Diffusion of Climate Knowledge through Social Networks

by

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Abstract.

Over the past several decades, quality climate information has become extremely valuable to environmental decision makers, yet little is known about how this information is distributed within a social network of professionals. This study focuses on a climate knowledge network associated with a NOAA Climate Impacts Research Consortium (CIRC) study of climate impacts in the Big Wood Basin of Idaho. Using this network as a foundation, this research attempts to determine how networks are formed, how they are organized, and how climate information from the network is used for environmental decision making. To conduct this research, a number of semi-structured interviews were conducted with members of the network. These interviews were then analyzed using both qualitative analysis and formal network analysis. Results of this analysis are examined through an application of the Diffusion of Innovations theory, and policy implications are discussed.

Keywords: Social Networks, Knowledge Networks, Climate, Diffusion of Innovations

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1. INTRODUCTION

1.1 *Statement of the Problem*

The impacts of climate change are becoming increasingly understood as climate science and modeling continue to improve. However, quality climate information cannot influence decision making if it does not reach decision makers. A growing body of research exists on the role of knowledge networks in the creation, transmission, and adoption of knowledge used in decision making. This includes the use of advanced network analysis techniques to explain complex system in fields such as management, psychology, sociology, and economics. One application for the concept of knowledge networks focuses on the spread and use of climate information. Interest exists in the spread and use of climate information due to its importance for potential climate adaptation, especially in areas of variable water availability, such as the western United States. Establishing a better understanding of climate-based knowledge networks has the potential to greatly improve the diffusion of innovative climate knowledge to decision makers.

1.2 *Study Background*

Data used in this study were collected in parallel with a collaborative modeling study conducted in the state of Idaho entitled "Big Wood River Basin Alternative Futures Project." This modeling study was conducted by the Pacific Northwest Climate Impacts Research Consortium (CIRC) based at Oregon State University. The goal of the project was to use a collaborative modeling process to explore interactions between climate and seasonal water availability, land use practices, and population growth in the Big Wood Basin (see Figure 1). To meet this goal, researchers collaborated with local stakeholders to create climate knowledge that focused on impacts important to stakeholders, while also creating a knowledge-to-action network in the area. With the cooperation of local stakeholders, the study aimed to produce original climate research that was useful to both public and private decision makers in the area. By incorporating local stakeholders in the modeling process, within the study community the goal was to create a sense of ownership over the results of the model, as well as increase the likelihood that the results will be used by stakeholders.

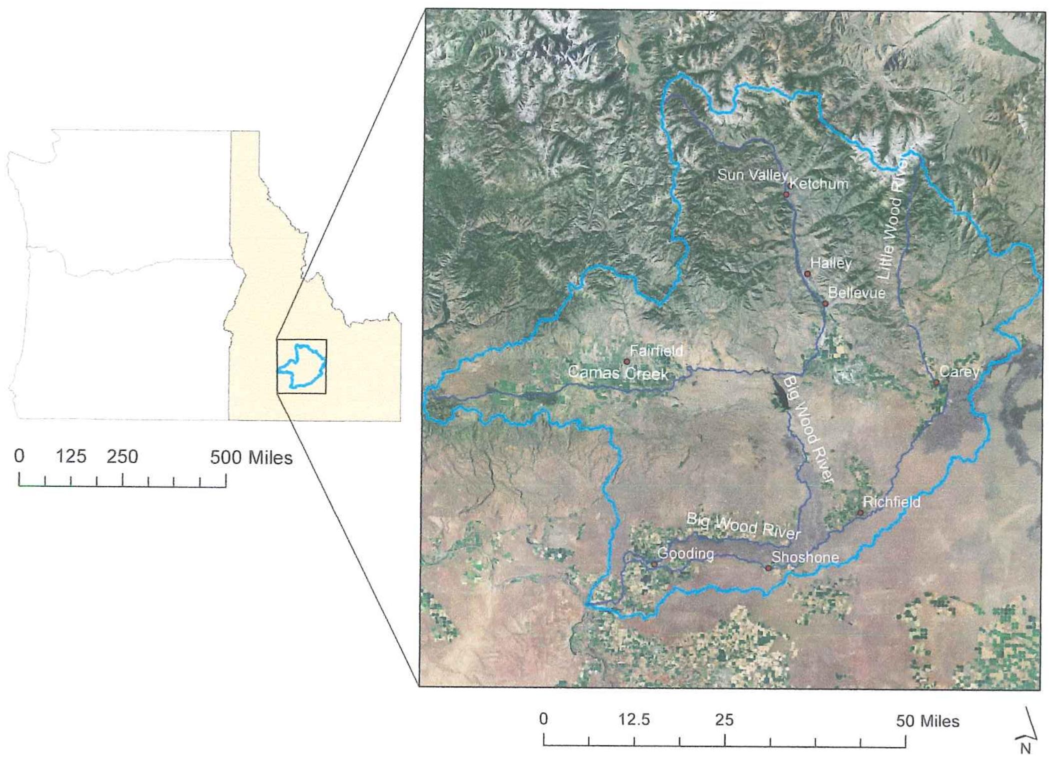

Figure 1: Big Wood Alternative Future Project study area

The study began in March, 2012 with a meeting between the CIRC research team and representatives from federal and state agencies, utility providers, canal operators, and others to identify climate research priorities in the basin. In August of 2012, CIRC hosted a workshop with stakeholders to identify important outcomes of the research effort. This workshop resulted in a concept map of future endpoints important to the stakeholder group, as well as their connection to important processes in the basin.[1] To begin to model the processes and endpoints identified by stakeholders, CIRC proposed a two-pronged approach to modeling the Big Wood Basin system. The first approach was a system dynamics model of the basin that explored relationships between components of the basin system. The second approach was to model the system using Envision, a spatially explicit model developed at Oregon State University.[2]

The first model produced for the project, the system dynamics model, was presented to stakeholders in March of 2013 at an in-person meeting held in Shoshone, ID. This meeting was also used to develop alternative future scenarios to be modeled using Envision. Preferences for future conditions identified by stakeholders were used to create four scenario narratives relating to degree of management of the system, as well as potential tourism and agriculture booms.[3] These scenario narratives provided the basis for policy decisions integrated into the Envision model. The alternative future scenarios identified by stakeholders were then used in cooperation with climate change projections to produce model outputs. Model results will be compiled and presented as endpoints identified by the stakeholder group in Spring and Summer of 2014.

1.3 *Study Overview*

This study utilizes network analysis to analyze a network of climate knowledge centered around the CIRC Big Wood Alternative Futures Project. To begin, literature on social networks is reviewed, including concepts of network analysis that are critical to understanding the network

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[1] CIRC Big Wood concept map included in Appendix A.
[2] CIRC Big Wood project proposal included in Appendix B.
[3] CIRC Big Wood scenario narratives are included in Appendix C.

identified in this study. Knowledge-to-action networks, or simply knowledge networks, are also examined. Rogers' (1962; 1995) "Diffusion of Innovations" theory is also explored, along with similar literature on the transfer and adoption of knowledge. Methods used in the study are explained, including interview and network analysis techniques. Results of the network analysis are explored, including an application of the diffusion of innovations. This is followed by a discussion of policy recommendations.

