to involve technical as well as subjective analysis. Both the technical and subjective analyses are likely to be further influenced by beliefs and values held by various stakeholders associated with a particular project.

The research is retrospective and covers Washington state projects which were issued permits by the regulatory agencies during 1997. The primary research method is a combination of semi-structured interviews and surveys. Additional detail is collected from permit applications, documentary evidence provided by project sponsors and reports in the media. Data collection revolves around the following questions:

- What was the design objective (functional requirement) that you were striving to achieve through ... (specification of material, choosing method of placement, etc.)
- Who contributed to or influenced the design process and decision?
- What were the constraints on how you achieved the objective?
- Where did the constraints come from?
- What was the range of alternatives you considered?
- Where did the alternatives come from?
- What constraints and alternatives were consciously kept off the table?
- What was the social network that surrounded the design phase of the project?

The study sample was drawn from project sponsors who recently received Washington State Department of Fish and Wildlife Hydraulic Project Approval (HPA) permits for small stream habitat improvement projects. We are looking for systematic evidence that core team members have processes to identify stakeholders and consciously factor stakeholder input into their design decisions.

DESIGN OF FISH HABITAT IMPROVEMENT PROJECTS

Stream habitat improvement projects necessarily involve collaborative efforts of landowners, agencies, contractors and various special interest groups. Many of the projects are initiated by agencies or interest groups other than the landowner. When someone other than the landowner initiates a project, the stream corridor landowners are recruited or otherwise brought into the project. In other cases landowners initiate habitat improvement projects for their own benefit, then bring agencies and other interests into the project to share costs, provide labor or provide political support favorable to gaining project approval by regulatory agencies.

Habitat improvement projects are generally accepted as having competing interests of bank protection, flood control, civil structures protection, landowner uses, recreational demands, etc. Thousands of small projects have been executed across the United States in the past decade. At least several hundred small stream projects have been conducted in the state of Washington. Through the collective experience of many projects, one would expect that identification of interest groups, development of communication linkages, and establishment of norms for involvement are showing signs of maturity. Social and communication networks involving project designers and stakeholders may be well established in some regions of the state.

Small streams are defined for our purposes as streams having normal summer flows of less than 100 cubic feet per second or channel width less than ten meters. Common habitat materials include concrete, steel, milled wood, automobile bodies, quarry rock, cobbles in gabions, placed logs and placed root wads. The choice of materials is a product of potentially conflicting needs such as cost, aesthetics, fisheries value, availability of materials, regulatory requirements and landowner preferences. Participants in the materials decision are likely to include the landowner, design firm, materials supply firms, regulatory agencies, environmental special interest groups, fisheries special interest groups, and installers.

Structure size and shape involves a trade-off of materials cost, placement difficulty, stream channel characteristics, hydrologic regime, and effectiveness for creation of fish habitat. The location and distribution of structures along a stream typically is affected by stream access issues, project budget versus technical optimal habitat creation, balancing of creating new pools versus reinforcing existing pool habitats, desire to modify the stream direction, etc. Method of placement ranges from hand labor to heavy equipment, cranes, logging skylines and helicopters. Tradeoffs include project budget, availability of labor, size of materials, environmental sensitivity and site accessibility. The method of anchoring can include choices to do nothing, drill and epoxy anchors into the streambed, tie cables from the structures to riparian trees, driving piles or structural elements into the stream bank and weighting the structure with large rocks.

In all of the above decisions there is the potential for dominance by value judgments, preferences of central stakeholders, and scientific/cultural norms that support one technical or analytical paradigm over another. We are attempting to identify the source of influence on design decisions during the course of the study.

Observations are being compared and contrasted across projects within a sponsor type and between sponsor types. We expect to find wide variation in stakeholder involvement practices within and between sponsor types. We will be able to describe and draw conclusions about how a limited number of designers and design teams practice stakeholder involvement. Exploration of the source of differences may lead to new understanding and ideas about how to improve stakeholder involvement training or processes. Hopefully, the resulting characterizations of similarities and differences will stimulate future research into 1) how stakeholders are involved in other design problem types; 2) other employer types; other geographical regions; and other natural resource industries such as agriculture.

RESULTS

The study covered fifty-one in-stream habitat projects on twelve watersheds in Washington State. Project size ranged from very small landowner initiated projects to multi-million dollar construction projects. Ninety-seven individuals associated with the projects were interviewed by phone or in person. More than 35 project sites were visited so materials and methods could be assessed. Most site visits were guided by one or more project participants. Their presence allowed unstructured exploration of reasoning behind many of the design decisions made by the project designers.

We were able to identify most project participants through snowball sampling (Biernacki and Waldorf 1981) starting with project sponsors and others listed on the HPA permit application filed with the Washington Department of Fish and Wildlife (WDFW). The number of project participants ranged from three to seventeen, with five to seven participants most common. Not all project participants were directly involved in design decisions. However, most projects had at least three persons identified as influencing design decisions. A few projects followed the traditional model of an arm's length relationship between designers and other project participants. However, this was rare in our sample.

ROLE OF ENGINEER PARTICIPANTS

From a classical engineering design and team process viewpoint, it is not apparent how very many of the projects we studied could be successful. There were no formal design processes and design optimization algorithms. There was no formal team building. It was rare that all project participants even knew one another. Yet, the designs we saw were adequate to receive landowner, funding agency and regulatory approval as well as meet stated project objectives.

Table 4-1. Participation by role in habitat enhancement projects in two watersheds (R & Z) of Washington State

	WIRA R (14 Projects)			WIRA Z (4 Projects)		
Role	# of Projects	% of Projects	# of Different Persons	# of Projects	% of Projects	# of Different Persons
Administration	0	0	0	0	0	0
Construction	3	21	3	2	50	2
Coordinator	3	21	5	0	0	0
Designer	6	43	7	4	100	2
Design Surrogate	3	21	6	3	75	2
Engineering Design	2	14	2	0	0	0
Engineering Analyst	5	36	5	1	25	1
Engineer / Project Manager	1	7	1	0	0	0
Field Supervisor	1	7	2	0	0	0
Landowner	4	29	4	3	75	4
Project Manager	6	43	6	1	25	1
Regulator	13	93	7	0	0	0
Regulator / Guidance	0	0	0	4	100	1
Regulator / Surrogate	4	29	1	1	25	1
Sponsor	1	7	2	0	0	0
Steward	3	21	2	0	0	0
Technical Specialist	4	29	6	4	100	6
Unknown	5	36	5	0	0	0

As shown in Table 4-1, we separated engineer roles into three distinct categories. Engineers acted as designers, analysts or project managers depending on the project and engineer. Some persons may have engineering degrees, yet are not included in the data as assuming an engineering role if they had no engineering role in a project.

The roles engineers played in the two watersheds suggest some important areas to explore. In WRIA R engineering designers were involved in two of fourteen projects, while in WRIA Z there were no engineering designers. WRIA Z engineers were called upon to do analysis and provide data or information to non-engineer designers. What is important to observe is that engineers are rarely given the role of designer within the projects we studied.

The role of engineering analyst was present in both watersheds. Engineering analysts were most often called upon to estimate stream depth at various storm event sizes so levee height could be established or habitat elements could be located to be effective during high water. Although we expected it, we found no instance where engineers were called upon to estimate hydraulic forces on in-stream structures or size anchor elements.

Another role that was expected to be more frequent was that of engineer/project manager. Only one of the eighteen projects was led by a person who had the shared roles of project manager and engineer. This finding is supportive of the belief among most project participants that habitat enhancement projects, including those which mitigate other instream activities, are not engineering projects.

We found substantial support for the notion that serious design was important to project success. We found agreement that projects included technical elements such as anchoring and hydraulic routing. However, the perception among most participants and project leaders was that engineering input was not necessary for project success.

At the outset of the present study, anticipated that instream habitat enhancement projects would be approached as engineering projects and generally accepted engineering design processes would guide the development of technical elements of the solution. Now that the data is conclusive that such is not the case, a number of questions beg study:

1. What are the cultural, political, historic or other explanations for habitat enhancement projects being non-engineering works?
2. What are the explanations for low engineer involvement in habitat enhancement projects? A number of interviewees suggested it is rooted in low willingness among engineers to participate in negotiations and indeterminant decision processes.

3. What are the risks to society that might be lowered through more traditional engineering involvement ?
4. In what ways would project outcomes be better (faster, cheaper, more satisfying) if more traditional engineering design methods were used?
5. What are appropriate roles for engineers in habitat enhancement project teams? How does the engineering community gain appreciation among other participants for the contribution (social benefit/cost ratio) engineering roles can have?

One explanation for why formal design processes were not followed is the observation that few projects were led by a trained engineer. Only engineers receive education in procedural design methods. Other professional disciplines tend to follow problem solving or participatory decision making processes when faced with "design" problems. In order for processes like QFD and Suh's principles of design to have much effect on how habitat projects are executed, the methods would need to be delivered to and accepted by the majority of project participants who have other technical or non-technical backgrounds.

It appears that multi-disciplinary, cross-agency projects adopt a collaborative team model. The basis for team membership, conflict avoidance, and role clarity appears to be professional respect and shared goals. The multiple goals of a habitat project appear to be understood, if not clearly expressed, to project leaders and key participants from the outset.

- Produce a gain in salmonid habitat
- Achieve "willing landowner" needs for property protection, aesthetics, etc.
- Achieve additional requirements set by funding agency and budget enabling language.
- Satisfy negotiated requirements of the regulatory agencies

Although we found no evidence that the four goals were explicitly documented by any project team, they were implicitly included in almost all of the projects studied. Only those skills, competencies and stakeholders necessary to achieve the goals appear to be brought into the project. An appropriate analogy would be the design and construction of a rural building. If the objective is to build a small wooden shed with no foundation, the design/build team would be quite different than if the objective was to build a concrete block dairy barn, or a high value rural estate home.

Project participants, including the project manager, trust other project participants to do their job well and link to resource specialists they need to support them. This form of collaborative organization was recently characterized as an "intellectual web" or "spider's web" (Quinn, Anderson, and Finkelstein 1996). The notion of a spider's web form of collaborative organization is based on networking rather than organizational matrices. The project manager knows three or four key persons who need to be involved in the project. Each of those persons knows others who are needed for more niche roles, and so on.

Another apparent key to success in this unstructured approach to design is the ability of key participants to rapidly identify who the key stakeholders are and figure out how to weight their conflicting needs during decision making. Mitchell, Angle and Wood (1997) called this "the principle of who and what really counts." This notion is supported in our finding that most project teams had an efficient four to seven participants, yet the list of potential participants could easily top a dozen or more. If critical stakeholders were excluded from project decision making we would have expected to see written testimony in the public comment files, or heard tales of threatened legal actions, etc. Such evidence was not present in the study sample.

Weighting of the conflicting needs of various participating stakeholders was almost universally characterized as a process of mutual learning, negotiation, brinksmanship and/or accommodation. The processes used were all social processes. In several projects one or more participants expressed concern about engineers and other technical specialists not being sensitive to the give and take of negotiated decision making and generally wanting to make the design process more deterministic and less negotiable.

CONCLUSIONS

We found compelling evidence that design of fish habitat projects in Washington State is a highly social process. Project participants represent a wide range of disciplines and agencies, each with a different culture and set of objectives / constraints to be satisfied during the project.

Decision making with respect to design elements (materials, placement, anchoring, etc.) was principally through social processes such as negotiation and collaboration. We found no evidence of analytic optimization, systematic exploration of alternatives, or other formal design methods.

We probed to discover what sort of design processes were followed by engineers, designers and project managers. We found that none of the design participants were comfortable characterizing their design process as procedural, rational, or standard. None of the designers we interviewed were familiar with Quality Function Deployment (Guinta and Praizler 1993) (Ullman 1992) or Suh's principles of design (Suh 1990). We were unable to discover a coherent design process for any of the projects we studied. This is not to suggest that projects were not successful. All of the projects we visited appeared to be functional and delivering on the objectives described in either the HPA permit or as framed by participants during our interviews.

CHAPTER 5: COLLABORATIVE DESIGN OF FISH HABITAT PROJECTS IN STREAMS AND RIVERS OF WASHINGTON STATE

Well beneath the media attention and political wrangling surrounding salmon habitat restoration in the Pacific Northwest, groups of individuals are going about the business of restoring, creating and enhancing salmonid habitat through technical projects. During the year of the present study, approximately 600 habitat projects received construction permits from the Washington State Department of Fish and Wildlife. Similar project activity is reported in Oregon, northern California, British Columbia and Idaho. Recent actions to list a number of salmonids under the Endangered Species Act will undoubtedly result in an increase in the number of habitat enhancement projects conducted each year.

Fish habitat projects typically involve modifying a stream channel and adding wood, rock or other structural elements with the intent of improving the carrying capacity for target salmonid fishes. Forest, civil and agricultural engineers often participate on habitat design teams; yet few habitat enhancement design projects are considered by other participants and leaders to be engineering projects. In an informal preliminary survey, most project participants indicated that purposeful design was important to the success of their projects. They further indicated that the process of design involved collaboration among a number of project participants, including landowners, regulators, biologists, construction crews and others.

Design and execution of fisheries habitat enhancement and restoration projects appears to be an exemplary case of the trend toward participative decision making in natural resource management. A number of studies have been conducted into how participative management decisions are made at the policy level (Adewole 1981; Carter 1996; Pukkala and Kangas 1996). Other studies have explored participative processes in industrial and engineering design teams (Allen 1992; Bodker 1996; Kautz 1996). The situation of collaborative design involving multiple entities and disparate participant motives typical of projects in the natural resources is believed to have unique aspects worthy of study.

Little is known about how design and decision making occurs at the project level. If engineers and other technical professionals are to successfully prepare to participate on habitat design teams, they would benefit from knowing how such teams work. The present study has an objective to characterize habitat design teams by identifying who is involved, their roles and methods of making decisions. Beyond direct participants, we sought to determine the indirect participation of other stakeholders and stakeholder-surrogates in the form of documents.

The observation that engineers and engineering might be less central to design of habitat projects may be indicative of a broader societal trend toward participative decision making. Engineers and other technical professionals are increasingly involved in multi-entity and multi-disciplinary teams. It may be that a new form of design team and design process is emerging as participative decision making matures.

Preliminary surveys by the author indicated that project level design decisions were being made without review and debate in a broad public forum. Although public agency and non-governmental organization involvement in projects provide statutory access by interested parties, there was little evidence of actual involvement at the project level by logical stakeholders. Additionally, early data suggested that project teams had little common individual membership across watersheds and regions, while similar team-member roles and employing agencies tended to be represented across projects. Thus, the question naturally arises, "Who is really making design decisions vis-à-vis fish habitat at the project level, and how do those who are involved arrive at the choices they include in their final design?"

COLLABORATIVE AND PARTICIPATIVE DESIGN

Collaborative or participative design implies a temporary social arrangement in which multiple social actors work together to achieve a shared goal (Roberts and Bradley 1991). Roberts identified five elements that are necessary for successful collaboration:

1. Transmutational purpose – a shared-goal-directed activity that results in action,
2. Explicit and voluntary membership of participants who have roles
3. Organization – either formal or informal
4. Interactive processes – expectation that communication will be multi-directional
5. Temporary nature – when the goal is achieved or a role is no longer needed then the organization disbands.