2. LITERATURE REVIEW

2.1 *Social Networks*

The concept of social networks is one that has received increased attention from social science researchers over the past several decades as a unique lens with which to view complex social systems. Social networks are defined by a set of relationships between network members, and the implications of those relationships (Kadushin, 2012; Wasserman and Faust, 1994). Network members, or nodes, typically consist of people or organizations, but are simply units that can be connected to other units within the network (Scott and Carrington, 2011). The study of these networks has come to be known as social network analysis, focusing on categorizing both nodes and relationships types within the network, as well as the structure of the network as a whole. (Scott and Carrington, 2011; Wasserman and Faust, 1994). Social network analysis has been used in a variety of fields, from sociology and psychology, to economics and management (Phelps et al., 2012).

2.2 *Knowledge Networks and Analysis*

Knowledge networks seek to adapt concepts of social network analysis to understanding how knowledge flows between participants of a network. Sometimes referred to as "knowledge-to-action networks," knowledge networks serve two functions: to facilitate coordination between participants, and to allow for the transfer of information, knowledge, and data between members of the network (Cash and Buzier, 2005). Knowledge in this context is not simply information. Instead, knowledge may also include tacit and context specific meanings, which require a certain skillset to be utilized (Fritsch and Kauffeld-Monz, 2008). Much research on knowledge networks focuses on factors that influence the diffusion and adoption of innovations or knowledge, often leading to a behavioral change by the adopter (Phelps et al., 2012). Many concepts effecting diffusion within a network have been explored in theoretical and empirical research. At the organizational level, important concepts include characteristics of network structure, relational properties, and nodal properties.

2.3 *Network Structure*

There are three general types of research on network structures: (1) network position, or the social proximity of a node to others in the network; (2) ego network structure, which focuses on the triadic closure, or whether a node's direct contacts have ties with each other; and (3) whole network structure, which deals with the density of the network (Phelps et al., 2012). Network position, often characterized by the number of direct ties with knowledge sources, has been shown to increase the likelihood of innovation adoption (Davis and Greve, 1997; Kraatz, 1998). Research has also shown informal interorganizational connections to be more effective than formal partnerships when sourcing external knowledge (Liebeskind et al., 1996).

Network analysis is often used to determine key actors that exhibit a relatively large amount of influence over the network. Centrality is a measure used to highlight these prominent nodes within a network, and is one of the most important concepts within network position research (Wasserman and Faust, 1994). Centrality quantifies a node's direct and indirect ties (indirect ties are those that run through an intermediary node, A to B, B to C). Greater centrality has been shown to increase access to more diverse knowledge in a timely manner (Beckman and Haunschild, 2002). Indirect ties have been shown to effect transfer within a network, as a direct tie has been found to be unnecessary for diffusion between two organizations (Burt, 1987). However, knowledge gained from indirect ties is often filtered or altered when traveling through a direct tie (Ahuja, 2000). Research also shows that an organization's centrality increases its ability to diffuse innovations in a timely manner within the network (Gibbons, 2004). Higher levels of centrality are also associated with higher social status (Podolny, 1993), and information acquired from high social status organizations is perceived to be of higher quality by potential adopters (Powell and DiMaggio, 1983).

A concept explored to a lesser extent in the organizational network analysis literature is that of ego network structure. However, some research does exist on the effect of structural holes on knowledge creation and diffusion. Structural holes exist when two nodes that share a connection are not connected to each other (see Figure 2). Research has shown structural holes to increase an organization's knowledge by allowing for more diverse information transfer between partners (Baum et al., 2000). However, studies have also shown ego network closure, or triadic closure (a tie between each node), to improve an organization's innovation (Ahuja, 2000; Schilling and Phelps, 2007). Studies have also shown ego network closure to enhance diffusion (Lawrence et al., 2002) and the transfer of tacit knowledge (Dyer and Nobeoka, 2000). As a whole, research on ego networks suggests that structural holes improve the diversity of information flowing in the network, but decreases the volume of information flowing between the three nodes.

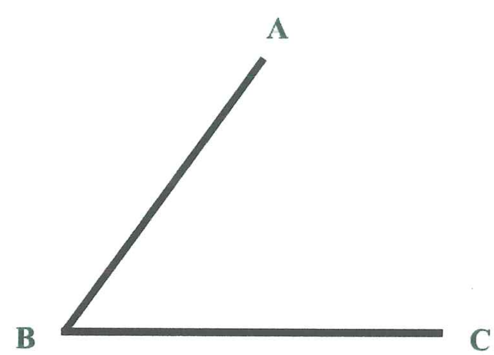


Figure 2: The lack of a connection between A and C in this triad represents a structural hole.

Whole network structure is another area where little research has been conducted at the organizational level. However, research that has been conducted shows dense network structures to increase the rate and extent of information diffusion, but reduces the diversity of information shared within the network (Lazer and Fiedman, 1998). Research also shows that dense clusters of organizations, with few ties to organizations outside the cluster, can improve organizational innovation (Schilling and Phelps, 2007; Uzzi and Spiro, 2005). However, excessive clustering can reduce the availability of diverse knowledge within each cluster (Uzzi and Spiro, 2005). This research suggests the closely knit organizational networks transfer information effectively internally, but struggle to access diverse information from external organizations.

2.4 *Relational Properties*

Beyond the structure of networks, the nature of relationships between organizations can heavily influence information transfer. Key network elements of interorganizational relationships largely fall into two categories; (1) tie strength, characterized by relationship duration, frequency, and intensity; and (2) the proximity and similarity of nodes within the network (Phelps et al., 2012). Tie strength is one of the most widely researched concepts in network analysis, and perhaps no research on tie strength is more widely referenced than Granovetter's "The strength of weak ties" (1973). He argues that weak ties, which act as bridges between separate clusters in a network, are uniquely valuable for diffusion across a network. Network participants who act as bridges within a network have also been shown to engage in more policy-oriented behavior (Frank et al., 2012).

Despite the value of weak ties and bridges as vehicles of diffusion within a network, strong ties have also been found to improve diffusion. Research shows strong ties between organizations increases innovation adoption (Goes and Park, 1997; Kraatz, 1998), and knowledge transfer (Tiwana, 2008). Williams (2007) finds that increasing the length of a relationship between organizations improves knowledge transfer. Strong ties have also been shown to increase organizational knowledge creation (Capoldo, 2007). A central theme to this body of evidence on strong ties is that establishing a close working relationship between organizations increases their willingness and ability to share knowledge. Maintaining different types of ties with organizations allows for greater diversity in knowledge acquisition (Beckman and Haunschild, 2002).

Like tie strength, research on the role of node similarity is also mixed. Sharing similar knowledge bases tends to improve the ability of organizations to acquire knowledge from each other, while organizational differences reduce knowledge sharing (Simonin, 1999). Evidence points to a sweet-spot of organizational similarity. When organizations share too much of their knowledge base, they have little to learn from each other. However, if organizations have completely separate knowledge bases, they find it difficult to communicate and share knowledge (Mowery et al. 1996). This suggests that moderate levels of knowledge overlap allow organizations to communicate effectively, while still having distinct knowledge to share.