Within collaborative decision making, it must be recognized that individual participants bring to the process an array of strategic interests, values and biases that arise from their employers, personal experiences and affiliations (Laumann and Knoke 1987). Therefore, one should expect collaborators to pursue personal/institutional agendas concurrently with shared goals (Arrow 1994). In the present research study, we seek to determine how broadly and strongly the primary project objective(s) are shared by collaborators. Is the unifying theme of salmonid habitat enhancement the primary motive for collaboration, or a secondary objective that has sufficient attraction to hold the collaborative organization together?

Membership on collaborative decision making teams is expected to be voluntary, and all members are to have discernable roles within the team (Roberts and Bradley 1991). Role is defined as a labeled set of behaviors that one who holds a certain status or position in a social unit exhibit (Cohen and Orbuch 1979). Roles provide conduits for communication within and across social unit boundaries (Bertrand 1972). Role development is a natural feature of society-building (Laumann and Pappi 1976). Role differentiation constitutes a division of labor (physical and/or cognitive). Role differentiation also plays an important part in averting conflict among team members. Individuals participating in a collaborative effort develop one or more identities associated with the roles they occupy. Roles common to natural resource projects include *project manager, designer, sponsor, landowner, regulator, contractor, technical specialist*, among others. Although there is some tolerance for deviation from an identified role, a participant who acts outside the one or more roles granted to him or her by the organization will stimulate conflict and resistance (Bertrand 1972). It would be useful to identify the roles held by various participants in natural resource design problems, paying particular attention to the roles held by engineers and other technical professionals.

Identified roles may provide a convenient way to map out the organizational structure of a social group such as a collaborative design team; however, organizational structure has limited power to explain levels of influence, power and involvement in design activities. Structural analysis of social networks adds substantial insight beyond a simple list of participants and their roles (Ronchetto, Hutt, and Reingen 1989). Of particular utility would be a determination of the individuals, organizations and roles that are central (Freeman 1978) to collaborative design social networks. Freeman developed a number of numerical graph-theory metrics for assessing the centrality or inconsequentiality of actors (participants) in social networks (Freeman 1978). Freeman's *degree* is a measure of how well connected each participant is to all other participants. A participant who is well connected has been demonstrated to have higher levels of influence on decision outcomes. Freeman's *betweenness* measure assesses how critical a participant is to foster or impede flow of information among network participants. In a spoke-and-hub organizational structure, the participant in the center is the only conduit of information between other participants. In a complete matrix structure, all participants have direct lines of communication with all other participants; hence, no one can effectively filter or change messages being passed. Freeman's *closeness* metric measures the independent access that each participant has to other participants. In simple network cases closeness is the opposite of betweenness, but in complex networks closeness is an important indicator of whether a participant is isolated from communication with other participants by circumstance as well as organizational intent.

In our study of collaborative design teams we would like to capture communication linkages as well as role and affiliations to allow social network analysis. Participant and role centrality may lead us to conclusions about how best to support collaborative design teams with engineering and technical services. If we find that technical professionals hold central positions in the social network, we might be able to use them as conduits for dissemination of improved habitat enhancement technology to other participants. However, if the technical participants tend to be peripheral and isolated, then technology dissemination will need to focus on a more non-technical audience.

Another use of social network analysis is to evaluate the propensity to exchange information and ideas across projects via *affiliation networks* (Faust 1997). Affiliation networks are similar to social networks except that connections are mapped between participants and projects or other events. Where there is a high overlap of membership across habitat enhancement project teams, we would expect that ideas and information would flow as well. If we find minimal participation in multiple collaborative teams within a watershed or across watersheds, then we would expect project team isolation to result in local stylistic project design outcomes, as well as a high incidence of "recreating the wheel" as multiple collaborative teams face similar design challenges.

Roberts' fourth point asserts that collaborative teams have mechanisms for interactive communication (Roberts and Bradley 1991). Predictable and ordered patterns of interaction among members of a social unit constitute an important part of the culture of the unit (Chinoy 1968). Graphical inspection of communication networks among participants using smallest space analysis (Takane, Young, and de Leeuw 1977) and sociograms (Krakhardt et al. 1995) provides visual clues to the communication patterns among project participants. In addition to graphical analysis, participants in a collaborative process may be asked to characterize the methods used for decision making. Common methods for decision making include negotiation, consensus building, voting, deference to experience, central authority, etc. If participants generally describe the decision process with terms indicative of interactions (negotiation, consensus, etc.) we would support a notion that interactive decision making is occurring. If we hear terms such as deference, power-based or if only one or two members of the project team can be identified with decision activities, then we might conclude that decision making was not interactive.

Roberts' fifth and final element of collaborative teams is temporality. Collaborative teams come together, do their collective job and disband. Participant membership from one project to another would be expected to vary widely. If project membership tended to persist over time, then the organization might be better characterized as something more self-sustainable than a collaborative team.

DESIGN AS A SOCIAL PROCESS

There are a great many theories and epistemologies about the ideal design process (Vincenti 1991). The dominant paradigm of the middle twentieth century was that design, particularly engineering design, should be deterministic and free of social influence (Hughes 1991). The social constructivist paradigm which asserts that design is a social process has developed an increasing following during the past two decades (Braha and Maimon 1998; Bugliarello 1991). Simon (1981) demonstrated that technical artifacts bear the imprint of their designers as much as they embodied sound physical principles. Bucciarelli (1994) established that design teams tend to follow social science principles rather than traditional scientific problem solving principles to arrive at designs that meet the needs of problem owners. Consistent with the collaborative theme observed in habitat enhancement project teams, Bucciarelli (1988) concluded that design decisions were not crisp and mathematical outcomes, but were rather the product of negotiations among participants in the design process.

There is considerable research underway to find ways to integrate deterministic engineering design with the social constructivist paradigm. Participatory design is one emerging tool set (Armillas 1972; Carter 1996; Kautz 1996). The techniques of participatory design have matured to the state where at least one handbook is available

(Kello 1996). Quality Function Deployment (Guinta and Praizler 1993) is another popular tool set for involving stakeholders, customers and others in the design process. The limitations of these and many other participative processes is that customers and stakeholders are kept outside the core design organization and social processes. By maintaining important stakeholders on the periphery of the social network, the design team cannot benefit from the richness of direct participation (Bodker 1996). Only through direct participation, can those executing a design project and those affected by it can develop shared meanings about the problem, potential solutions and decision criteria (Braha and Maimon 1998).

Other design research programs are developing decision support tools that more fully accommodate the collaborative nature of social constructivist design teams. McIntyre (1989) made an important contribution by establishing methods for "ownership" of objectives, solutions and constraints by various stakeholders or stakeholder collectives. McIntyre's contribution provided a convenient method to force central designers to interact with other stakeholders and avoid unilateral decision making. Subrahmanian (1993), Konda (1992) and others in their design process lab are developing a number of advanced computer-based tools to assist collaborative design teams. Dooley and Fridley (1996) have worked with others to develop the Appreciative Design tool set that allows stakeholder-intensive design teams to track decision logic as well as project feature and constraint ownership. The Appreciative Design method is being practiced and refined within Dooley's product engineering firm (Dooley and Paulson 1998).

Of interest to the present study is whether actual collaborative design teams in the natural resources follow an established or emerging design paradigm. If there is a dominant design paradigm in current use, then educators and agency managers can specially prepare their technical specialists to participate within such paradigms. If a mix of design processes are in use, then students and practitioners must receive a broader education in how to adapt to the various design processes in use.

Engineering design researchers and tool developers are interested to learn how well emerging participative and collaborative design tools might work in the context of natural resources design projects. Where might emergent tools add value, and where are they off the mark?

RESEARCH STUDY

The present study is part of an ongoing empirical exploration of fish habitat projects across Washington State. The current study focuses on design decisions related to fish habitat improvement projects involving small streams. Fish habitat improvement projects typically involve the design and placement of structures within the riparian area and stream channel. Design decisions include specification of material, specification of structure size and shape, location and distribution of structures along the stream, method of placement, and method of anchoring. Each of these design decisions is likely to involve technical as well as subjective analysis. Both the technical and subjective analyses are likely to be further influenced by beliefs and values held by various stakeholders associated with a particular project.

RESEARCH METHOD

The research was retrospective and covers a cross-section of Washington state projects which were issued Hydraulic Project Approval (HPA) permits by the Washington Department of Fish and Wildlife (WDFW) during 1997. The primary research method was a combination of semi-structured interviews, surveys and direct project inspection. Additional detail was collected from permit applications and documentary evidence provided by project sponsors.

The study covered sixty-five in-stream habitat projects on thirteen watersheds in Washington State. Project size ranged from very small landowner-initiated projects to multi-million dollar public works projects. Ninety-seven individuals associated with the projects were interviewed by phone or in person. More than 30 project sites were visited so materials and methods could be assessed. Most site visits were guided by one or more project participants. Their presence allowed unstructured exploration of reasoning behind many of the design decisions made by the project designers.

Data collected included:

- Complete listing of project participants, their roles and agency affiliations
- Project objective and scope, along with motives of key participants
- Design elements and technical features of the project
- Social network matrix showing which participants knew and worked with which other project participants

Data was collected and summarized by project, watershed and geopolitical region of the state of Washington. Social network analysis was executed with the aid of UCINET 4 (Borgatti, Everett, and Freeman 1992) and UCINET 5 (Borgatti, Everett, and Freeman 1999) software. The centrality (Freeman 1978) of actors and their employing agencies was calculated to determine who was in the center of communication matrices and which agencies most often were cited as influencing project design and features. Graphical analysis via multi-dimensional scaling, also known as smallest space analysis, provides a graph theoretic sense of similarities and differences between participants (Wasserman and Faust 1994). Sociographs (Scott 1991) provide the spatial information of multi-dimensional plots, yet show communication linkages between project participants. Inspection of sociographs allows rapid determination of how well connected individual participants or participating agencies are to other participants or agencies.

RESULTS AND DISCUSSION

The date presented here represents two regional subsets of the data collected on projects across the state of Washington. The two sets were selected to represent a rural southeastern WRIA and a mostly urban/suburban western WRIA. These data sets are similar to others in the more extensive set covering 65 projects and 14 WRIA. To protect the confidentiality of project participants, all projects and WRIA are coded. WRIA were randomly assigned a single letter code A-Z. Projects within a WRIA were numbered. For example, project "m7" represents the seventh project studied in the WRIA coded "m." All project participants were identified by a three-digit number. Participant identifiers are linked to actual employer agency and the role the participant played in a project. Roles were identified by a three-letter code. Employers were identified by additional distinct codes. The sets of participants (over 250) representing agencies (over 50) and roles (17) are sufficiently large that it is improbable that participant identifiers can be accurately linked to actual persons.

It appears that design of fish habitat projects fits well with what is termed *the social constructivist* approach to design (Subrahmanian et al. 1993). The social constructivist approach is characterized by all participants interacting to negotiate a solution that accommodates conflicting motives and expectations of the participants. This method of design is akin to the concept of *mutual adjustment* in sociology as put forth by Lindblom (1990).

Transmutational Purpose

Roberts (1991) asserts that collaborative teams share a goal or overarching purpose that unifies participants. The data suggests that individual participants often have widely different, and frequently conflicting goals they pursue through project activities. What appears to bring the design team together, and hold there interest is a goal of resolving issues relative to habitat elements of the design. In some cases, participants share a goal of improving habitat. However, the majority of the participants are drawn into the process by a need to satisfy habitat related constraints on achieving their individual goals.

Explicit and Voluntary Membership

A list of core membership in project and design teams was relatively easy to obtain via semi-structured interviews. The average number of project participants was 7.3 (sd=3.7) and average number of designers was 4.6 (sd=2.5). Most of the participants became involved in design decisions at one point of a project or another.

During the interviews and site visits, each participant was asked to self-identify their role in the project and its design, as well as the roles of other participants. By having both self-identification and third party identification of participant roles, we are confident that participant roles are accurately characterized. The long list of roles stated in the words of the interviewees was aggregated following an affinity process to 13 distinct roles. Each of the roles can be identified by a set of consistent behaviors and activities across projects. Some roles, such as *project manager, administrator, designer,* etc. are important for smooth operation of the collaborative organization. Other roles, such as *regulator, landowner, contractor, sponsor*, etc. are representational in that the role is tied to an interest that is being protected or represented.

Table 5-1. Project Membership and Roles

	WIRA R (14 Projects)			WIRA Z (4 Projects)		
Role	# of Projects	% of Projects	# of Different Persons	# of Projects	% of Projects	# of Different Persons
Administrator	0	0	0	1	25	1
Construction	3	21	3	3	75	2
Coordinator	3	21	5	0	0	0
Designer	6	43	7	4	100	2
Design Surrogate	3	21	6	4	100	2
Engineering Design	2	14	2	0	0	0
Engineering Analyst	5	36	5	1	25	1
Engineer / Project Mgr.	1	7	1	0	0	0
Field Supervisor	1	7	2	0	0	0
Landowner	4	29	4	3	75	4
Project Manager	6	43	6	1	25	1
Regulator	13	93	7	0	0	0
Regulator / Guidance	0	0	0	4	100	1
Regulator / Surrogate	4	29	1	3	75	1
Sponsor	1	7	2	0	0	0
Steward	3	21	2	0	0	0
Technical Specialist	4	29	6	4	100	6
Unknown	5	36	5	0	0	0

We can further analyze roles by determining role centrality across projects and watersheds. Table 5-2 adds insight beyond the presence data presented above. Degree centrality is a measure of how well connected each role is to other participants. Higher degree values indicate that the person(s) holding that role have higher number of direct communication links to other project participants. Betweenness is a measure of how central a role is to communication between participants that the role does not have direct contact with. Closeness is an inverse measure of the path distance from a role to all other participants. Higher closeness values indicate that messages need to be passed through fewer intermediaries to reach all other participants.

Table 5-2. Normalized Role Centrality Across Projects and Watersheds R and Z (Mean Values)

	Degree		Betweenness		Closeness	
	Watershed		Watershed		Watershed	
Role	R	Z	R	Z	R	Z
Administrator	-	17	-	0	-	50
Construction	1	6	0	0	3	39
Coordinator	2	-	0	-	3	-
Designer	2	25	0	3	4	54
Design Surrogate	2	17	0	1	4	42
Engineering Design	2	-	0	-	4	-
Engineering Analyst	2	33	0	5	3	56
Engineer / Project Mgr.	8	-	0	-	4	-
Field Supervisor	2	-	0	-	2	-
Landowner	2	16	0	4	4	48
Project Manager	8	25	7	4	4	53
Regulator	6	-	9	-	3	-
Regulator / Guidance	-	75	-	63	-	80
Regulator / Surrogate	6	6	21	0	5	46
Sponsor	2	-	0	-	4	-
Steward	2	-	0	-	3	-
Technical Specialist	2	19	0	3	3	50
Unknown	1	-	0	-	3	-

Regulators held central positions in both watersheds. Differences in regulator role between the watersheds are that the regulators in WRIA R maintained a purely regulatory role, while those in WRIA Z provided guidance to the design process. The landowner, designer and technical specialist roles are also more central in WRIA Z. We can also note that seventeen distinct roles were found in WRIA R versus the ten roles identified among participants in WRIA Z. Differences may be due to the highly urban nature of WRIA R, more complex social environment of WRIA R and/or sheer volume of projects executed each year in WRIA R versus WRIA Z. With respect to collaborative teaming, it is clear from Tables 5-1 and 5-2 that role differentiation occurs in both watersheds. Role differentiation is an important indicator of social organization (Lindblom 1990).