2.5 *Nodal Properties*

Research on nodal properties attempts to determine how characteristics of an organization affect its ability to create, adopt, and share knowledge. Research has shown the capability of an organization to experiment with new ideas and approaches increases its ability to learn from other organizations (Fey and Birkinshaw, 2005). Technical experience improves an organization's ability to create, employ, and share solutions (Weigelt and Sarkar, 2009). Evidence suggests that an organization's ability to transfer knowledge increases as the collective teaching experience of the organization increases (Zhao and Anand, 2009). Developing the ability to collaborate can be beneficial to an organization by establishing effective means of searching for knowledge from partner organizations (Reuer, Zollo, and Singh, 2002). Prestige, or status, of an organization has also been found to affect diffusion, with innovations from more prestigious organizations being more likely to be adopted (Still and Strang, 2009). Organizational size is also a factor for the success of interorganizational knowledge sharing. As organizations increase in size, they rely more heavily on knowledge created internally, and external partnerships become less beneficial (Rothaermel and Deeds, 2004).

2.6 *Overview of Network Properties*

Network properties can be grouped into three categories: (1) properties of the network structure; (2) of the relationships in the network; and (3) properties of the members themselves (also known as nodes). Properties of the network structure include the proximity of nodes to others in the network, the closure of triadic relationships, and the density of the network structure. Important network analysis measures of network structure include centrality (in multiple forms), triadic closure, and the density of the network. Properties of relationships include tie strength, as well as the proximity and relative similarity of nodes within the network. Tie strength can be gathered largely from qualitative information collected in interviews, while characteristics of network organizations shed light on node similarity. Nodal properties focus on how characteristics of an organization effect their ability to process and share information. Nodal property information comes primarily from interview data.

2.7 *Diffusion of Innovations*

Much research has been conducted on how information, knowledge, and innovations travel through networks and come to be adopted. One such body of work was introduced in Rogers' book, *Diffusion of Innovations* (1962). Diffusion of innovations refers to the spread of complex ideas and concepts, technical information, or practices within a social system, where the spread of innovation denotes flow from a source to a potential adopter (Rogers, 1995). *Diffusion of Innovations* theorizes that the key elements of diffusion are characteristics of the innovation, communication channels between participants, time, and social systems. Rogers (1995, p. 11) defines an innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption." Communication channels are defined as the process by which participants share information, whereas diffusion is a type of communication where the information communicated is a new idea. The concept of time in diffusion theory is applied in several ways: (1) the time-span between the introduction of an innovation and its adoption or rejection; (2) the relative timeframe of adoption – either early or late – compared to other members of the system; and (3) the rate of adoption of the innovation. Lastly, the social system refers to "a set of interrelated units that are engaged in joint problem solving to accomplish a common goal" (Rogers, 1995, p. 24).

Expanding upon Rogers, Wejnert (2002) creates a diffusion framework that groups elements of diffusion into three categories: (1) characteristics of innovations; (2) characteristics of innovators; and (3) environmental context. Wejnert characterizes an innovation by its public vs. private consequences, as well as its benefits and costs. "Private vs. public consequences refer to the impact of an innovation's adoption on entities other than the actor (public consequences) versus that on the actor itself (private consequences)" (Wejnert, 2002, p. 299). According to this framework, innovations with public consequences are adopted when "norms, values, or expectations about certain forms or practices become deeply ingrained in society" or institutionalized (Wejnert, 2002, p. 300). The media plays an important role in the institutionalization of practices, providing information to the public (Uhlin, 1995). Wejnert (2000, p. 300) argues that adoption of innovations with private consequences occurs "largely due to spatial and temporal contiguity between a source and a potential adopter." Critical components of this contiguity include geographical proximity, interpersonal communication, and the effect of social networks. Wejnert's framework asserts that strong geographical and interpersonal ties foster diffusion. Costs and benefits are also identified as an important component of diffusion, as high direct and indirect costs can act as a barrier to adoption.

Characteristics of innovators, or actors involved in diffusion, are also a major component of Wejnert's framework. Diffusion is affected by the size of the social entity involved, such as individuals vs. large collectives of actors, like nations. Individuals and small collectives of actors, such as organizations, tend to adopt innovations with private consequences. Large collectives of actors tend to adopt innovations with public consequences. Perceived novelty of an innovation is a barrier to adoption. When a potential adopter is familiar with an innovation, "the perception of risk by an adopter is substantially reduced, facilitating adoptive behavior" (Wejnert, 2002, p. 304).

Wejnert's framework also identifies status characteristics as a component of adoption rates. The high status position of an innovation source within a social structure increases the likelihood of an innovation's adoption. Diffusion has been shown to improve when socioeconomic characteristics improve an organization's adoption ability, such as through the use of advanced information technologies (Mahajan and Muller, 1994). Wejnert also recognizes the role of social networks in her framework, arguing that diffusion among organizations occurs either horizontally, between like organizations, or vertically, given a more hierarchical network structure. Personal characteristics are also identified by Wejnert as playing a role in adoption, suggesting that the culture of an organization, including risk-taking, is an important determinant of innovation adoption.

The final component of Wejnert's diffusion framework is that of the environmental context, acknowledging that diffusion depends largely on environmental factors that an innovation encounters. The first of these factors is geographical setting, which applies to both the applicability of the innovation and the probability of adoption. Firstly, geography can influence the diffusion of an innovation by limiting its applicability. For example, agricultural innovations may be limited to certain regions, climates, soil types, etc. (Saltiel et al., 1994). Geography also plays a role in knowledge transfer, as proximity increases the opportunity for interaction between innovators and potential adopters, thus fostering diffusion. Societal culture is another environmental factor effecting diffusion, as organizations are less likely to adopt innovations that conflict with societal and cultural norms (Herbig and Miller, 1991). Political conditions are also important to diffusion. In the case of organizations, "national policies, the structure of government, bureaucracies, the political character of a state…" all influence adoption (Wejnert, 2002, p. 315). Wejnert also highlights the role of global uniformity to innovation diffusion, suggesting that the adoption of institutionalized practices, global adoption of technologies, and connectedness to modern communication systems all increase diffusion.

When Rogers (1962, p.11) introduced the Diffusion of Innovations theory, he posited that the spread of a new "idea, practice, or object" depended on factors that include: (1) characteristics of the innovation; (2) communication channels between participants; (3) time; and (4) social systems. Wejnert (2002) adds to the literature on the diffusion of innovations by breaking elements of diffusion into three distinct categories: (1) characteristics of innovations; (2) characteristics of innovators; and (3) environmental context. This study uses network analysis techniques to explore these three elements of diffusion within the context of the study population (Figure 3). For the purpose of this study, original climate information is treated as the innovation and organizations within the network are considered innovators. Framing the study in this perspective allows the network to be analyzed as the environmental context in which diffusion occurs. This study design allows network concepts to be applied to an analysis of the diffusion of climate information.

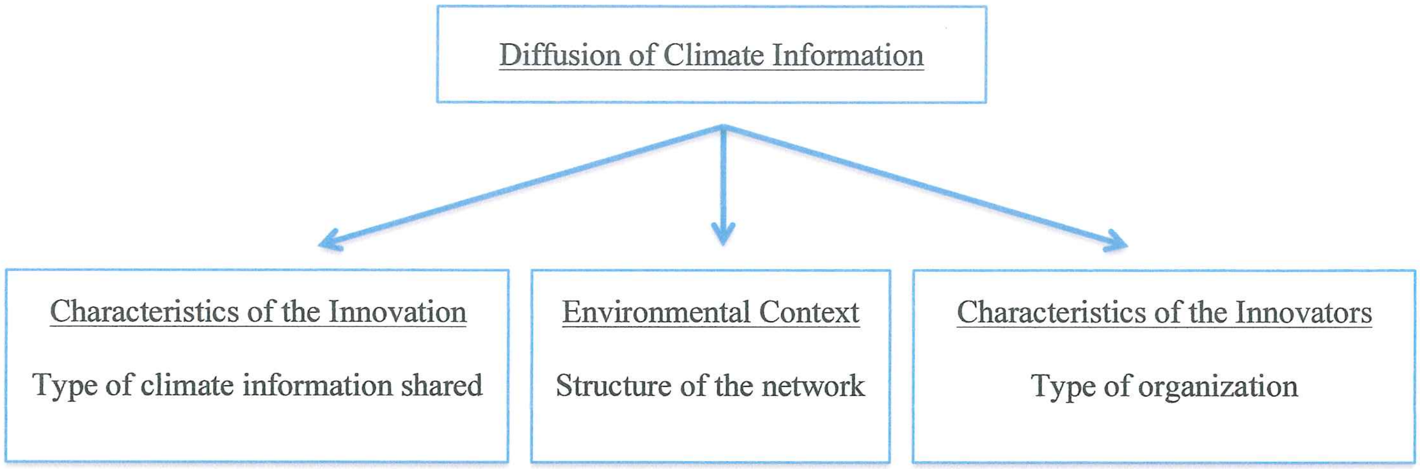


Figure 3: The three elements of diffusion and their respective roles within the study.

3. METHODS

3.1 *Sample Population and Participants*

This study was centered around a community of professionals and organizations with an interest in the future of the Big Wood Basin in central Idaho. Individuals interviewed for this study were members of an informal group of stakeholders involved with the CIRC Big Wood Collaborative Modeling Project. This group consisted of between 40 and 50 stakeholders representing a diverse group of interests. Interviewees were recruited through a number of email invitations to the stakeholder group, as well as an invitation to participate during an in person meeting. All individuals who volunteered to participate were included in the study, resulting in ten interviews. Those that chose to participate represented a diverse group of organizations involved in the project, and no potential participant was denied participation in the interview process. The external validity of this study is limited by the unique nature of the sample population.

3.2 *Interviews*

Data for this analysis were collected from a series of semi-structured phone interviews with stakeholders involved in the CIRC Big Wood project. A semi-structured format was used in order to collect data on certain topics, while allowing the interviewer flexibility to adapt the interview as appropriate to the individual and their organization.[4] To increase flexibility, "climate information" was not given a specific definition, and interviewees were free to describe anything they felt could be described as climate information. In order to collect data on the climate knowledge network, interviewees were asked questions on three main themes. These themes include how an interviewee uses climate information gained from the network; where their climate information comes from within the network; and where the interviewee shares their climate information. In addition, interviewees were asked about the form in which information was transferred between organizations. All interviews were recorded using a digital voice recorder and hand written notes were taken to assist in the interview process and clarify statements made.

3.3 *Data Analysis*

Participant interviews were then transcribed and coded using NVivo 10, a qualitative analysis software program.[5] Interviews were coded to highlight information critical to the study, including organizations within the network, information regarding knowledge transfer and use,

[4] The interview outline used in this study is included in Appendix D.
[5] NVivo qualitative data analysis software; QSR International Pty Ltd. Version 10, 2012.

and demographic information. Data regarding organizations involved in the climate knowledge network was established through interviews with individual actors within the network. Precedent exists for using data collected from individual actors to represent that actor's organization (Kriesi and Jegen, 2001). However, it must be stated that not all organizational relationships could be captured using this technique as individuals may be unaware of all organization network ties. After collection, network data were analyzed using UCINET, a network analysis tool, to explore a number of network characteristics (Borgatti et al., 2002). In addition to the main network of organizations, two network subsets were analyzed. The first of these subset network includes only interviewees and shifts the unit of analysis from organizations to individuals. The second subset network removes the central nodes from the network, allowing for additional analysis.

4. RESULTS

This section highlights the results of the network analysis methods used in this study. Results shown in this section will be analyzed and discussed in greater detail in the following Discussion section. This section presents graphical depictions of the network, as well as network property measures. Because these network measures are distinct from traditional statistics, an explanation of each measure is included. Figure 4 gives a graphical visualization of the study network as a whole, and includes organizations colored by type. Figure 5 is a visualization of only the interviewee organizations. Finally, Figure 6 removes the organizations with 10 or more network ties, without removing organizations left without any ties in the network (islands). All network diagrams include arrows indicating the direction of climate information flow between organizations.