Methods of Communication

Decision making was via interactive processes in 78% of the 50 projects for which decision making data was available. The term "negotiation" was used to describe the method of decision making in 58% of the collaborative projects, and "collaboration" was the descriptor for an additional 16% of the collaborative projects. In most (7/11) of the non-collaborative projects, decision making was driven by an acceptance of prior experiences with successful designs.

When we contrast the data sets from an eastern rural watershed (n=4) with data from an urban/suburban western watershed (n=14) we find that collaborative methods were present in 79% of the western projects and 100% of the eastern projects. In all of the eastern projects, the collaborative method was characterized as a negotiation process.

Comparison of the two focus watersheds led to analysis of decision making methods across all 50 projects in the study for which method of decision making could be determined. Results are shown in Table 5-3. Collaborative processes (negotiation, collaboration, consensus and goal driven) were used by 78% of the project teams. The remaining 22% used non-collaborative methods including deference to the leader, relying on the experience of experts and reliance on consultants. There may have been interaction between participants and decision makers during in the non-collaborative projects, but decisions appeared to have been somewhat singular.

Table 5-3. Distribution of Design Decision-Making Methods

Decision Method	ALL Projects (N=50)		WIRA R (N=14)		WIRA Z (N=4)	
Collaborative	# of Projects	% of Projects	#of Projects	% of Projects	# of Projects	% of Projects
Negotiation	29	58	8	57	4	100
Consensus	1	2	0	0	0	0
Collaboration	8	16	2	14	0	0
Goal Driven	1	2	1	7	0	0
	sum = 39	% = 78	sum = 11	% = 79	sum = 4	% = 100
Non-collaborative						
Experience	7	14	2	14	0	0
Deference	1	2	0	0	0	0
Consultants	3	6	1	7	0	0
	sum = 11	% = 22	sum = 2	% = 21	sum = 0	% = 0

Surrogates for Participation by Natural Persons

Design, technical and regulator surrogates played roles in projects in ways similar to natural persons. Measures of centrality were similar for surrogates as for natural regulators and designers. Adler (1995) suggests that informational surrogates reduce the need for "face-to-face interaction" (p. 152) and provide alternative mechanisms for coordination across organizational boundaries. In the case of habitat projects, regulatory surrogates assisted project teams to meet requirements of agencies, and design surrogates often served as surrogates for engineers, fluvial geomorphologists and other technical specialists.

We did not attempt to assess the utility of surrogates as a proxy for natural person involvement in habitat project teams. On the one hand, lack of direct participation by highly experienced regulatory specialists, restoration engineers and others deprives other participants of the richness of discourse. However, the impracticality of coordinating and funding direct participants of experts is a reality that all project teams face. The relative merits of surrogates vs. direct participation could be measured only under conditions of a carefully staged set of research projects.

Temporal Nature of Project Teams

We would expect the organizational structure that unifies collaborative teams to cease at the conclusion of each project and reform with at least some new participants for subsequent projects. One indicator of temporality would be high turnover across projects within a watershed. We assessed turnover by considering the centrality of participants across all projects in each watershed, and by quantifying the commonality of team membership across projects in each watershed.

The findings are striking in the degree to which project participants are isolated from project to project. Table 5-4 shows that the number of participants who participated in more than one project is a very small percentage of the total participants. Of the 57 persons who were involved in 14 projects within WRIA R, only one was involved in more than two projects. We see somewhat broader participation in WRIA Z due to broader involvement of conservation district and regulatory persons.

Table 5-4. Participant involvement in one or more projects within WRIA R and WRIA Z

	WRIA R (N=14)		WRIA Z (N=4)	
	Persons	Surrogates	Persons	Surrogates
Number of Participants	57	7	25	3
Number in 2+projects	4	2	5	1
Number in 3+ Projects	1	1	3	0
Number in 4+ Projects	1	1	1	0

The low repeat use of design and regulatory surrogates across projects in the two watersheds is also of interest. It appears that different project teams are relying on different documentary information sources. If we had seen broad reliance on one or two design handbooks or guides, we might be able to conclude that surrogates provide some continuity and source of commonality. Unfortunately, such was not the case.

Multidimensional Scaling / Smallest Space Analysis

Another way we can look at project participant overlap or isolation is by applying multidimensional scaling (MDS) to plot affiliation networks using smallest space analysis (Takane, Young, and de Leeuw 1977). Application of MDS to the affiliation networks will make similarities and differences between participants visible (Wasserman and Faust 1994). Using UCINET 5 (Analytic Technologies) (Borgatti, Everett, and Freeman 1999) we were able to convert affiliation networks into MDS. Non-metric multidimensional graphing is a method that allocates a set of points in k-dimensional space, such that the Euclidian distances among the points corresponds closely to a rank-preserving transformation of the input proximities (Borgatti, Everett, and Freeman 1999). If there were no affiliations between participants, all the points would tend to be equidistant from all other points. If all participants were tightly connected to all other participants, the plot would show a concentration at the diagram's center.

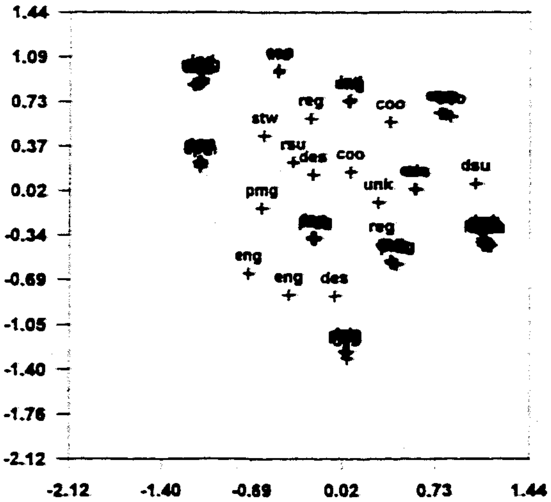

Figure 5-1. Non-metric multidimensional scaled plot of 64 participants in 14 projects across WRIA R. Data is from affiliation network. Designators are role codes (Appendix A).

It is immediately apparent from Figure 5-1 that most participants are located in ten clusters. The clusters in the upper left of the diagram are similar to each other, but substantially different from the clusters in the lower right quadrant. The fact that only ten clusters represent the fourteen projects is an indication that some projects do have substantial similarities in membership. Twelve of the 64 participants are located between project clusters, indicating their similarity to more than one project team. A small cluster exists at approximately the (0,0) midpoint of the diagram. These participants are most central to all projects, and include regulators and others who participate in multiple projects.

If we turn our attention to WRIA Z, the MDS plot is shown in Figure 5-2. We again see a few clusters that group participants that were solely involved in each of the four projects we studied. The outer "ring" of participants tends to include contractors (con) and technical specialists (tsp) who had contact with only one other participant in projects across the watershed. Towards the center of the plot we find the regulator, several landowners and other participants who tended to work across the watershed.

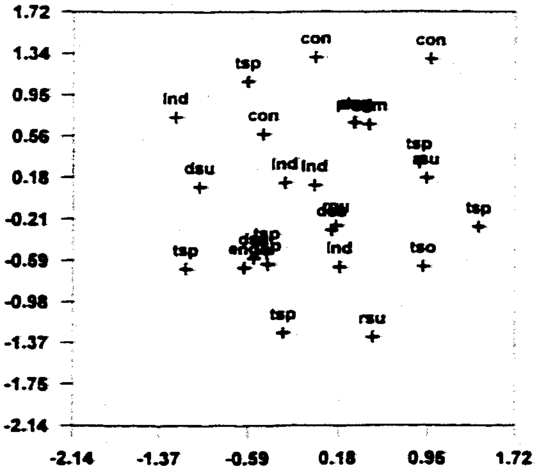

Figure 5-2. Non-metric multidimensional scaled plot of 25 participants in 4 projects across WRIA Z. Data is from affiliation network. Designators are role codes (Appendix A).

In the center of the MDS plot we find the regulator and conservation district coordinator among surrogates and other more widely participants. The cluster in the upper right at approximately (0.8, 0.8) includes participants in a project in a remote sub-basin of the watershed. The smaller space, generally between –0.6 and +0.9, that the WRIA Z participants suggests a tighter social community and less communication isolation across project groups.

CONCLUSIONS AND IMPLICATIONS

We found support for our characterization of instream habitat teams as following the collaborative model as described by Roberts (1991). The unifying purpose appears to be related to completing a project rather than pursuit of any one technical or societal objective. Participation at the project level is voluntary, except for mandatory regulator presence, and roles with respect to the project are readily apparent. The regulator appears to exercise free will as to how involved to get in project activities and decisions. Some regulators stayed pure to their regulatory role, while others embraced a more participatory approach. Role differentiation both at the project level and design decision making level indicates that organization exists. Collaborative decision making methods, most commonly negotiation, were used by 78% of the project teams. Teams appear to be relatively isolated from project to project within and across watersheds.

The role of surrogates in the form of design guides and regulatory documents was similar to that of natural person participants. The extremely low number of participants and surrogates that participated in more than two projects precludes any conclusions about how knowledge and experience is shared across projects and over time. Regulators, particularly the WDFW Area Habitat Biologists, and conservation district coordinators appear to be the most likely sources of cross-project information flow. Further study is needed to understand how knowledge and information flows.

CHAPTER 6: IMPACT OF PROBLEM FRAMING ON DESIGN OF FISH HABITAT PROJECTS IN STREAMS AND RIVERS OF WASHINGTON STATE

Design is among the basic human activities. Design is a method of intentional problem solving that results in new or altered solutions to problems that face individuals or society. A common feature of most design processes is an initial problem definition activity. Problem definition is an attempt to bring clarity and crispness to often ill-defined problem statements. Problem definition has been researched in fields such as policy analysis and management, but there has been little systematic research in definition of engineering and technical problems. Through processes of problem analysis and evaluation a problem situation is digested into a crisp statement of a specific problem to be solved (Majone 1980). Rein and Schon (1977) conclude that the output of problem analysis is "framing and naming." It is readily acknowledged that how a problem is defined or perceived by problem-solvers has a strong biasing influence on the ultimate solution (Christianson and Rohrbach 1986; Smith 1989). Although there has been considerable research into technical design methods, little attention has been given to the problem definition phase and its impact on downstream design activities.

The present study explores the nature of problem framing as part of defining design problems in the natural resources. Problem framing has been broadly explored in the fields of behavioral psychology, marketing and special interest group communication. While problem framing is accepted as an important method of biasing how people think about a problem, the impacts on engineering design have not been systematically studied.

Problem framing is an act of prejudicing the internal representation of a problem situation through the use of semantics or simplifying assumptions. Framing may be an internal activity when a participant in a problem situation creates their own interpretation of the problem. Framing may be external to a participant when a problem situation is presented to the participant in a certain light or with biasing descriptors. Wang (1996b) lists three types of framing effects: 1) those that affect one's willingness to accept or reject a risk, 2) those that affect how one labels or "codes" a situation or event, and 3) those that affect the persuasiveness of a communication between actors. In the context of the current study, all three framing effects may be present within and across projects.

Engineering design problems arise in one of two ways – assigned or self-discovered. Assigned problems are presented to a designer or engineer by a sponsor or problem owner. Frequently, the presentation of a problem situation by the problem owner includes framing statements. The problem solver assimilates the problem statements and frame presented to him or her, then either accepts the problem as stated or reframes the problem to better suit the skills, interests or prior knowledge of the designer (Schrader, Riggs, and Smith 1993). Alternatively, self-discovered problems are always internally framed by the problem solver since he or she is concurrently the problem owner.

Problem framing has been demonstrated in other fields to have a strong biasing influence on decision behaviors (Bierman 1989). It is an objective of the present study to explore and characterize the role and influence of problem framing on a particular type of engineering design problem.

LITERATURE REVIEW

The notion of problem framing has been explored across the fields of decision behavior (Kuhberger 1995; Miller and Fagley 1991), marketing (Bettman and Sujan 1987), interest group communication (Davis 1995a; Krogman 1996), artificial intelligence (Ford and Hayes 1991) and technical problem solving (Roth and Bowen 1993). The study of problem framing was pioneered by Tversky and Kahneman (1974; 1981). They demonstrated that decisions made under conditions of risk or uncertainty often have systematic errors when equal potential outcomes are presented in either a positive or negative manner, in spite of the decision maker having access to complete information (Tversky and Kahneman 1974). Their work led to the development of prospect theory (Kahneman and Tversky 1979), a concept that decision makers will maximize the perceived utility of a choice, and that framing has a profound impact on perceived utilities. Wagenaar and Keren (1986) concluded that problem framing includes the combined effects of internal and externally derived perspectives on a problem.

Within the management literature there are a number of studies on the role and effect of framing on decisions. Dunnegan (1993) verified the Tversky and Kahneman findings in his controlled experiments related to management decisions. Dunegan demonstrated that mental models about a problem situation were constructed by decision makers, and the models strongly biased subsequent decisions related to project management. A number of other management researchers independently found that semantic framing of problem situations had similar effects on risk propensity or aversion of managers faced with common business problems (Bazerman 1984; Highhouse and Paese 1996; Sitkin and Weingart 1995).

The concept of framing as a biasing influence pervades the disciplines of marketing and political action. In the marketplace, whether competing products are consumer products or just causes, framing (called *positioning* in the marketing literature) plays an important role in advertising (Bettman and Sujan 1987; Ries and Trout 1986). Activists (Davis 1995b) and special interest groups (Laumann and Knoke 1987) frame social problems for the media and policy makers in ways they hope will further their cause.

At times the effects of framing have been found to be unpredictable and erratic (Wang 1996a). Wang explored the events surrounding framing events and concluded that antecedent conditions either reinforced or minimized framing effects. Wang's findings suggest that culture, common experiences, business unit procedures and other environmental factors influence how problem solvers respond to externally framed problems. Roth and Bowen (1993) found that 8th- grade science students routinely framed field research problems in terms of prior experiences.

Framing-like behavior also has been demonstrated to affect communication and innovation within technical groups. Busby and Williams (1993) observed that different functional units of a manufacturing firm framed problems and cross-functional coordination issues differently, often as a result of managers' prejudices. Eisenhardt and Tabrizi (1995) studied processes of innovation in the computer industry and observed that "sensemaking" was an important factor in product development. Sensemaking is clearly within the scope of framing activities.

The question logically arises as to what the role of problem framing is with respect to engineering design and decision making related to the creation of artifacts. Although not concerned with engineering, Hogarty (1993) identified problem framing as the first of four steps in her concept of optimal decision making processes. Shrader et al. (1993) assert that experienced designers used mental models to make sense of problem situations, and those models influence how a new problem is solved. Curtis et al. (1988) hint at problem framing when they observe that early critical assumptions made by design teams about the variables that were at play in a problem could explain success versus failure of design projects. They found that more senior engineers who were placed in leadership roles tended to bring unstated, but important customer needs into engineering design decisions.

RELEVANCE OF FRAMING TO ENGINEERING DESIGN

Broadbent (1979) explored the applicability of Kuhn's ideas about paradigms (Kuhn 1962) to the field of design. Broadbent notes that designers are subject to the same sorts of group pressures that scientists face. Engineering designers tend to receive similar education in creative and design methods, read the same journals and have interconnected networks of influencers.

Designers have typically been trained and managed to maintain their objectivity by deferring judgment calls to the client (Davis and Johnson 1987; Glegg 1971; Pahl and Beitz 1984). The conditioned response on the part of engineers to accept client statements at face value is suspected to make engineers more susceptible to the effects of external problem framing statements. The present study explores how design problems are framed by sponsors and various participants, and how designers respond to framing.