Figure 4: Organization Network Visualization

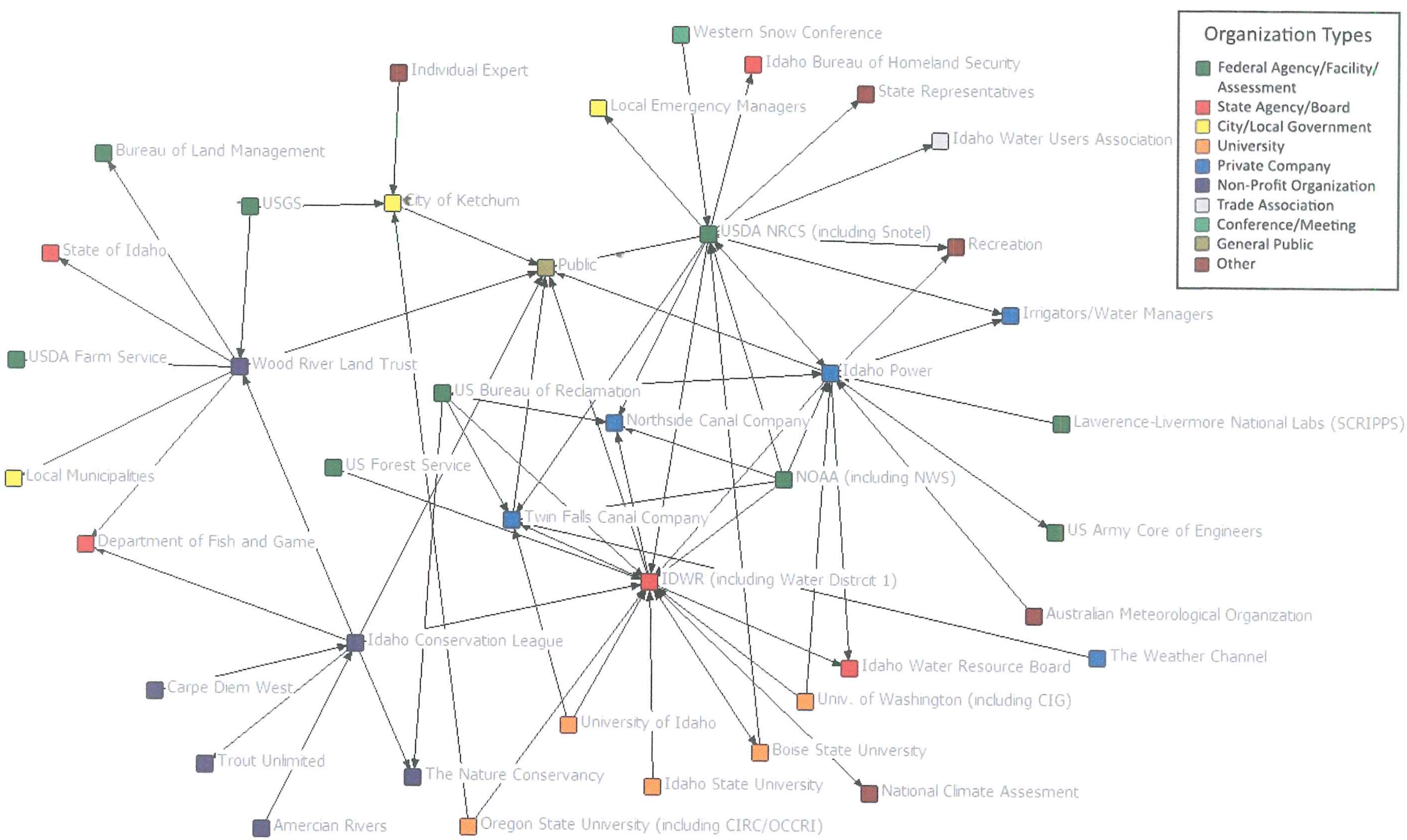


Figure 5: Interviewee Network

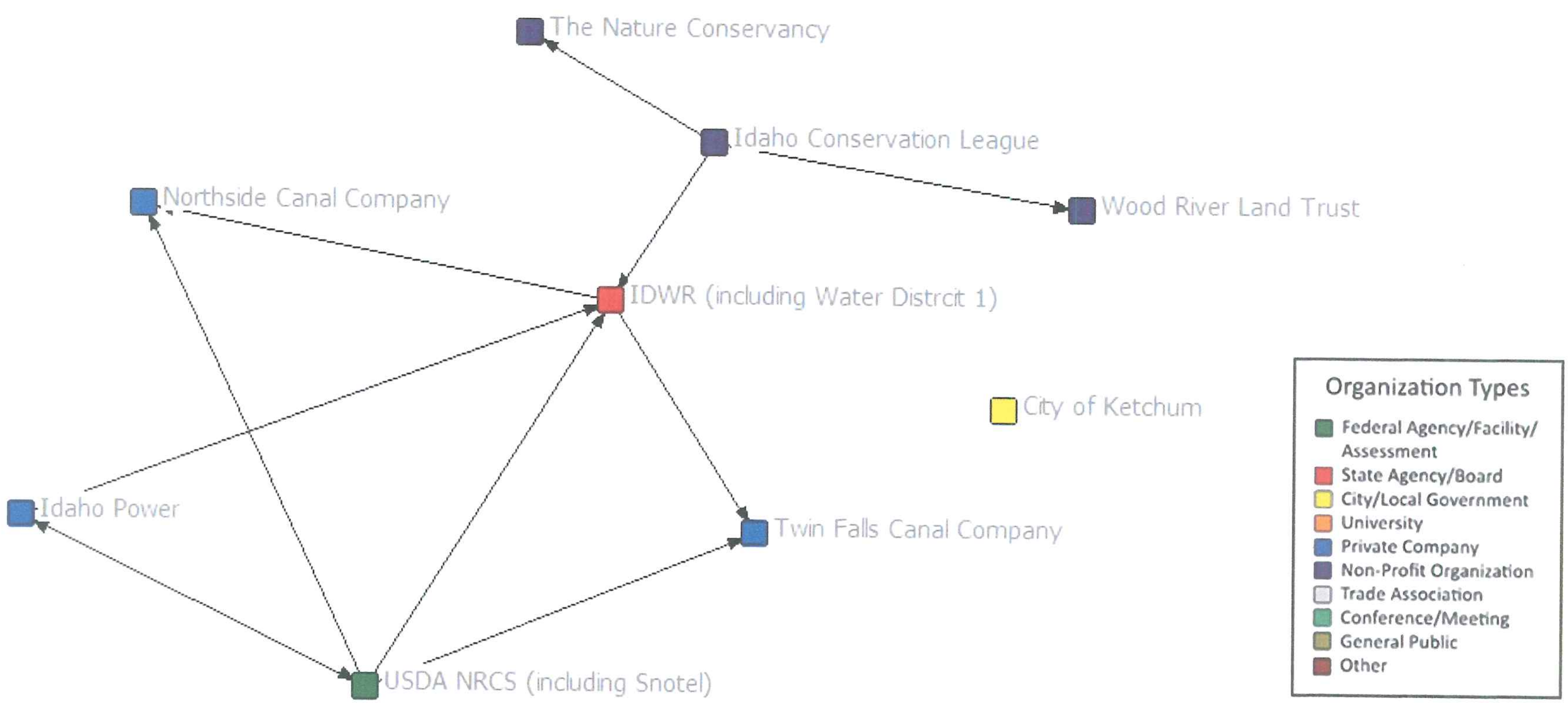


Figure 6: Central Organizations Removed

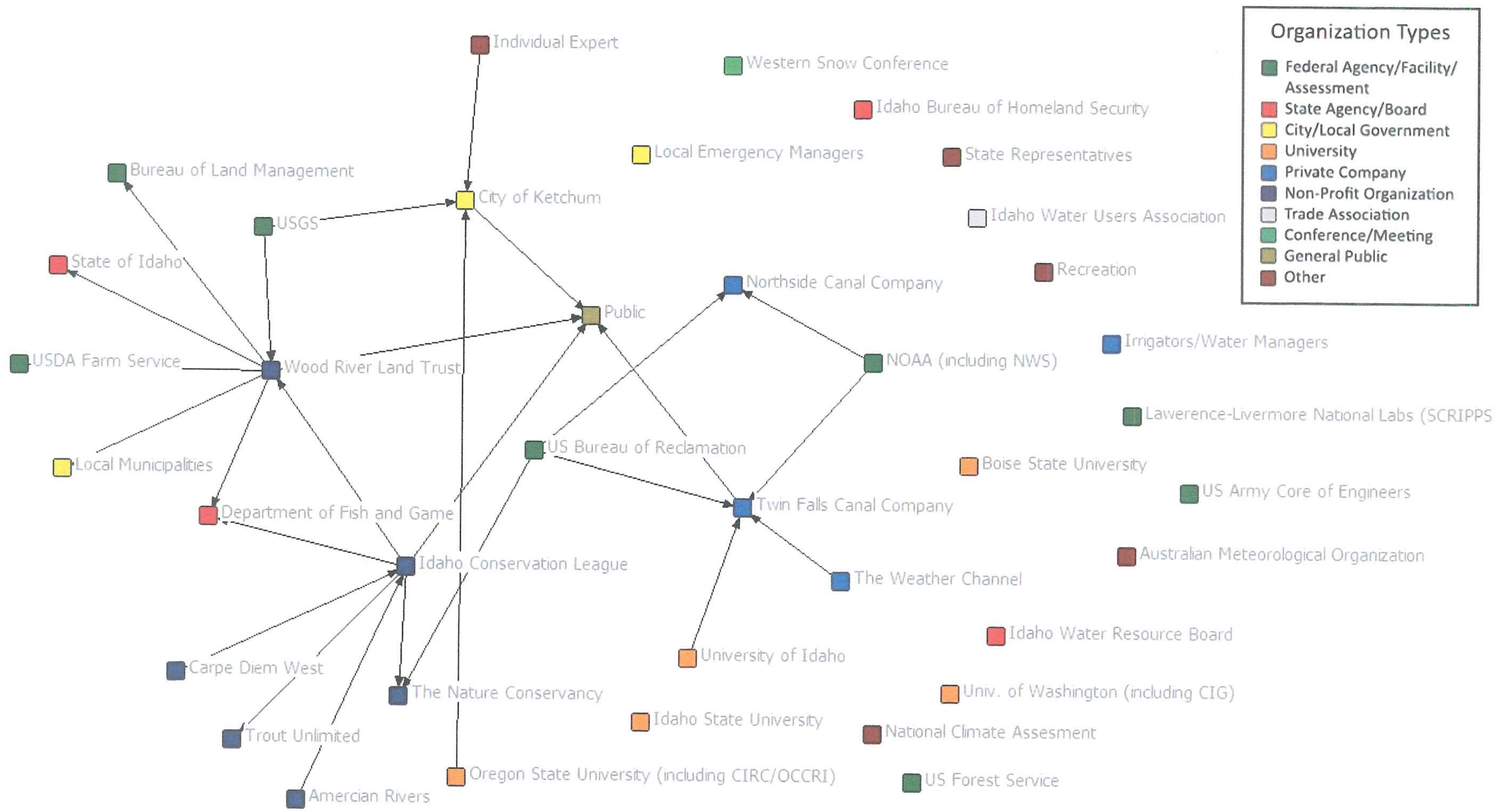


Table 1 shows descriptive statistics of the complete organization network (Figure 4). *Average Degree* indicates the average amount of ties organizations have in the network. *H-index* measures the maximum ties *h*, each tie having *h* ties of their own. For example, if a node has four ties, each of which have 4 ties of their own, that node has an H-index of 4. *Density* is a ratio of ties to all possible ties in the network. *Components* are subgroups in the network where each node can be reached by all others in the subgroup. *Component Ratio* is a ratio of the number of components compared to the total nodes in the network. *Fragmentation* shows the proportion of pairs that are unreachable, while *Connectedness* is simply 1 minus the fragmentation. *Triadic Closure* shows the ratio of closed triads to total triads in the network. *Average Distance* is a measure of the average amount of ties between any two organizations in the network, while *SD Distance* give the standard deviation of distance in the network. *Diameter* is a measure of the maximum amount of ties for the shortest path between two organizations.

Table 1: Network Structure Measures

Avg Degree	1.68
H-Index	4.00
Density	0.04
Components	36.00
Component Ratio	0.88
Fragmentation	0.78
Connectedness	0.22
Triadic Closure	0.17
Avg Distance	2.58
SD Distance	1.28
Diameter	6.00

Table 2 below shows centrality measures for each organization in the network. *Out Degree* and *In Degree* show the number of direct ties with other organizations in the network. *Out Bon Pwr* displays the outbound Bonacich Power of each organization, a measure of centrality that takes into account the connections of an organization's direct ties (i.e. secondary connections). *Eigen* shows eigenvector centrality, which adds weight to ties with more central nodes. *Between* gives the betweeness centrality of each organization, indicating how often a node acts as a bridge along the shortest path between two nodes. In addition, Table 3 gives descriptive statistics for each centrality measure.

Table 2: Network Centrality Measures

Organization	Out Degree	In Degree	Out Bon Pwr	Eigen	Between
USDA NRCS (including Snotel)	11	4	1511.3	0.395	142.75
Idaho Power	8	6	2021.7	0.356	92.58
IDWR (including Water District 1)	6	12	881.9	0.462	154.08
Idaho Conservation League	6	2	464.6	0.156	50.00
Wood River Land Trust	6	2	6.0	0.086	17.50
US Bureau of Reclamation	5	1	1505.3	0.213	16.00
NOAA (including NWS)	5	0	2286.0	0.266	0.00
Univ. of Washington (including CIG)	2	0	1501.8	0.128	0.00
Boise State University	2	1	1238.2	0.134	96.00
Oregon State University (including CIRC/OCCRI)	2	0	458.0	0.082	0.00
USGS	2	0	5.6	0.023	0.00
University of Idaho	2	0	458.0	0.116	0.00
Twin Falls Canal Company	1	6	1.0	0.278	2.08
City of Ketchum	1	3	1.0	0.062	2.00
Idaho State University	1	0	456.5	0.072	0.00
US Forest Service	1	0	456.5	0.072	0.00
Australian Meteorological Organization	1	0	1045.3	0.056	0.00
Lawrence-Livermore National Labs (SCRIPPS)	1	0	1045.3	0.056	0.00
The Weather Channel	1	0	1.5	0.043	0.00
American Rivers	1	0	241.0	0.024	0.00
Carpe Diem West	1	0	241.0	0.024	0.00
Individual Expert	1	0	1.5	0.01	0.00
Western Snow Conference	1	0	781.7	0.062	0.00
National Climate Assessment	1	1	456.5	0.072	0.00
Northside Canal Company	0	4	0.0	0.209	0.00
The Nature Conservancy	0	2	0.0	0.058	0.00
Irrigators/Water Managers	0	2	0.0	0.117	0.00
Public	0	7	0.0	0.281	0.00
Idaho Water Resource Board	0	2	0.0	0.128	0.00

US Army Core of Engineers	0	1	0.0	0.056	0.00
Recreation	0	2	0.0	0.117	0.00
Trout Unlimited	0	1	0.0	0.024	0.00
Department of Fish and Game	0	2	0.0	0.038	0.00
Idaho Water Users Association	0	1	0.0	0.062	0.00
Local Emergency Managers	0	1	0.0	0.062	0.00
Idaho Bureau of Homeland Security	0	1	0.0	0.062	0.00
State Representatives	0	1	0.0	0.062	0.00
Local Municipalities	0	1	0.0	0.013	0.00
USDA Farm Service	0	1	0.0	0.013	0.00
Bureau of Land Management	0	1	0.0	0.013	0.00
State of Idaho	0	1	0.0	0.013	0.00

Table 3: Centrality Descriptive Statistics

	Out Degree	In Degree	Out Bon Pwr	Eigen	Between
Mean	1.68	1.68	416.28	0.11	13.98
Standard Deviation	2.54	2.40	622.45	0.11	37.74
Sum	69	69	17067.40	4.58	573.00
Variance	6.47	5.77	387448.25	0.01	1424.23
SSQ	375.00	347.00	22602713.80	1.00	64977.33
Minimum	0	0	0	0.01	0
Maximum	11.00	12.00	2285.99	0.46	154.08
N of Obs	41	41	41	41	41

Table 4 displays ego network statistics for the each organization in the network. The *TriDegree* measure indicates the number of triadic ties for each organization. *EffSize*, *Efficiency*, *Constraint*, and *Hierarchy* are measures described by Burt (1992). *EffSize* is a measure of triadic connections for the organization, minus the average triadic connections of other organizations in the triad. *Efficiency* gives *EffSize* divided by the number of nodes in the ego network. *Constraint* is a measure of the extent to which an organization is constrained by organizations within the triad. If an organization's triadic ties all have one another as partners, constraint on the organization is high. *Constraint* values of 1.000 indicate that the organization has only one network tie. *Hierarchy* indicates the extent to which constraint on the organization is concentrated in a single triadic tie. Higher values indicate that constraint on an organization is concentrated in a small number of ties. *Hierarchy* values of 1.000 indicate the all constraint is located in one tie, while values of 0.000 indicate that the organization does not belong to any close triads.