RESEARCH METHOD

An ongoing empirical study is exploring how stakeholders influence decision-making by design teams in the natural resources. The current study focuses on design of fish habitat improvement projects involving small streams. Fish habitat improvement projects typically involve the design and placement of structures within the riparian area and stream channel. Design decisions include specification of material, specification of structure size and shape, location and distribution of structures along the stream, method of placement, and method of anchoring. Each of these design decisions is likely to involve technical as well as subjective analysis. Both the technical and subjective analyses are likely to be further influenced by beliefs and values held by various stakeholders associated with a particular project. It is further hypothesized that design decisions are influenced by how each project problem situation is framed to or by the design team.

The research was retrospective and covers a cross-section of Washington state projects which were issued Hydraulic Project Approval (HPA) permits by the Washington Department of Fish and Wildlife (WDFW) during 1997. The primary research method was a combination of semi-structured interviews, surveys and direct project inspection. Additional detail was collected from permit applications and documentary evidence provided by project sponsors. Data collection relevant to problem framing was organized around the following questions:

- How was the project purpose framed on the HPA permit application?
- How was the project purpose framed by the project manager and other key participants during interviews?
- What was the impact of problem framing on how design decisions were made?

- What was the overall influence of problem framing on project execution and outcome?

The study covered sixty-five in-stream habitat projects on thirteen watersheds in Washington State. Project size ranged from very small landowner-initiated projects to multi-million dollar public works projects. Ninety-seven individuals associated with the projects were interviewed by phone or in person. More than 30 project sites were visited so materials and methods could be assessed. Most site visits were guided by one or more project participants. Participant presence allowed unstructured exploration of reasoning behind many of the design decisions made by the project designers.

RESULTS

Data from the study of small-stream habitat projects suggests two different forms of problem framing. One form of framing is related to technical and functional objectives for the project. The other framing is a social problem type that sets the stage for communication among project participants. The two forms of framing appeared to be independent, and have different effects on projects and their outcomes.

Technical and Objective Framing

Technical and functional objective framing is common in engineering projects (Hausjah 1995). As shown in Table 6-1, we analyzed text of the Hydraulic Project Approval (HPA) permit to determine each project purpose as presented to approving agencies. Affinity processes were used to aggregate similar purposes into the twelve included in the table. Interview and site visit data was subjected to similar analysis. The richer data set from interviews and site visits allowed determination of primary and secondary technical purposes for most projects. Independent of whether a technical objective was primary or secondary, we attempted to also assess whether a purpose was a factor in making design decisions.

Table 6-1. Distribution of Project Purpose by HPA and Participant Interviews (n=65)

	Percentage of Projects			
Data Source	HPA Permit	Participant Interviews & Site Visits		
Purpose of Project	Stated Purpose	Primary Purpose	Secondary Purpose	Factor in Design Decisions
Conveyance	0	2	0	1
Develop Public & Private Works	11	6	3	7
Education	0	0	2	1
Fish Passage	0	3	0	2
Flood Control	0	2	0	1
Habitat	23	15	23	31
Mitigation	2	3	3	5
Modify Channel	2	3	0	2
Protect Private Property	0	8	2	6
Protect Public Works	0	8	0	5
Repair / Maintain	8	11	0	6
Stabilize Bank	46	17	11	20
Unknown	9	23	25	14
None	-	-	32	-

The "conveyance" category includes projects intended to speed the flow of flood waters through the project area. "Develop public and private works" combines activities by public agencies, developers and private land owners who are doing instream work incidental to other construction projects. "Education" objectives included public education about natural resources, stream processes and the like. "Fish passage" projects attempted to remove barriers to migration for salmonids. "Flood control" projects include protection of nearby property by dikes or preventing channel meander. "Habitat" projects generally involve the construction of hydraulic works or placement of materials for the purpose of creating fish habitat. "Mitigation" is the construction of habitat to offset human-caused damage to the environment. "Protect public works" objectives are indicative of projects meant to protect roads and bridges, well sites or other public infrastructure. "Repair / maintain" includes projects to repair storm damage to previously installed projects or to conduct routing maintenance to such projects. The "stabilize bank" category was assigned to projects meant to prevent bank erosion, sediment delivery, etc. Projects were assigned to the "unknown" category when it was impossible to discern one or more project objectives. The "none" category is used only for projects were participants did not identify a secondary objective.

The data allowed a project-by-project comparison of how well the participant's description of project objectives matched those stated on the HPA documents. A total of 47 projects could be compared. For 37 of the projects the descriptions of objectives generally agreed and for ten of the projects the descriptions were materially different between the permit wording and participant descriptions.

Along with comparison of permit objectives with those synthesized from interviews and visits, we compared descriptions of technical objectives across participants in a project. The participants may have used different words, but generally agreed on the primary objective for 25 of the 32 projects for which multiple interviews occurred. Participant descriptions of project objectives diverged substantially for the remaining seven projects.

During site visits, the researchers were able to probe for explanations as to the differences between permit objectives and participant objectives. Fairly consistent reasons for variation between how project purposes were stated in different forums were heard. All were clearly framing statements to have an impact on selected audiences.

1. Permit wording was chosen to secure positive review of the permit. If a project could be framed as a habitat project, it was perceived to receive less regulatory scrutiny than mitigation projects. Permit wording avoided the use of "red flag" words that were known to the applicant to trigger internal or regulatory scrutiny. For example, many agency and non-profit projects that involved a willing private landowner made no mention of property protection goals in the permit applications in order to fall within the scope of conservation and habitat enhancement program priorities. It was well-known that conservation and habitat projects were exempt from certain

regulations, while bank stabilization, civil works and property protection received much more detailed agency review.

2. Permit wording was chosen to appeal to funding sources internal or external to the applicant. If the project was to be funded out of a roads maintenance budget then words such as "culvert" or "bank stabilization" were often used to ensure the project was perceived to be within the scope of the roads budget even if such elements were incidental to a primarily habitat project. Project participants readily admitted to including or omitting project objectives from their permit applications in order to gain financial support from funding or cost-sharing sources.

3. Project manager/coordinator statements of project purposes frequently reflected the interests of the project execution organization and the landowner upon whose property the project was happening.

4. Regulatory fisheries biologist statements of project purposes typically represented what they perceived to be the dominant objective or constraint that controlled design decisions. Regulatory biologists also tended to frame projects as either *enhancement* or *mitigation* projects (more about that later). Interview notes suggest that regulatory fisheries biologists were unusually perceptive about identifying the "real reason" for projects. Hence, they fairly quickly were able to frame projects as enhancement or mitigation in spite of multiple stated objectives.

5. Private landowners almost universally framed projects as property protection in one form or another. They also tended to be supportive of habitat creation being an important collateral objective. It appeared that most private landowners placed substantial sentimental or aesthetic (quality of life) value on the streams that crossed their properties. The ultimate designs tended to balance landowner needs for property protection that might suggest a rock lined ditch with their needs for naturalness that might suggest more natural looking design and materials.

Differences in technical and objectives problem framing by different participants in a project appeared to be a function of perspective, role and/or stake. Such differences in framing are similar to the findings of Hausjah (1995) who explored engineering projects and Smith(1989) who explored management problem solvers.

The impact of problem/project purpose framing on how design decisions were made was also evident from the interviews and site visits. Framing conflicts appeared to be the root cause of most serious debates and disputes among project participants.

Communication and Negotiation Framing

We looked for indicators that the habitat problems were being framed in ways other than technical objectives. We analyzed the data to discover systematic positioning (Ries and Trout 1986) and message framing (Davis 1995a) that might affect design decisions. Positioning and message framing can readily be observed in data related to habitat enhancement vs. habitat as mitigation for other projects activities. We were able to assess such framing by considering how habitat features entered individual projects. If habitat was a primary objective, then the project is clearly enhancement motivated. However, if habitat was clearly a low priority objective or only included to achieve regulatory approval, then the habitat is clearly mitigation motivated.

Table 6-2. Incidence of problem framing as mitigation vs. enhancement.

	HPA Permit	Mitigation from Interview	Enhancement from Interview	Unknown
Problem Frame	Number of Projects			
Mitigation	2	2	0	-
Enhancement	15	3	10	2
Other	48	36	7	5
Number of Observations	65	41	17	7

In Table 6-2 we can see that only two of the 65 HPA permits discussed the project objective as being mitigation for other in-stream activities. Interviews confirmed the accuracy of the permit framing. Of the 15 projects that were framed as enhancement on the HPA permit, we could confirm that enhancement was an objective of ten of the projects. Three were clearly mitigation, and for two the data was inconclusive. When we pool the data for all other project purposes as stated on the HPA permit, we find habitat was included only as mitigation in 36 of the 48 projects. Habitat was an unstated, yet core objective on seven projects. For the remaining five projects the data was unavailable or inconclusive.

Table 6-3. Framing Effects on Decision Methods (Not all projects could be classified as mitigation or enhancement driven)

Decision Method	All Projects (N=50)		Habitat as Mitigation (N=30)		Habitat as Enhancement (N=15)	
Collaborative	# of Projects	% of Projects	#of Projects	% of Projects	# of Projects	% of Projects
Negotiation	29	58	21	70	6	40
Consensus	1	2	1	3	0	0
Collaboration	8	16	5	17	1	7
Goal Driven	1	2	0	0	1	7
	sum = 39	% = 78	sum = 27	% = 90	sum = 8	% = 53
Non-collaborative						
Experience	7	14	2	7	5	33
Deference	1	2	0	0	2	13
Consultants	3	6	1	3	0	0
	sum = 11	% = 22	sum = 3	% = 10	sum = 7	% = 47

DISCUSSION

Problem framing behavior was relatively easy to decipher from key words used in documents and interviews. Tversky and Kahneman (1981) assert that how a decision maker frames a problem is a function of how the problem is formulated and internalized. They observe that most problems can be framed in more than one way, predominantly due to different perspectives held by decision makers. The data from the present project clearly show that project administrators and sponsors frame projects by functional objectives attractive to permit reviewers, funding agencies and others outside the project team whose support is needed. At the same time, it is apparent that project team members and direct participants frame the functional objectives of habitat projects to match their own perspectives on the problem and its context.

If we focus on framing as mitigation vs. enhancement, the data shows that how a project is framed by most of the participants affects decision methods used by the design team. Negotiation was the decision-making method in 70 percent of all projects and 90 percent of the mitigation-framed projects. In contrast, delegation and deference to experience was the primary design decision method in 16 percent of all projects and 47 percent of the enhancement projects. A possible explanation for these disparities might be that mitigation projects tend to have many areas of conflict within the design, while participants in enhancement projects tend to let the experts prevail.

It was not apparent from the data that framing systematically affected the scope or detailed design of habitat features within projects. Some mitigation projects included extensive habitat features, while some enhancement projects included minimal habitat content. Of higher impact appeared to be personal philosophies toward the meaning of key words such as *enhancement* and *mitigation*. To some key project participants the use of the term mitigation meant "no net loss of habitat from the current project primary purpose" while others interpreted the term in ways that gave them license to negotiate and argue for maximum habitat content. Similar differences in attitude were found in enhancement projects. In some cases key project participants saw no purpose in exceeding the minimum expectations of funders, while others worked aggressively to maximize the habitat content per dollar of funds available.

Although none of the project design teams followed a formal design process, we looked at the project data to see how well it fit into established engineering design models. The data best fits the case based design models. Project participants discussed the problem in pairs and small groups, proposed an apparently viable solution based on group knowledge of past successes and failures, and evaluated its merits during the approval and execution phases. In 17 of the 36 projects for which data was available, alternatives were considered for at least one habitat feature of the project. Alternatives were rejected for aesthetics, economic and/or logistics reasons.

An attempt was made to fit the data to the ASE (assess, synthesize, evaluate) design model. Although there was considerable discussion about the problem, there was no evidence of creative synthesis, novel solutions, nor was there any sort of formal evaluation of alternatives. The alternatives that were considered in the 17 projects were alternatives were considered were all previously known to project participants.

We also fit the data to axiomatic design (Suh, 1991) and the author's derivative Appreciative Design (Dooley and Fridley, 1998) models. We were able to state the project purposes as independent functional requirements and constraints. Project features were restated as design parameters. For mitigation projects, we sought to discover if the project outcome could be better explained when the primary purposes were both stated as functional objectives versus having the habitat purposes only stated as a constraint. The analysis is inconclusive, probably due to the fact that tended to approach the problem as a messy whole and attempted to arrive at a wholistic solution. Another possible explanation is that different project participants framed the problem differently. What one participant called a functional requirement, another participant called a constraint. There were no processes nor perceived needs to resolve conflicting objectives/constraints.

Another possible explanation for the difficulty of seeing how initial problem framing affected project outcomes is that project participants interact at multiple levels from policy making to detailed design decisions. It is plausible and expected that a constraint at a policy level decision might reemerge as a functional requirement at a detailed design level decision. The retrospective nature of the present study did not allow exploration of how decision making played out over time during project planning and design.

In a few cases we were able to have a discussion with a key project participant about problem framing and the axiomatic design method. The general reaction was that having an understanding of framing and seeing a problem as a set of objectives (FRs) and constraints would help them in future projects. The limitations of such education and process are that:

1. There aren't time or resources for education and team building,
2. The participants in a project are unpredictable in number and membership over time,
3. Many of the project participants are not "processes oriented" and have no tolerance for process activities, and
4. Turnover among project participants, particularly landowners and sponsors, within a watershed from year-to-year is very high, meaning an high cost for annual education events.
5. There are no natural forums for delivering education on framing and design process to all current and near-future project participants; hence, the logistics of delivering timely education for both the educator and student are challenging.

CONCLUSIONS AND CARRY-FORWARD MESSAGES

Problem framing was prevalent in the projects studied. Two kinds of framing behavior were noted. One form of framing created labels for project functional objectives. Functional objective framing appeared to be intentional for the purposes of affecting project funding and regulatory approval. The other form of framing was more to establish negotiating positions or otherwise affect communication among participants.

Framing has the potential problem in collaborative teams of creating both errors of omission and errors of commission. Technical and engineering professionals whose role in a project is limited, and whose communication is channeled through their direct client are likely to see the project as their client sees it. There are few, if any, vehicles for independent assessment of the problem and its context. The narrow window into the project and team creates a risk that a partial solution might be proposed in ignorance or an elegant solution to what others perceive to be the wrong problem is proposed. In both cases the engineering or technical professional's reputation suffers.

A more formal study of framing effects on a limited number of project designs is encouraged. Important research questions include:

1. How is the problem situation and context framed to each engineer and technical professional involved in a project? To what extent is the information complete or narrowly framed subset of the complete picture that matches the biases of the professional's direct client?
2. To what extent do participating engineers and technical professionals seek to discover alternative framing by other core project participants?
3. To what extent do engineers and technical professionals develop and use an internally developed frame that differs from that of their client?
4. How is framing traceable to actual project design decisions? What decisions would have had different outcomes if framed according to another project participant's viewpoint?

Engineering and technical professionals would benefit from education in framing behavior and its effect on project definition and solution. Professionals need to be able to recognize framing behavior and work through alternative framings as they assess the problem at hand and how they might contribute to its solution. In many cases, the professional who understands framing and its impact on decision outcomes, may use that knowledge to negotiate solutions that are globally better for all project stakeholders.