Table 4: Ego Network Measures

Organization	TriDegree	EffSize	Efficiency	Constraint	Hierarchy
IDWR (including Water Distrcit 1)	16	14.306	0.894	0.153	0.092
USDA NRCS (including Snotel)	14	12.300	0.879	0.189	0.166
Idaho Power	12	10.357	0.863	0.231	0.221
Wood River Land Trust	8	7.500	0.938	0.196	0.074
Idaho Conservation League	8	7.250	0.906	0.223	0.065
Public	7	5.214	0.745	0.384	0.050
Twin Falls Canal Company	7	5.000	0.714	0.400	0.150
City of Ketchum	4	4.000	1.000	0.250	0.000
US Bureau of Reclamation	5	3.917	0.783	0.453	0.164
NOAA (including NWS)	5	2.600	0.520	0.641	0.066
Northside Canal Company	4	2.000	0.500	0.704	0.057
The Nature Conservancy	2	2.000	1.000	0.500	0.000
Oregon State University (including CIRC/OCCRI)	2	2.000	1.000	0.500	0.000
USGS	2	2.000	1.000	0.500	0.000
Boise State University	2	1.167	0.583	1.003	0.110
Univ. of Washington (including CIG)	2	1.000	0.500	1.125	0.000
Idaho State University	1	1.000	1.000	1.000	1.000
US Forest Service	1	1.000	1.000	1.000	1.000
Australian Meteorological Organization	1	1.000	1.000	1.000	1.000
Lawerence-Livermore National Labs (SCRIPPS)	1	1.000	1.000	1.000	1.000
Irrigators/Water Managers	2	1.000	0.500	1.389	0.000
University of Idaho	2	1.000	0.500	1.125	0.000
The Weather Channel	1	1.000	1.000	1.000	1.000
Amercian Rivers	1	1.000	1.000	1.000	1.000
Carpe Diem West	1	1.000	1.000	1.000	1.000
Individual Expert	1	1.000	1.000	1.000	1.000
Western Snow Conference	1	1.000	1.000	1.000	1.000
National Climate Assesment	1	1.000	1.000	1.000	1.000
Idaho Water Resource Board	2	1.000	0.500	1.125	0.000
US Army Core of Engineers	1	1.000	1.000	1.000	1.000

Recreation	2	1.000	0.500	1.389	0.000
Trout Unlimited	1	1.000	1.000	1.000	1.000
Department of Fish and Game	2	1.000	0.500	1.125	0.000
Idaho Water Users Association	1	1.000	1.000	1.000	1.000
Local Emergency Managers	1	1.000	1.000	1.000	1.000
Idaho Bureau of Homeland Security	1	1.000	1.000	1.000	1.000
State Representatives	1	1.000	1.000	1.000	1.000
Local Municipalities	1	1.000	1.000	1.000	1.000
USDA Farm Service	1	1.000	1.000	1.000	1.000
Bureau of Land Management	1	1.000	1.000	1.000	1.000
State of Idaho	1	1.000	1.000	1.000	1.000

5. DISCUSSION

5.1 *Environmental Context*

The organization network identified by stakeholders involved in the Big Wood project (Figure 4) has very low density, with only 4% of possible ties being fulfilled. Organizations in the network also average just 1.68 ties. A major factor influencing the lack of density in the network are organizations that appear to exist on the periphery of the network, including 19 organizations with only one tie. Despite the large number of organizations with minimum connections, several organizations appear central to the network. The USDA NRCS, Idaho Power, and IDWR all have over 10 ties in the network. When these organizations are removed from the network (Figure 6), the number of organizations connected to the network drops from 41 to 22, nearly a 50% decline in network size. The importance of these central nodes is reflected in network centrality measures included in Table 2.

Despite having only five network ties, NOAA has the highest Bonacich Power value of any organization in the network (2286.0), indicating that NOAA is connected to influential organizations in the network. NOAA's value to the network comes in the form of providing climate information (outward flow) to other organizations central to the network, including the USDA NRCS, Idaho Power, and IDWR. The interviewee from Idaho Power explained the connection with NOAA, "I get most of my current climate data from NOAA, the Climate Prediction Center,…" This data tends to be more technical, such as model output or extended forecasts, "I do look at and utilize some of the National Weather Service or NOAA extended products, but most of the longer term products that I've looked at as far as modeling out 10, 15, 20 years…"

IDWR has the largest eigenvector centrality (0.462), suggesting the organization has substantial influence over the flow on climate information in the network through connections with other central organizations. IDWR is also identified as an organization with a significant ability to connect organizations across the network, having the largest betweeness centrality score in the network (154.08). This measure indicates that IDWR often acts as a bridge in the network, connecting organizations and sharing information that might otherwise not be shared. One interviewee representing Twin Falls Canal Company highlights the ability of IDWR to act as a bridge, connecting Twin Falls Canal Company to climate information, "Idaho Department of Water Resources, they, well [the Water Master] on the Upper Snake, so I communicate with him pretty regularly year around… He keeps track of climate and aquifer levels, snow packs, river flows, irrigation demands, all that kind of stuff."

The structure of this network suggestions that climate information is more likely to diffuse through the network if it passes through one of several central organizations. Bonacich Power statistics also indicate that information gathered from technical research organizations are more likely to be diffused through the network, despite the fact that many of these organizations have relatively few ties. The Australian Meteorological Society, Lawrence-Livermore National Laboratory, Western Snow Conference, and the National Climate Assessment all have Bonacich Power statistics above the network-wide average (an average of 832.19 compared to the network average of 416.82), yet have only five network ties between them. This also holds true for Universities in the network. The five universities identified in the network average only two ties, but each have higher than average Bonacich Power values (an average of 822.52, compared to the network average of 416.82), suggesting that though these universities have limited connection to the network, they are connected to influential organizations. Connecting the dots, the environmental context of the network encourages the diffusion of technical information from research organizations on the periphery, through central nodes and outward to less central organizations.