CHAPTER 7: OBSERVATIONS ON THE APPLICATION OF SOCIAL NETWORK ANALYSIS TO MAKE SENSE OF DESIGN AND PROJECT TEAMS

There are a number of fundamental paradigms about the nature of engineering. The dominant paradigm of the past forty years has been that engineering is objective, deterministic, and outside the influence of value systems and societal pressures (Vincenti 1991). A counter-movement has developed over the past two decades to suggest that engineering is as equally influenced by social processes as any other decision making activity (Pinch and Biiker 1987; Simon 1981; Sladovich 1991). While the notion that design is a social process is not yet mainstream, it is receiving increasing attention among theory-builders and design tool developers (Braha and Maimon 1998). A premise of the present research program is that design in the natural resource field *is* a social process, thus is subject to influence from bias, values, negotiation and all other social dynamics.

During the past two decades, a number of important studies were conducted to understand and improve team approaches to design, including cross-functional and concurrent engineering teams. Bucciarelli (1988) (1994) studied the inner workings of design firms and concluded that design is a collaborative social process, with the outcome being a blend of designer worldviews. Ullman drew upon his experience as a designer and educator to propose design processes that reflect how teams of product designers actually approach problems and make decisions (Ullman 1992). Smith and his associates studied how design problems were approached in manufacturing firms (Eppinger et al. 1994; Hausjah 1995; Smith and Eppinger 1995; Smith and Hausjah 1996). The emphasis in each of these prior works was to discover the inner culture and norms of an engineering or business subgroup. A few authors have studied communication and conflict between new product development groups and other parts of the firm (Dougherty 1992; Pelled and Adler 1994). These authors looked at counterproductive behaviors that correlated with lack of project success and then suggest ways to minimize the effects.

Most previous studies have focused on design teams with limited membership, and identification of counterproductive behavior in the hopes of discovering ways to improve corporate culture and management. The present study is a departure in that it focuses on cross-organizational design teams and successful (or at least seemingly successful) project outcomes. Another departure from most engineering design research is that the present study explores projects where engineers are a minor factor, both numerically and team-wise, in the design activities.

Team approaches to design are predicated on the belief that conversation, multi-perspective debate and group dynamics will result in better decisions being made than could be made by individuals working in isolation or in serial on a design project. Bucciarelli characterizes the team approach to design as a "social process of negotiating and consensus somewhat awkwardly expressed in the final product" (1994, p. 20-21). Tom Brown (1992) is more optimistic when he observes that the value of team processes comes from a sense of common purpose, willingness of team members to listen to each other and resolve inevitable conflicts, and a "true sense of synergy." Patrick Brown (1991, p. 23) adds to T. Brown's view when he observes that the richness of team approaches to design arise from the facts that 1) each team member brings special knowledge about his or her functional specialty, 2) each team member will hear a common sense of product requirements, and 3) collective understanding of design alternatives and decisions will allow individual members to identify early-on the potential for downstream problems in their own functional areas.

How team members approach decisions within the team environment is a function of 1) the social organizations from which team member are from, 2) the cultural background of individual members, 3) the personality of each participant, and 4) each participant's worldview (Checkland 1981), thought world (Dougherty 1992) or perceptions of the team situation (Bertrand 1972). The challenge of doing design in the natural resource field is that project teams necessarily are comprised of representatives from many different organizations, each bringing a personal set of biases, motives and expectations. An object of the present research is to characterize how design is actually done in the context of an exemplary natural resource engineering problem, and hopefully discover insights about how to improve the performance of engineers who are participants or leaders of future design projects.

OBJECTS OF THE CURRENT STUDY

The objective of the current study is to better understand the dynamics of design teams where the team is comprised of persons representing multiple organizations and interests. Such design teams are increasingly common in industry where regulators, vendors, outside fabricators, customers and others are all included in, and often numerically dominate, product design teams. In the natural resource industries, complex design teams are becoming the norm. In our project, we set out to explore the social network surrounding the design of technical components of select design projects, and how the participants in the social network influenced the specification of design parameters. We were particularly interested to discover new insights by applying the tools of social network analysis to project teams.

EXEMPLARY PROBLEM

An increasingly common design problem facing engineers and managers in the natural resources is salmonid habitat improvement and restoration. Stream habitat improvement projects necessarily involve collaborative efforts of landowners, agencies, contractors and various special interest groups. Many of the projects are initiated by agencies or interest groups other than the landowner. When someone other than the landowner initiates a project, the stream corridor landowners are recruited or otherwise brought into the project. In other cases, landowners initiate habitat improvement projects for their own benefit, then bring agencies and other interests into the project to share costs, provide labor or provide political support favorable to gaining project approval by regulatory agencies.

Stream improvement projects are generally accepted as having competing interests of flood control, habitat enhancement, landowner uses, recreational demands, etc. Thousands of small projects have been executed across the United States in the past decade. At least several hundred small stream projects have been conducted in the state of Washington. Through the collective experience of many projects, it appears that identification of interest groups, development of communication linkages, and establishment of norms for involvement are showing signs of maturity. Affiliation and communication networks involving project designers and stakeholders may be well established in some regions of the state.

METHODS

Social network analysis (Gartner and Wagner 1996; Knoke 1990; Marsden and Lin 1982; Wasserman and Faust 1994) provides a useful, and established method to characterize relationships between all of the participants in a design project. A social network is a set of actors who are linked together by affiliation, communication or other social trait. Social network analysis is a structured process for investigating and describing the relationships between members of a social network (Wasserman and Faust 1994).

We would expect participants who have the most direct communication with other to exert higher levels of influence on design decisions than participants who have indirect communication channels (Freeman 1978). We are also able to use Social network analysis to explore the centrality of participants by role and the agency they represent. Thus, we are able to concurrently study individual, role and agency factors.

A point of departure from conventional social network analysis is that we consider the role of participant surrogates as part of the social network. Surrogates fit within the broad social network definition that includes actors and relationships between them. Surrogates are likely to include non-participating-stakeholder reputation, regulations, reference materials, and legacy effects of past direct involvement. Surrogates may have the same or stronger effect on design decisions than direct personal stakeholder connections.

Surrogates are expected to drive perceptions and beliefs on the part of core team members and the problem owner that form an important basis for judgment of the utility for alternative design parameters (Checkland and Casar 1986; Checkland and Scholes 1990).

Each of the members of the core design team and the project sponsor (collectively called "research subjects") were mailed an introductory letter, then contacted by telephone and asked to list all of the people they were aware of who either participated in, influenced or otherwise contributed to design decisions. Research subjects were also be asked to list key references and other surrogates. A compiled listing was reviewed with each research subject to prompt addition of missing individuals, entities and surrogates. Additionally, an attempt was made to contact all other participants with a telephone call and/or mail survey instrument to solicit their input on roles, relationships and communication linkages.

The data is summarized in an adjacency matrix (Wasserman and Faust 1994) of the form shown below. All research subjects plus all influencers, participants, stakeholders and surrogates (IPS&S) are listed along both axes of the matrix. Where no acknowledgment of participation existed a "0" is entered in the corresponding cell. Where acknowledged participation existed between pairs of participants a "1" is entered in the corresponding cell. The diagonal a-a ... n-n represents communication between a participant and itself so a "1" is entered in the corresponding cell.

Table 7-1. Hypothetical Communication Matrix for Design Team

Actor	a	b	C	d	e	f	g
A	1	1	1	0	0	0	0
B	1	1	1	0	1	0	1
C	1	1	1	0	1	1	1
D	0	0	0	1	1	1	0
E	0	1	1	1	1	1	0
F	0	0	1	1	1	1	1
G	0	1	1	0	0	1	1

In the above hypothetical communication matrix the core design team and sponsor are actors a, b, and c. Stakeholders, influencers and others are represented by actors d, e, f and g. Careful study of the matrix shows that the core team members are well connected with each other. Actor a is not connected to anyone outside the core team. Actor d is indirectly connected to the design team through actors e and f.

An easier-to-follow portrait of the same data would be to draw a sociograph (Wasserman and Faust 1994) of the form shown below. Each actor is assigned a node and links between nodes represent lines of communication.

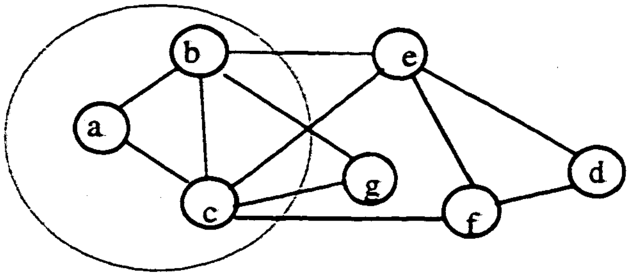

Figure 7-1. Sociograph of the data presented in Table 7-1.

The sociograph makes it more apparent that actor d is not as isolated as might be concluded from the communication matrix. Actors d, e and f form a triad and potential coalition with two lines of communication into the design team.

Social network analysis is readily executed with the assistance of two specialized software packages. UCINET (Borgatti, Everett, and Freeman 1992; Borgatti, Everett, and Freeman 1999)] (Analytic Technologies) appears to be the social network analysis tool of choice for determining the centrality of participants in a social network (Wasserman and Faust 1994). UCINET has the capability to measure centrality, connectivity and positions of subgroups. The software also has statistical routines to do network hypothesis testing, conduct multivariate analysis and do matrix algebra. KrakPlot (Krakhardt et al. 1995) (Analytic Technologies) is a social network visualization program that reads UCINET files to produce corresponding network diagrams. KrakPlot automatically organizes network nodes based on multidimensional scaling and simulated annealing techniques.

METHODS

An ongoing empirical study is exploring how stakeholders influence decision-making by design teams in the natural resources. The current study focuses on design decisions related to fish habitat improvement projects involving small streams. Fish habitat improvement projects typically involve the design and placement of structures within the riparian area and stream channel. Design decisions include specification of material, specification of structure size and shape, location and distribution of structures along the stream, method of placement, and method of anchoring. Each of these design decisions is likely to involve technical as well as subjective analysis. Both the technical and subjective analyses are likely to be further influenced by beliefs and values held by various stakeholders associated with a particular project.

The research is retrospective and covers Washington state projects which were issued permits by the regulatory agencies during 1997. The primary research method is a combination of semi-structured interviews and surveys. Additional detail is collected from permit applications, documentary evidence provided by project sponsors and reports in the media. Data collection revolves around the following questions:

1. What was the design objective (functional requirement) that you were striving to achieve through ... (specification of material, choosing method of placement, etc.)
2. Who contributed to or influenced the design process and decision?
3. What were the constraints on how you achieved the objective?
4. Where did the constraints come from?
5. What was the range of alternatives you considered?
6. Where did the alternatives come from?

7. What constraints and alternatives were consciously kept off the table?
8. What was the social network that surrounded the design phase of the project?

The study sample was drawn from project sponsors who received Washington State Department of Fish and Wildlife Hydraulic Project Approval (HPA) permits in 1997 for in-stream habitat improvement projects. A total of 65 projects were studied in thirteen watersheds (WRIA) of the state. Over 90 persons participated in structured telephone interviews and more than 30 projects were visited. More than 250 unique participants were identified and mapped using social network analysis methods. Each participant was identified with a unique identifier. The projects they participated in, their roles and affiliations were associated with each participant identifier.

RESULTS

The data and discussion presented here represents a comparative subset of the data collected. Data is from one rural eastern Washington watershed (designated WRIA **Z** in the coded data) which had four projects in the study and one suburban western Washington watershed (designated WRIA **M** in the coded data) which had fourteen projects in the study. There were other watersheds with many more and many fewer projects. Complete results are presented elsewhere (Dooley 2000).

Projects in the two watersheds were similar in objectives and scope. Most projects combined property protection with habitat enhancement. The number of design participants in projects from WRIA Z ranged from three to six and from WRIA R ranged from one to eight. Engineers in both watersheds typically played analytic and resource professional roles.

A focus of the present study is to explore the additional understandings of team and design processes that social network analysis can provide. Structural analysis of social networks at the watershed level allows us to determine the central or peripheral positions held by engineers and others involved at the project level. In Table 7-2 we show three measures of centrality for each of the eighteen distinct roles present across project teams. The data has been symmetricized and normalized with UCINET routines.

Table 7-2. Social Network Analysis of Project Leaders and Engineers – Mean Values

	Degree		Betweenness		Closeness	
	Watershed		Watershed		Watershed	
Role	R	Z	R	Z	R	Z
Administrator	-	17	-	0	-	50
Construction	1	6	0	0	3	39
Coordinator	2	-	0	-	3	-
Designer	2	25	0	3	4	54
Design Surrogate	2	17	0	1	4	42
Engineering Design	2	-	0	-	4	-
Engineering Analyst	2	33	0	5	3	56
Engineer / Project Mgr.	8	-	0	-	4	-
Field Supervisor	2	-	0	-	2	-
Landowner	2	16	0	4	4	48
Project Manager	8	25	7	4	4	53
Regulator	6	-	9	-	3	-
Regulator / Guidance	-	75	-	63	-	80
Regulator / Surrogate	6	6	21	0	5	46
Sponsor	2	-	0	-	4	-
Steward	2	-	0	-	3	-
Technical Specialist	2	19	0	3	3	50
Unknown	1	-	0	-	3	-

Designers and design surrogates are fairly central, yet engineering designers are not present or peripheral. The only engineering role with any degree of centrality is that of engineering analysis, which has structural position similar to that of other technical specialists. This finding led us to further explore the source of high designer centrality, and who occupied that role. We found that the role of designer was assigned to persons whose primary contribution to the project was selection of materials and their arrangement. The role was held by persons with all levels of experience, training and non-project societal role. At times the role was held by an engineer, but other project participants did not look to that person to contribute what they considered engineering knowledge to the design process. It is significant that the designer role and the normative behaviors associated with it are very different within the engineering community as compared to that held by these multi-agency, multi-interest project teams.

Beyond the tabular metrics for centrality, we can apply graphical techniques using multidimensional scaling to role affiliation data to map the relationships between role holders. A simple graphical model is to draw a proximity matrix (Borgatti, Everett, and Freeman 1999) that uses smallest space analysis to arrange all participants in the network according to their relative proximities and proximity to the most central participants. The multidimensional scaling (MDS) plot shown in Figure 7-2 for WRIA R maps all participants based degree of similarity (closer together) and differences (farther apart).

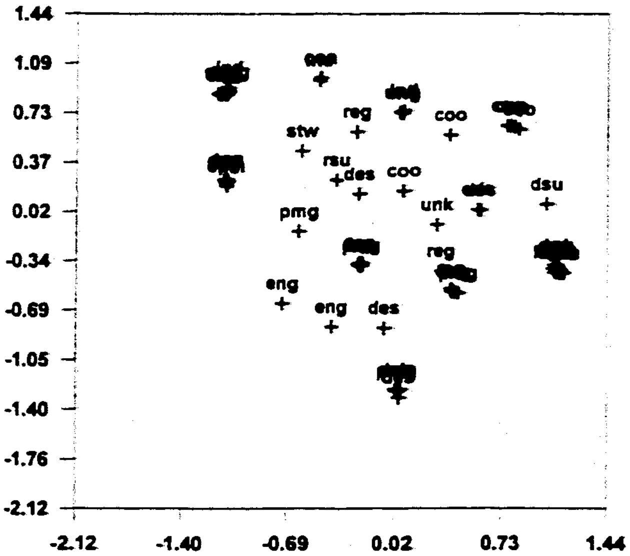

Figure 7-2. Nonmetric multidimensional plot showing smallest space analysis for roles across all projects in WRIA R using affiliation matrix data. (N=64)

What is immediately observable is the clustering of participants into project cliques. In between the clusters are regulators, coordinators and a few other participants who are present in multiple projects. An important use of MDS plots is to identify those roles and persons which are in between project cliques. From the plot, and its associated numerical table, we can readily identify from the population of 64 total participants the 14-16 persons whose roles appear to cross project lines.

The next two MDS plots, Figures 7-3 and 7-4, allow us to explore the implications of pursuing data at increasingly deeper levels. The data used to create Figure 6-2 above was drawn from 18 interviews and 14 permit documents. We were unable to obtain addresses to allow a survey of all 64 participants from WRIA R so we could develop a complete communication matrix. However, during the interviews and site visits across WRIA Z, participants indicated a willingness to participate in follow-on surveys, and to provide contact information for others they knew were involved. Figure 7-3 is based on data from ten interviews and four permit files. The WRIA Z data set includes twenty identified participants, including surrogates.

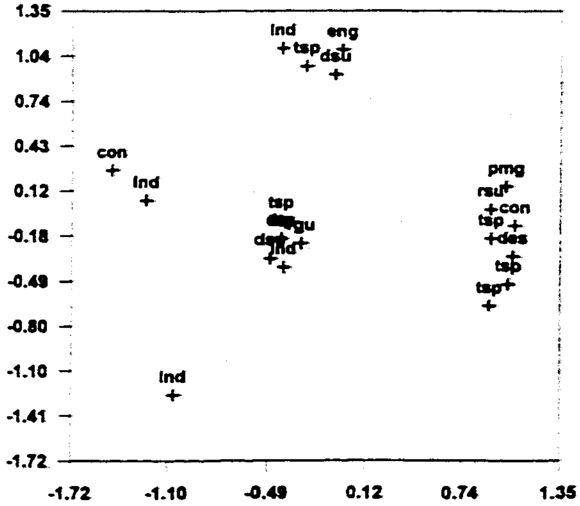

Figure 7-3. Nonmetric multidimensional plot showing smallest space analysis for roles across all projects in WRIA Z. (N=20)

In Figure 7-3, we see twenty participants involved in four projects. A number of social relationship differences are immediately apparent. There are three clusters and a few participants who are far remote from any project. Inspection of the raw data suggests that the outer two clusters align with projects in three sub-basins of the watershed. The group to the right of the plot are associated with two neighboring projects. The cluster in the center of the plot includes regulators, technical specialists and others who worked across the watershed. The landowner (lnd) in the lower left corner was a neighbor to one project and was informed of, but not involved in any project decisions.

After we analyzed the interview and permit document data, we mailed a communication and influence survey to all WRIA Z project participants. In the survey we listed all the participants and asked respondents to mark those who they worked with on one of the projects in our study. We also asked them to identify natural persons and surrogate sources that influenced how they thought about habitat projects. The "everyone-by-everyone" survey was mailed to the thirteen natural persons identified in earlier research. We received eight responses, including three from persons who were not interviewed. The surveys identified five "new" participants which were subsequently added to the communication network. Four of the five were natural persons and one was a surrogate. The survey results are shown below in Figure 7-4 for communication network and Figure 7-5 for the influencer network.

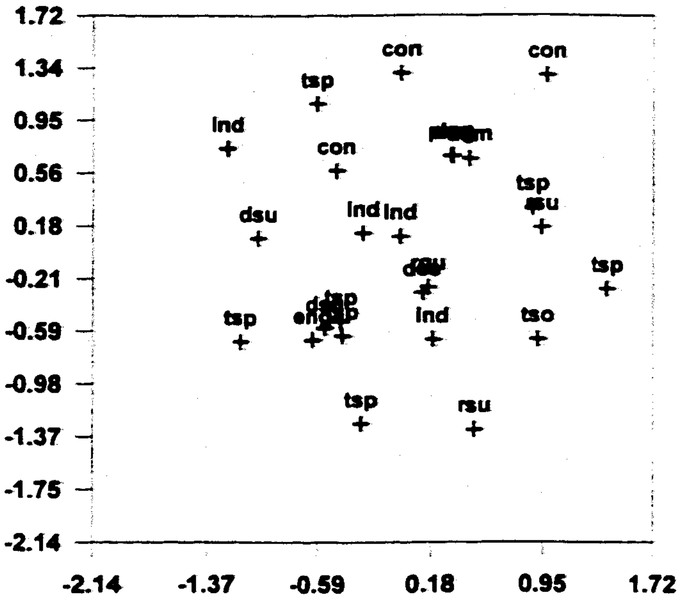

Figure 7-4. Non-metric multidimensional scaling plot of affiliation matrix for WRIA Z including participants identified during final survey. (N=25)

Comparing the MDS plots from Figure 7-3 to Figure 7-4 we can see that additional data results in a more complex plot. All but one of the added participants were connected to only one other participant. Two persons noted that a representative from a federal water agency was involved in their project teams, but was missing from earlier data sets. No new technical specialists or engineers were identified during the follow-on survey.

New data that was collected during the follow-on survey was an attempt to identify influencers and influencer communication networks. Survey respondents identified those persons and surrogates "that have influenced how you think about stream enhancement projects." We then used that data as a filter to create a communication matrix that just included influencers. Our objective in this analysis is to determine how well connected the influencers are to each other.

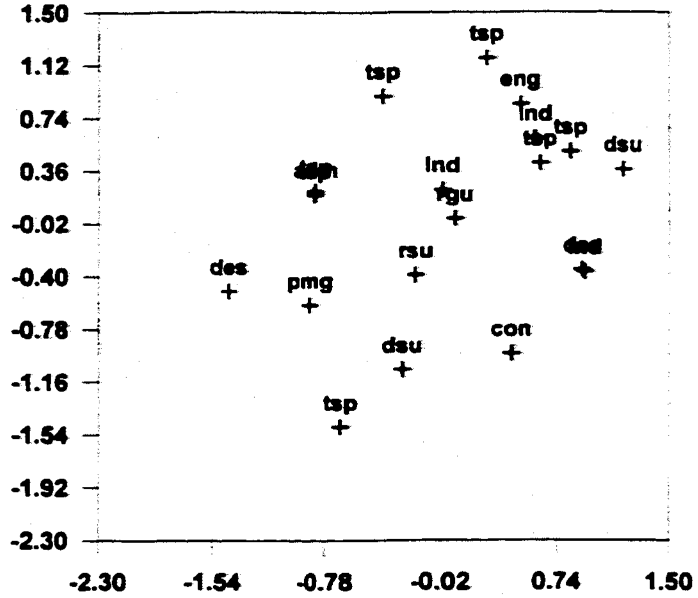

Figure 7-5. Non-metric multidimensional scaling plot of communication network among influencers from WRIA Z based on final survey data. (N=20)

The MDS plot shows one particularly interesting group feature worth commenting upon. In the upper right corner are a set of influencers who happen to be affiliated with a major federal conservation agency. They are relatively well connected to each other but distant from others in the communication network.

Influencer centrality can also be measured by closeness measures using the same methods we used earlier to identify role centrality. A social network was developed that just included the influencers identified by participants of WRIA Z. Analysis of the network may provide clues about how information flows between and among persons in positions of influence. The data in Table 7-3 has been normalized and symmetricized within UCINET.

Table 7-3. Centrality measures for influencers involved in projects across WRIA Z.

		Range of Values Across Participants Holding Role			
		Degree		Closeness	
Role	N	Influence	Participant	Influence	Participant
Administrator	1	17	17	15	50
Construction	3	0-4	4-4	4-15	34-47
Designer	1	8-13	21-29	15	52-56
Design Surrogate	1	8-17	17-17	15-15	41-42
Engineering Analyst	1	29	33	15	56
Landowner	4	0-17	4-21	4-15	35-53
Project Manager	1	17	25	15	53
Regulator / Guidance	1	71	75	16	80
Regulator / Surrogate	2	0-8	4-8	4-15	45-47
Technical Specialist	7	0-29	8-33	4-15	39-57

Table 7-3 shows that project design influence can come from persons holding many different roles. The table displays degree centrality among a network that just includes influencers and another that displays normalized centrality within a network that includes all participants. Within the influencer community, the central actors tend to hold the roles of engineering analyst, regulator and technical specialist. The influencer community degree centrality data is similar to the position of the influencers in the broader participant communication network as displayed in the "participant" columns.

If we look at the closeness data, a slightly different pattern emerges. Closeness is a measure of how many intermediaries messages must pass to get to all other members of the social network. We discover that influencers have low scores for closeness to other influencers, yet relatively high scores for connection to the population of project participants. This disparity suggests that influencers operate in different social circles from each other.

CONCLUSIONS AND CARRY-FORWARD MESSAGES

Social network analysis facilitates the explanation of features of design teams that may not be readily apparent or measurable using other analytic techniques. While one might suspect that engineers are more peripheral than central, surveys asking project participants to place the engineers on a linear Linkert scale (Dillman 1975) from "central" to "peripheral" might not fully measure the context in which engineers participant on design teams. Social network analysis appears to allow rapid assessment of team structure and dynamics on multiple levels and multiple dimensions.

There are a number of implications for engineering educators and scientists. Team members come from a multitude of agencies and interests, each with a set of motives and objectives that need to be considered during design decision making. Technical specialists, including engineers and non-regulatory biologists tend to be on the periphery of design teams rather than central. The combination of diverse team membership and peripheral roles for engineers and technical specialists presents a type of working relationship that few technology professionals are educated to deal with.

Elsewhere in the ongoing research project, we learned that fish habitat design teams do not follow structured processes for design, decision making and documentation of decision logic. Adding the lack of structure to the mix is likely to contribute to high discomfort by engineers and other professional technologists. Anecdotal evidence from the interviews and site visits confirmed that technologists were often uncomfortable with their peripheral role as information resource or analyst. Other team members felt challenged when engineering participants attempted to impose structure on the design process.

The implication for engineering and technology professions educators is that students need to be better exposed to team processes where the professionals are part of "someone else's" project, and the someone else has a non-technical background. Current teaching assumes that the scientist or engineer will assume leadership and control of decision process and lead those without technical training to make good technical design decisions. The present research suggests such an approach is a recipe for conflict and isolation.

Engineers and other technology participants need to be prepared to enter teams that are amorphous both in time and membership. Team members do not participate in group sessions to "come together" as a team, develop team behavioral norms, common processes, etc. Teams in the fish habitat business are akin to pick-up basketball teams on a city open court. Everyone who enters the gates knows the basic game and has personal skills to contribute, yet may not know more than one or two of the other players on the court. Somehow, everyone finds a niche role to play within the first few minutes of action. Fish habitat design teams are comprised of members who are invited in, members who are imposed by regulatory role, and members who opt in through interest, sense of duty or other motive.

Social network analysis has the potential to add a dimension to engineering design and team process research. Tools and techniques drawn from the social sciences allow quantification and visualization of communication patterns, team dynamics and otherwise obscure networks of collective action.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

During the course of this project, we completed a first assessment of project and design teams involved in a contemporary natural resources design problem. Since this was a first assessment, the research was necessarily broader than deep. We are able to draw a number of general conclusions. Equally important, we are able to propose a set of research questions that are relevant to achieving a deeper understanding of how design is done in the natural resources. We can also make observations on how technical professionals and engineers might better prepare for their roles in collaborative project teams.

GENERAL CONCLUSIONS

1. Design of fish habitat mitigation and enhancement projects in Washington State involves many (typically four to seven) direct participants with diverse motives, agency affiliations, expectations and levels of design expertise.
2. Design problems are easily framed as mitigation, property protection, enhancement, and/or public works protection. More than one framing is often at work in any one project due to divergent interests of key participants.
3. Engineering and technical specialist participants are in the minority of team membership and typically on the periphery of design social networks.
4. Design decision making is a social process involving negotiation, brinksmanship, and deference to professional reputation and experience. Decision making tends to follow the collaborative model as developed by Roberts (1991).
5. Formal and traditional engineering design processes are not followed, in part because few design team leaders have training in engineering or design methods.
6. Social networks are weak both within projects and across projects within a watershed. Project design teams tend to operate a social isolates.

7. The central actors in rural watershed-scale social networks appear to be area habitat biologists and conservation district project coordinators. In larger western Washington watersheds, the area habitat biologists and, to some extent, fisheries enhancement group coordinators tend to hold central positions.

8. There is no evidence that stakeholders who did not actively participate in design discussions had any influence on design decisions. Hypothesis 1. that design decisions are influenced by stakeholders who are not team members is rejected.

9. For the one watershed where influence networks were mapped, the level of influence does not correlate with position in the social network, except for the most central actors. Several peripheral participants exerted substantial influence on design decisions. The number of design team participants was high, yet the social networks were weak, suggesting a broad participatory decision making process. It appears that influence can come from anywhere in the social network. Hypothesis 2. that level of influence on design decisions is related to stakeholder position in the social network is rejected.

10. Surrogates in the form of stakeholder policies, engineering design manuals, reference works, proceedings, and the like rarely were cited as influencing the design of fish habitat projects, even though over 75 such works were documented in a literature review (Dooley 1999). Design teams were aware of environmental, governmental and other special interest groups that were likely to take an interest in their projects, yet only those groups which had a representative on the design team appeared influence design decisions. In most cases, design leaders and other participants were ignorant of available design handbooks and reference materials. Where designer surrogates were cited, their influence was similar to that of other technical and engineering specialists involved as direct participants. Hypothesis 3, that stakeholder surrogates influence design decisions in ways similar to "natural" stakeholders, is accepted.

MANAGEMENT IMPLICATIONS

For Engineering Educators

Engineering students are trained and drilled in structured design methods and objective decision processes, yet there was no evidence of such processes being used in the projects studied. Students need to learn how to be effective as minority members of cross-functional and multi-interest collaborative teams. They further need to learn how to apply the "first principles" of design and engineering within non-engineering design processes models.

Engineers and other technical specialists are frequently on the periphery of social networks and design groups. In peripheral roles, engineering analysts and specialists are tasked to provide knowledge, advice and analytic results to support decision making by non-technical designers. Students need to learn how to assess a project situation, determine an appropriate scope for their involvement, and determine the most effective form for communicating their results to their client and the client's audience.

When engineers and other technical specialists participate as peers or resource professionals, their ability to influence outcomes depends upon mutual learning, persuasion, coalition building and other soft skills, rather than position power.

For Habitat Restoration Specialists

Habitat restoration specialists who are consultants or employed by governmental or non-governmental organizations are frequently expected to organize and lead projects. Effective project organizer/leaders appear to follow collaborative models rather than large group process models. Project participants have a low tolerance for group meetings and group decision processes. Yet, interactive communication among participants with multiple motivations and affiliations is a requisite for decision making.

The majority of projects (>70%) include habitat features as mitigation for other in-stream and riparian activities. These projects frequently include conflict between "no net loss" and "maximize habitat content" biases held by various project participants. Examples were found of creative use of habitat features that contribute to non-habitat functional objectives, yet improved habitat well beyond the no-net-loss state.

For Grant Givers and Program Managers

Project objective framing is highly complex and easily manipulated to make projects appear to be broader or narrower than the actual case. It should be no surprise that project objectives are framed in language thought to support approval and/or funding. Less well understood is that the *quid pro quo* of "willing landowner" and other critical participant involvement is addition of stakeholder-inspired functional objectives to projects. Project coordinators and leaders must be given sufficient guidance that they can make wise ethical and programmatic decisions about allocation of dollars and resources across objectives. Managers and sponsors should develop improved methods for supporting simultaneous solution of design problems that include multiple objectives.

For Extension and Outreach Specialists

Extension and outreach specialists must adapt their programs and information for the reality of multiple objective projects. Nearly all projects, whether the primary motive was habitat enhancement or mitigation, included multiple objectives.

Isolation and fragmentation of participants in habitat enhancement presents a major challenge for educators, researchers and agencies that desire to transfer knowledge to decision makers and influencers. We found no evidence of widely-shared resource materials, broadly attended seminars / workshops, common professional affiliations or other expected means of efficient knowledge dissemination. We found a lack of government agents whose primary task was habitat education and outreach.

Information exchange and knowledge diffusion across isolated project teams appears to fall on the shoulders of the few agents who are necessarily involved in multiple projects due to regulatory or funding agency roles. Area habitat biologists whose primary responsibility is to interpret and enforce statewide rules and regulations are central to communication networks in most watersheds. Even in areas where the area habitat biologist characterized their role as purely regulatory, other project participants acknowledged the contribution and influence of the AHB with respect to design alternatives and design decisions. In select rural watersheds, project coordinators from conservation agencies played a similar knowledge transfer role in addition to their role as program administrators.

TOPICS FOR FOLLOW-ON RESEARCH

Social Aspects of Design in the Natural Resources

We found differences in the level of participation and centrality of landowners for projects in western Washington versus eastern Washington. When we looked at data from rural western Washington watersheds compared to urban/suburban western Washington watersheds, we did not see a material difference in landowner participation. We have no structural or cultural explanation for the east/west differences. Further research is needed into the antecedents of landowner involvement or disinvolvement in habitat projects.

We found the inclusive collaborative organizational model to be a surprise. We expected to find a core project and design group surrounded by a set of regulators and service providers. One possible explanation for the centrality of regulators and other service providers is that they are *de facto* holders of experiential and educational knowledge . Is their centrality a rational feature of early-stage society building, or is it a feature of the natural resource design landscape that persists over long time? A longitudinal study of other more mature design activities such as forest harvest unit and transportation system design might provide important clues.

We found a few watersheds where habitat enhancement has been going on with a limited set of landowners for more than ten years. A targeted study of how project social networks evolved and matured in these watersheds might help understanding of society building and projection of likely trajectories and endpoints for project-level organization in other less mature watersheds.

In all but one watershed, our social networks were incomplete. The nature of voluntary participation in surveys and interviews inevitably results in incomplete data sets. In the one watershed were we collected reasonably complete data (WRIA Z), our conclusions about centrality of project participants, communication networks and influence networks improved with additional data. To aid future researchers, it would be useful to further explore methods for collecting and analyzing social research data associated with collaborative design teams.

Framing Effects

Framing was readily evident in all projects. Framing took on two forms – framing of functional objectives, and framing of messages. Framing of objectives appears to aid labeling of projects for mapping to past design cases as well as to bias decisions by external audiences. Framing of messages such as "enhancement vs. mitigation" appear to be targeted at audiences internal to the project to establish a context for negotiation and decision making. To our knowledge, no existing research considers the concurrent framing of both objectives and messages.

We were surprised to find that framing effects were not evident in project outcomes. One potential explanation is that group interaction, negotiation among participants with different perspectives, and trade-offs between multiple objectives collectively have an integrating effect that dilutes framing effects. Another explanation is that our data set was so broad that framing effects were hidden by population variance. Framing effects may be more visible in targeted study of one particular type of project, or projects with certain functional objectives.

Engineering Design and Decision Methods

If design teams for projects in the natural resources in general, and fish habitat projects in particular, are led by and comprised mostly of persons with no training in design methods and processes, then one needs to assess whether design process knowledge is a necessary condition for effective design to occur.

One can further ask if imposition of a design process on the projects studied is likely to result in better solutions, with better being defined as cheaper, easier to implement, more effective at achieving the desired functionalities, and/or more tolerant to changes in future conditions that might make a lesser design fail.

If one knows the nature of the decision making and social environment is different than the prevailing paradigm:

- How do you teach future designers?
- How do you deliver continuing education and technical knowledge ?
- In what ways do design tools and methods need to change?

If engineers involved in design teams are 1) on the periphery of the team, and 2) in the clear numerical minority of team membership, then engineering students need to learn tools and techniques for achieving their goals by working with and through other people.

Engineering Role in Society

Engineers were non-existent or had limited roles in most projects and watersheds. Two watersheds, P and M, had engineer involvement in nearly all projects. Participants characterized the engineer's roles as either "engineering" or " project manager / engineer." Further research is needed to determine why engineering involvement is low in most cases, yet high in two examples. What are the structural and cultural explanations for low engineer participation in what appears to be highly technical engineering works?

A related question that warrants independent study is how social groups decide what is and is not an engineering project. There is an apparent continuum between technical works that are not worthy of engineering input and those which would never be undertaken without participation of highly competent engineers. In-stream habitat, bank protection and related projects are but a few examples that arise from the present research. In a broader natural resource engineering context, where do culvert design, low volume road specification, trail design and other technical works fall along the spectrum? Is it in society's best interest to enact legislation to require professional engineer certification of designs for all works in streams and rivers? If no legislative requirements exist for engineer involvement, how do project coordinators and participant networks decide whether to involve engineers or not? If they decide to involve engineers, what are the relevant engineering questions that should be addressed by the holder of the engineer role?

VALUE OF RESULTS TO SOCIETY

Over the past two decades, dramatic changes have occurred in policy for managing the natural resources of the United States. Management goals changed from production and employment toward aesthetic, recreation and ecological services. Policy-level decision making has become much more open and participative. Little attention has been paid to changes at the operating or project level. The present study exclusively focuses on project-level decisions and processes.

We found that habitat projects, whether motivated by enhancement or mitigation, are collaborative works involving a range of stakeholders. Design outcomes tend to represent the perspectives and needs of those who directly participate in the process. Decision processes are primarily negotiations among participating stakeholders, making influence difficult for concerned citizens and agencies not at the design "table."

The results draw attention to a changing or new role for engineers and technical professionals in the development of technical works. Projects involving instream placement of habitat features affect channel hydraulics, channel stability and conveyance. Failure of habitat features may endanger downstream public works, property and communities. Yet, habitat elements of projects are generally exempt from technical analysis and risk assessment. Engineers and other technical professionals assume roles of information providers and analysts in support of broad-based decision making social groups. The historic responsibility and potential liability that society places on engineers and technical professionals has been eliminated for the most part. As a result, society at-large assumes responsibility for success or consequences of project design faults. This apparent shift in accountability has unknown long term effects.

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APPENDIX A: ROLE CODES

Role codes were assigned to all participants to label their role in project teams.

Role	Role Code
Administrator	adm
Construction	con
Coordinator	coo
Designer	des
Design Surrogate	dsu
Engineering Design	eds
Engineering Analyst	eng
Engineer / Project Manager	epm
Field Supervisor	fsp
Landowner	lnd
Project Manager	pmg
Regulator	reg
Regulator / Guidance	rgu
Regulator / Surrogate	rsu
Sponsor	spo
Steward	stw
Technical Specialist	tsp
Unknown	unk

APPENDIX B: WRIA Z PARTICIPANT COMMUNICATION MATRIX

WRIA Z Participant Communication Matrix

filename: wria z communication matrix 20000118.xls

				ppm	stb	feb	nac	feb	feb	feb	feb	ppc	ppn	csq	ppd	ccd	cto	cto	cto	cto	stb	fed	voa	feb	cto	coe	stg	fec
				ind	rgu	eng	tsp	tsp	dsu	des	tsp	ind	ind	dsu	ind	con	des	tsp	tsp	pmg	rsu	tsp	con	tsp	adm	con	rsu	tsp
Part.				296	151	246	242	274	275	181	225	121	297	210	134	298	258	237	162	130	244	144	299	300	256	301	302	303
	Affil.	Role	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
296	ppm	ind	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151	stb	rgu	2	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	1	1	1	0	1	1	1	0	1	1
246	feb	eng	3	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
242	nac	tsp	4	1	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
274	feb	tsp	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	feb	dsu	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	feb	des	7	0	1	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
225	feb	tsp	8	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
121	ppc	ind	9	0	1	0	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
297	ppn	ind	10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210	csq	dsu	11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	ppd	ind	12	0	1	0	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
298	ccd	con	13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
258	cto	des	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
237	cto	tsp	15	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	0	1
162	cto	tsp	16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
130	cto	pmg	17	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0
244	stb	rsu	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
144	fed	tsp	19	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
299	voa	con	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
300	feb	tsp	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
256	cto	adm	22	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0	0	0
301	coe	con	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
302	stg	rsu	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
303	fec	tsp	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

APPENDIX C: WRIA Z INFLUENCER COMMUNICATION MATRIX

WRIA Z Influencer Communicatoin Matrix

filename: wria z influencer matrix 20000118.xls

				ppm	stb	feb	nac	feb	feb	feb	feb	ppc	ppn	csq	ppd	ccd	cto	cto	cto	cto	stb	fed	voa	feb	cto	cce	stg	fec
				Ind	rgu	eng	tsp	tsp	dsu	des	tsp	Ind	Ind	dsu	Ind	con	des	tsp	tsp	pmg	rsu	tsp	con	tsp	adm	con	rsu	tsp
Part.				296	151	246	242	274	275	181	225	121	297	210	134	298	258	237	162	130	244	144	299	300	256	301	302	303
	Affil.	Role	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
296	ppm	Ind	1	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151	stb	rgu	2	0	0	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0
246	feb	eng	3	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
242	nac	tsp	4	0	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
274	feb	tsp	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	feb	dsu	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	feb	des	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
225	feb	tsp	8	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
121	ppc	Ind	9	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
297	ppn	Ind	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210	csq	dsu	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	ppd	Ind	12	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
298	ccd	con	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
258	cto	des	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
237	cto	tsp	15	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	0	0	0
162	cto	tsp	16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
130	cto	pmg	17	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
244	stb	rsu	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
144	fed	tsp	19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
299	voa	con	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	feb	tsp	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
256	cto	adm	22	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
301	cce	con	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
302	stg	rsu	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
303	fec	tsp	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

VITA

JAMES HENRY DOOLEY

University of Washington

2000

CURRENT POSITION:

President & CEO - Silverbrook Limited - Federal Way, WA
Executive Manager – Forest Concepts, LLC – Federal Way, WA

EDUCATION:

B.S., Agricultural Engineering - California Polytechnic State U., 1971
M. Engr. - Agricultural Engineering. University of California, Davis, 1972
Ph.D. Candidate - University of Washington, Seattle, WA

CERTIFICATIONS :

Registered Professional Engineer, Hawaii
Registered Professional Engineer, Washington
Certified Site Facilitator/Trainer, Total Quality Management

EMPLOYMENT HISTORY

Silverbrook Limited - Federal Way, Washington

Jan. 1995 - President & CEO

Silverbrook Limited provides intellectual property management, product development and consulting services to small and large firms through its Trout Creek Associates and Baetis Technology divisions. Baetis Technology also develops new products and technologies for licensing to others.

Forest Concepts, LLC - Federal Way, Washington

Dec. 1998 -	Executive Manager Forest Concepts develops, manufactures and distributes engineered wood products for environmental restoration, habitat enhancement and landscape applications.

Weyerhaeuser Company - Tacoma, Washington:

1994 - Jan. 95	Interim Manager, Strategic Biological Sciences Program **Major Research Program Management** - Managed plant biotechnology research program in support of commercial application of somatic embryogenesis in forestry. Scope of responsibilities included an operating budget of approximately $2.5 million, full-time staff of twenty professionals and technicians, management of intellectual property, external research grants and contracts. **Total Quality Management Program Instructor / Facilitator** - Coordinated and led delivery of Total Quality education to new employees in Forestry Research.
1991-1994	Program Manager - Corporate Research and Development Division **Technology Protection, Acquisition and Marketing** – Provided management of intellectual property related to biology, engineering, biotechnology, sensors and software. Developed intellectual property protection strategies. Provided technology assessment and license marketing. Managed intellectual property during sale and divestiture of business units where technologies overlapped those of retained businesses. **Special Programs Management** - 1) Led and facilitated total quality and other cross-functional project teams. 2) Provided agribusiness industry insight to product and market development efforts related to paper, packaging and other forest products. 3) Promoted quality engineering and technology education by representing the agricultural engineering profession and the company on the Engineering Accreditation Commission and various educational advisory boards. **Senior Biological and Agricultural Engineer** - Provided oversight and counsel to engineering for forest plant propagation and nursery research programs. **Total Quality Management Program Instructor / Facilitator** - Provided education to research and operations staff in principles and

practice of Total Quality. Led major Quality Improvement Story team to improve cost effectiveness of R&D travel. Provided team facilitation for several storyboard teams.

1989-90 Product Engineering Manager - Sensor and Simulation Products Division
Product Engineering Management - Established reliable processes for design and documentation of new products related to infrared image based sensors in high temperature hostile environments such as recovery boilers, kilns and utility boilers. Coordinated product definition, specification, design and testing for new products and model changes with production, technology and marketing managers.

1986-89 Director of Research and Engineering, Nursery Products Division -
New Product Development and Introduction - Managed live plant and hard lines product collection, evaluation and introduction programs.
Market Research - Supervised retail and landscaper market research activity for division.
Process Improvement - Led development of improved quality and lower cost production methods for plant propagation business, containerized nurseries and distribution centers.
Research Management - Coordinated biological and engineering research programs executed at Weyerhaeuser Technology Center, on business sites, at arboreta and at universities.
Business Planning and Development - Participated in development of business plans for several starter-plant businesses. Provided competitive environment and technology assessment portions. Prepared economic (cash flow, NPV, DCF-ROI) models for businesses.
Facilities Planning and Design - Developed functional specifications and design details for nursery products production and distribution facilities. Participated in supervision of construction, commissioning and debugging of new facilities.
Senior Biological and Agricultural Engineer - Conducted engineering research related to plant propagation, nursery practices, plant tissue culture and production labor productivity, including ergonomics. Provided functional supervision of junior-level engineers at remote locations.

1982-1985 Manager, BioMechanical Engineering Unit - Diversified R&D
Engineering Services Management - Managed diversified small-projects engineering unit in support of Chemicals Business, Personal Care Products, Nursery Products, Timberlands.
Capital and Technology Planning - Provided ongoing support to business management in development of mid-term capital plans, particularly related to facilities, technology implementation and equipment

replacement decisions. Evaluated systems and unit operations costs to determine technology leverage points and establish economic acceptance criteria for technology development programs.

New Business Development - Supported Diversified Businesses with evaluation of agricultural and food business opportunities.

1977-82 Manager, Nursery, Seed Orchard & Greenhouse Systems Unit - Silvicultural Engineering Dept.

Engineering R&D Program Management - Managed engineering support to forest regeneration activities nationwide, including research engineering units and shop facilities in Tacoma, WA and Hot Springs, AR. Unit members received several patents.

Project Value Analysis - Provided leadership to cost/benefit analysis for R&D programs based on DCF/ROI skills developed earlier at AMFAC.

Puna Papaya, Inc., an AMFAC Company - Keaau, HI

1973-77 Director of Control and Development

New business startup - Participated in creation of new business to utilize surplus lands for production of tropical fruit and horticultural starter materials. Responsibilities included financial reporting, business planning, facilities and equipment design, biological and engineering research management, and supervision of quality control. Negotiated supplies contracts with packaging vendors (including Weyerhaeuser) and managed vendor relationships. Business scale included placing 1000 acres of former sugar cane and coffee land into production and achieving revenues of about $2 million per year in the fourth year.

Agricultural Engineer - Developed three self-propelled vehicles from the ground up for pesticide application, herbicide spraying and papaya harvesting. Designed and supervised construction of fresh papaya treating, packing and storage facility. Developed improved packaging and shipping conditions for tropical fruit. Provided biological engineering consulting for sugar cane division related to drip irrigation and seed cane treating.

AMFAC, Inc. Agricultural Group - Honolulu, HI

1973 Engineering Intern

Business planning and analysis - Attached to new business development and diversification group to do technology assessment, capital planning and financial analysis of acquisitions and new ventures.

Forensic engineering – Conducted analysis of equipment failures and accidents to determine design flaws and operator actions which contributed to accident, injury or equipment damage.

University of California, Agricultural Engineering Department - Davis, CA

1971-72 Graduate Student Aide - University of California - Davis, CA
Design engineering – Provided design, fabrication and testing of a self-propelled picking aid for the strawberry industry.

Daniel J. Stewart & Associates, Paso Robles, CA.
1967-71 Associate
Survey crew leader, drafter – Provided field surveying and drafting services for a small civil engineering consulting company in Central California. Managed client relationships on select projects.

MEMBERSHIP IN PROFESSIONAL AND TECHNICAL SOCIETIES

ASAE - The society for engineering in agriculture, food, and related biological systems
Association of University Technology Managers
Council on Forest Engineering
Institute of Biological Engineering
Licensing Executives Society
Society of American Foresters

PROFESSIONAL AND COMMUNITY SERVICE ACTIVITIES

ABET Board of Directors (Oversees Accreditation of Undergraduate Engineering Programs in USA)
    Representative Director, 1999-2002
Engineering Accreditation Commission of ABET
    Member, Appointment 1990 - 1995
Agricultural Engineering Department Advisory Group - Cal Poly, San Luis Obispo
    Member, 1992 - 1998
Biological Engineering Program Industrial Advisory Group - Washington State University
    Member, 1994 - Present
Institute of Biological Engineering
    President, 2000
    Council Member & Treasurer, 1997

Forest Biology Project Advisory Committee - Institute of Paper Science and Technology
    Member, 1994
Comprehensive Review Team, US Department of Agriculture, Cooperative State Research Service - University of Georgia - 1993
    Pennsylvania State University - 1991
    Auburn University - 1989
Ad Hoc Committee to Review ASAE Foundation - ASAE
    Member, 1994
Strategic Planning Committee (E-03) - ASAE.
    Member, 1989-1994
Engineering and Technology Accreditation Committee (P-204) - ASAE
    Member, 1984 - Present
Biological Engineering Advisory Committee (BI-02) - ASAE
    Past Chairman, 1992-1993.
Plant Biological Engineering Committee (BI-30) - ASAE
    Charter Member
Emerging Technologies Development Committee (ET-07) - ASAE.
    Chair, 1994 - 1995
Emerging Technologies Advisory Committee (ET-01/02) -ASAE
    Chair, 1995 - 1996
Nursery & Greenhouse Plant Production Systems Committee (PM-59) - ASAE
    Member, 1977 - Present
Environment of Plant Structures Committee (SE-303) - ASAE
    Member, 1979 - Present
Task Force on University, Industry and Government Cooperation
    Task Force Member - 1989
Experiment Station Committee on Organization and Policy (ESCOP); National Association of State Universities and Land Grant Colleges. Subcommittee on Sensor Research for Agriculture
    Task Force member - 1986
Papaya Administrative Committee
    (Federal Marketing Order Oversight Committee)
    Grower Member Alternate -1977

SPECIALIZED TRAINING & EDUCATION

Small Business Innovative Research Program - 1993 (Small Business Administration)

Biotechnology Patents Workshop - 1993 (Assn. of Biotechnology Companies/BIO)

Technology Transfer Course - 1993 (Licensing Executives Society)

Weyerhaeuser Paper Company Quality Improvement Story, Weeks 1 & 2 - 1991

Negotiation of Software License Agreements - 1991 (Data-Tech Institute)

How to Successfully Transfer Products and Processes from R&D to Manufacturing -1990 (AMA)

Tuck Marketing Strategy Program - 1988 (Amos Tuck School of Business Administration)

Expert Systems Short Course - 1986 (ASAE)

Weyerhaeuser Managerial Skills Training (MST) - 1983 (Weyerhaeuser)

Stress Management - 1981 (AMA)

Hydraulic Systems Analysis - 1979 (Parker Hannifen)

Podium Power course - 1979 (Communispond)

How to Become a more Effective Supervisor - 1979 (Batten, Batten, Hudson & Swab)

Dupont Strategy of Experimentation course - 1977 (Dupont)

SPECIAL RECOGNITION AND AWARDS

1996	Elected to ASAE Fellow membership grade
1996	ASAE Director's Citation for contribution to engineering education and accreditation
1995	Elected to Xi Sigma Pi, the National Forestry Honorary Society
1994	Forestry Research Recognition Award for assistance with organization of Methyl Bromide Alternatives Workshop
1994	Forestry Research Recognition Award for leadership of Total Quality training program
1994	ASAE Director's Award for contribution to development of Emerging Technologies area
1994	ASAE President's Citation for contribution to integration of Biological Engineering into ASAE
1993	Manufacturing Technology Recognition Award for facilitation of Staff Development Quality Improvement Team
1993	Corporate Research Recognition Award for leadership of Travel Practices Quality Improvement Team
1990	Recognition Award for creating a product engineering function within the Sensor and Simulation Products division of Weyerhaeuser Company.
1989	Recognition Award for co-authorship of "Weyerhaeuser Tissue Culture Center Business Plan" Presented by Weyerhaeuser Company Nursery Products Division

1989 Achievement Award for contributions to "Weyerhaeuser Trees Business Development Plan" Presented by Weyerhaeuser Company Technology Commercialization Division

1988 Recognition Award for technical contribution to "Encapsulated Somatic Embryo Agreement" Presented by Weyerhaeuser Company Strategic Biology Unit

1982 Achievement Award for leadership of "Accelerated Precision Sower Development" Presented by Weyerhaeuser Company Timberlands Division

1980 Weyerhaeuser Timberlands Vice-Presidential Award for "Development of Improved Forest Seedling Lifter." (with Mike Yancey)

1971 Beck Award for Outstanding Leadership in the School of Agriculture and Natural Resources California Polytechnic State University

PATENTS

Engineered Wood Structure – US Patent 5,823,710
A method to construct large diameter wood structures from small logs for watershed restoration and habitat enhancement

Seed Planter - U.S. Patent 4,449,642
Canadian Patent 1,218,266
A double-row vacuum precision sower for forestry and other densely planted seeds.

Seed Supply System for Multiple Row Sower - U.S. Patent 4,491,246
Canadian Patent 1,231,869
A method of ensuring all rows of a sower run out of seed at the same time.

PEER REVIEWED PUBLICATIONS

Dooley, J. H. 1983. Transplanter for Forest Nurseries. *Transactions of the ASAE* 26(6):1661-1664. St. Joseph, MI: American Society of Agricultural Engineers.

Fridley, J.L., J.H. Dooley, C.L. Hansen, G.W. Isaacs, J.B. Hunter, P.N. Walker, R.E. Young. G.E. Kaiser, B.J. Stokes and H.T Wiedemann. 1993. Fostering new tools at the intersection of biology and engineering: a discussion of the impact of integrating biological engineering into agricultural engineering by the Emerging Technologies Division of ASAE. *Agricultural Engineering*, November 1993 p 11A-15A.

OTHER PUBLICATIONS

Dooley, J.H. and K.M. Paulson. 1998. Rivers Get a Second Chance. *Resource, Engineering and Technology for a Sustainable World.* 5(11):7-8, St. Joseph, MI: ASAE.

Dooley, J.H. and K.M. Paulson. 1998. Engineered Large Woody Debris for Aquatic, Riparian and Upland Habitat. Special Publication. Federal Way, WA. ELWd Systems division of Forest Concepts, LLC.

Dooley, J.H. and K.M. Paulson. 1998. Engineered Large Woody Debris for Aquatic, Riparian and Upland Habitat. ASAE Paper 982018. St. Joseph, MI: American Society of Agricultural Engineers

Dooley, J.H. 1998. Recasting Industrial Problems for Use in an Academic Setting. ASAE Paper 985003. St. Joseph, MI: American Society of Agricultural Engineers

Dooley, J.H. and J.L. Fridley. 1998. Application of Social Network Analysis to Forest Engineering Design Decisions. ASAE Paper 987023. St. Joseph, MI: American Society of Agricultural Engineers

Dooley, J.H. , and J.L. Fridley. 1996 Appreciative Design: Incorporating Social Processes into Engineering Design. ASAE Paper 965004. St. Joseph, MI: American Society of Agricultural Engineers

Dooley, J.H. 1994. The Emergence of the Entrepreneurial Engineer. *Resource, Engineering and Technology for a Sustainable World.* November 1994. St. Joseph, MI: ASAE. 1(7): 8-10.

Dooley, J. H. 1994. The Best and the Brightest. *Agricultural Engineering.* March 1994. St. Joseph, MI: American Society of Agricultural Engineers

Dooley, J. H. and D. R. Woodward. 1991. Plant Tissue Culture Vessel Including Ergonomic Considerations. ASAE Paper 91-7532. St. Joseph, MI: American Society of Agricultural Engineers

Dooley, J. H. 1991. Influence of Lighting Spectra on Plant Tissue Culture. ASAE Paper 91-7530. St. Joseph, MI: American Society of Agricultural Engineers.

Dooley, J. H. 1989. Research Opportunities in Plant Biotechnology. ASAE Paper 89-7560. St. Joseph, MI: American Society of Agricultural Engineers.

Andros, M. and J. H. Dooley. 1988. Development of Self-Propelled Work Cart for Use in Ornamental Nurseries. ASAE Paper 88-1652. St. Joseph, MI: American Society of Agricultural Engineers.

Dooley, J. H. 1988. Technical Considerations for Specification of Plant Growth Chambers. ASAE Paper 88-4527. St. Joseph, MI: American Society of Agricultural Engineers.

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SEMINAR AND EDUCATIONAL MATERIALS

Dooley, J.H. 1999. Design Alternatives to Concurrently Achieve Instream Habitat Enhancement and other Functional Objectives. Seminar prepared for Washington Farm Forestry Association.

Dooley, J.H. 1999. Doing Design in a Crowd: Adapting to the Changing Nature of Project-Level Design. Workshop prepared for Idaho Society of Professional Engineers / Washington Society of Professional Engineers Joint Annual Meeting. Post Falls, Idaho. April 8 – 10.

Wagner, R. W., H. G. Riedy, and J. H. Dooley. 1992. Intellectual Property Protection - Policy and Overview. Weyerhaeuser Company (Proprietary).

Dooley, J. H. 1989, 1990. Elements of Product Design. Weyerhaeuser Company (Non-Proprietary).

Dooley, J. H. and J. Nye. 1991, 1992, 1993. ASAE Accreditation ABET Visitor Training Program for New and Experienced Program Evaluators.

Dooley, J. H. 1983. Rapid Methods for Estimating NPV and ROI for Research and Small Capital Projects

Dooley, J. H. 1982. Equipment Replacement Vs. Rebuild Decision Methods

Dooley, J. H. 1980. Evaluation and Improvement Methods for Solid Set Irrigation Systems

SPEECHES AND ORAL PRESENTATIONS

1999. “Design of Salmonid Fish Enhancement Projects Across Washington State.” Seattle Fly Fishers. June 15, Seattle, WA

1996. “Appreciative Design: Incorporating Social Processes in Engineering Design” Oral Plenary Presentation to ASAE Pacific Northwest Section Meeting, September 23, Yakima, WA.

1996. “Managing Private Industry Trade Secrets and Patents During University Cooperative Projects. Oral Presentation to ASAE International Meeting, July 17, Phoenix, AZ.

1996 “Rationale for the Current Low Investment of Private and Public Funds in Research and Development to Benefit the Nursery Industries.” Invited Oral Presentation to ASAE International Meeting, July 17, Phoenix, AZ.

1996. “What are the Requirements of a Successful Engineer: A good GPA is not Enough” Invited Departmental Seminar, University of Georgia. February 20, Athens, GA.

1996. “Appreciative Design: Incorporating Social Processes into Problem Solving and Engineering Design.” Presented to Weyerhaeuser Company, Tacoma, WA (four presentations to-date)

1995. “Controlling Disclosure of Confidential Information for Small Business Owners.” Entrepreneurial Engineering and Business Development Program. ASAE International Meeting - June 19, 1995. Chicago, IL.

1995. “Biological Engineering: Finally - It’s Time for a New Perspective.” Invited presentation to the students of the Agricultural Engineering Department, California State Polytechnic University, San Luis Obispo. May 25, 1995.

1995. “Biological Engineering: Finally - It’s Time for a New Perspective.” Invited seminar at the Agricultural Engineering Department, Texas A&M University. March 23, 1995.

1994. “Biological Engineering in Agricultural and Food Systems” Invited keynote presentation at Institute for Biological Engineering Forum. Atlanta, GA. December 12, 1994.

1994. "Engineering Opportunities in the Forest Products Industry." Presented to ENGR 100 class at Pacific Lutheran University. November 4, 1994

1994. "Changing Public Expectations and Their Effect on Engineering in the Natural Resource Industries." Presented at: "Incorporating Biological Science Technology in Processing, Machine and Natural Resource Systems Designs" sponsored by the Kansas Section of ASAE. Manhattan, Kansas. October 21, 1994

1994. "Entrepreneurial Engineering - A Legitimate ASAE Emerging Area" Presented to ASAE Summer National Meeting, Kansas City, MO.

1993. "Outcomes Assessment as an Engineering Accreditation Tool" Presented to ASAE Winter National Meeting, Chicago, IL.

1993. "Paradigms for the 21st Century 'Living World' Engineer - Redefining the 'System'". Invited presentation at: International Symposium II - The Culture of Engineering in a Rapidly Changing World. University of California at Berkeley, November 8-10, 1993.

1993. "Opportunities for Engineering Graduates in Industry - The Weyerhaeuser Perspective" Presented to ASAE National Student Branch meeting, Spokane, WA.

1992. "Careers in Transition- The Changing Challenge - Alternative Opportunities" Market Emphasis Panel Discussion. ASAE Winter International Meeting, Nashville, TN.

1992. "Where does Biological Engineering Take You in the Forest Products Industry" Oral presentation to the ASAE Winter International Meeting, Nashville, TN.

1990. "Our Biosphere - Our Responsibility; Agriculture's Contract with Society; Bioengineering Stimulator Presentation". December 1990. American Society of Agricultural Engineers Annual Meeting.

1988. "Opportunities for Agricultural Engineers in the Plant Biotechnology Industry". October 27, 1988. Presented at Purdue University as part of the Graduate Seminar Series in Agricultural Engineering.

1987 "Role of Agricultural Engineering in Biotechnology". February 1987. Presented at University of California - Davis as invited lecture in Agricultural Engineering Department.

1976. "Puna Papaya - Marketing Aspects" Presented to the 12th Annual Hawaiian Papaya Industry Association Conference.