5.2 *Characteristics of Innovators*

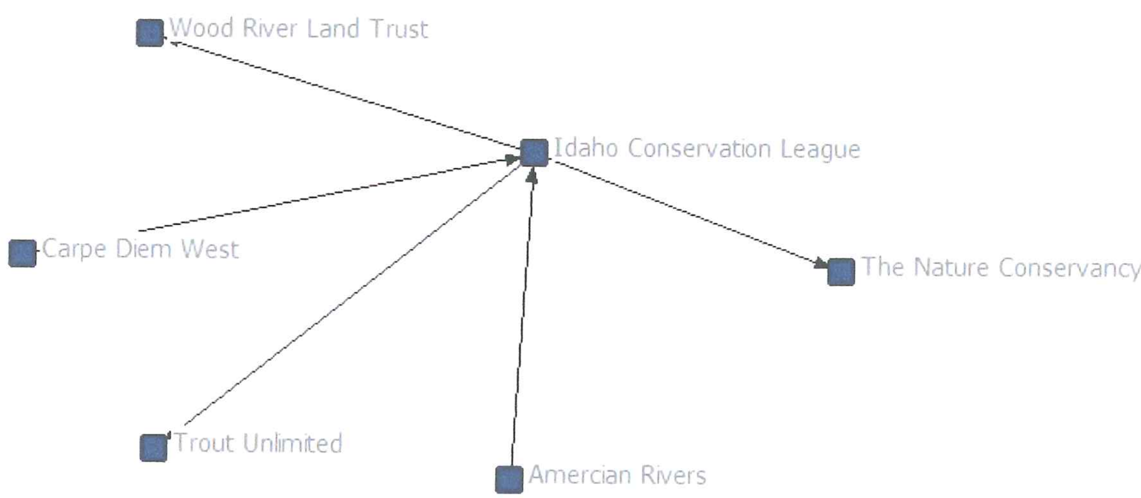
Wejnert (2002) emphasizes the importance of characteristics of innovators in the diffusion of innovations. One important characteristic is the type of organization involved in the network. Table 4 below shows average centrality measures for each type of organization included in the network. On average, state organizations, private companies, and local governments all identify more incoming climate information ties than outgoing ties. Federal agencies, universities, and non-profit organizations all identify more outgoing than incoming ties. In the case of non-profit organizations, the tendency toward sharing information with others may be due to the way these organizations use climate information in advocacy work, as conveyed by a representative of the Idaho Conservation League, "a lot of what I do is advocacy, not necessarily legal advocacy, but education and outreach, and then just… being a part of other groups or meetings where we're trying to get people to open up to the idea of how we use water, to be altered in some way." A representative of the Wood River Land Trust described a similar use for climate information, "The idea is that when we're looking at our [organization's] conservation strategies for this area, there's a lot of different impacts associated with the environment…" Both these organizations identify conservation as a goal for the organization's advocacy, though this is not likely the primary goal of all non-profits involved in climate information diffusion.

Table 4: Average Centrality Measures by Organization Type

Organization Type	N	Avg Out	Avg In	Avg BonPwr	Avg Eigen	Avg Between
State Agency/Board/Representatives	6	1.00	3.17	146.98	0.13	25.68
Private Company	5	2.00	3.60	404.85	0.20	18.93
City/Local Government	3	0.33	1.67	0.33	0.05	0.67
University	5	1.80	0.20	822.52	0.11	19.20
Federal Agency/Lab	9	2.78	0.89	756.68	0.12	17.64
General Public	1	0.00	7.00	0.00	0.28	0.00
Non-Profit Organization	6	2.33	1.17	158.77	0.06	11.25
Conference/Meeting	2	1.00	0.50	619.09	0.07	0.00
Other	3	0.00	2.00	0.00	0.12	0.00
Trade Organization	1	0.00	1.00	0.00	0.06	0.00

Wejnert (2002) recognizes the importance of horizontal and vertical diffusion between organizations. Network data in this study indicates the tendency for non-profit organizations to share information horizontally, between like organizations. Figure 7 below shows the network of non-profit organizations. This network has a greater density value (0.166) than the organization network as a whole (0.037). This finding indicates that horizontal connections between like non-profit organizations are more likely than connections between other types of organizations. A representative of the Idaho Conservation League explains several of their connections to non-profits, "I spend a fair amount of time using American Rivers, they have a pretty healthy website with all sorts of information and they're an organization that does a lot of different studies… There is a group called [Carpe Diem]… It's a group that.. try to do free information sessions, so webinars, they also produce studies on climate. Primarily climate change and water."

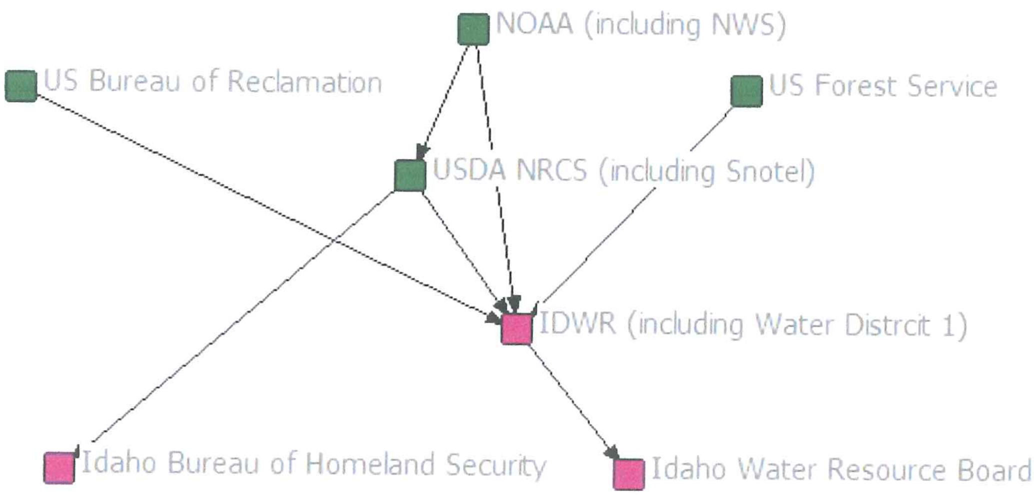
Figure 7: Network of Non-Profit Organizations



In contrast to the horizontal information diffusion demonstrated between non-profit organizations, climate information sharing between federal and state organizations exhibits a more vertical, or hierarchical, structure. Figure 8 shows the network between state and federal organizations who share ties (organizations without ties to other state/federal organizations have been removed). In this network, climate information flows exclusively from federal to state organizations, or between state organizations. Interviewees from the Idaho Department of Water Resources described several of the connections illustrated in Figure 8 when asked about non-university sources of climate information "Well [yes], some of the interactions that we have with the NRCS, the Snotel sites… National Weather Service… NOAA." The Idaho Department of

Water Resources plays a large role in this federal and state organization network, gathering information from four federal organizations. Additionally, in contrast to the non-profit network in Figure 7, this state and federal organization network is less dense then the original organization network (Figure 4), with a density of 0.029 compared to 0.037.

Figure 8: Connected State and Federal Organizations



5.3 *Characteristics of the Innovation*

Wejnert (2002) also highlights the innovation itself as a factor in diffusion. The network identified in this study is focused on the diffusion of general climate knowledge. However, climate knowledge is used differently among the network organizations. To meet the needs of these organizations, different types of climate information are diffused within the network. For the purpose of this analysis, climate information was broken into two types, general information and technical information. General information refers to information about climate trends, which tends to be used for more long-term uses, such as advocacy work. For example, general information might include climate outlooks for the future, such as water availability trends described by the Nature Conservancy interviewee, "I think probably the way that we do use [climate information] is talking about water and just the fact that we think that water is probably going to be more scarce in the future." Technical information refers to climate information used for more immediate decision making; this information tends to be more quantitative in nature. The interviewee from the Northside Canal Company gives an example of technical information and how it is used, "...basically looking at the long-lead temperatures we were seeing, going on to kind of get an idea of how much water use we might be able to expect into our irrigation and how to best manage our water supply to get through the irrigation season."

Of the organizations interviewed, 55% primarily described their organization's use of technical information, while 45% primarily described their organization's use of general climate information. About two-thirds (66%) of organizations described working primarily with water related climate information, such as streamflow or snowpack information. All organizations that described primarily using technical information were also mainly focused on water information. Table 5 below shows the disparity between the network roles of organizations that primarily use technical information, verse those that primarily use general information. Organizations using technical information described more incoming ties than those using general information, and also exhibit more centrality in the network. However, compared to technical information organizations, general information organizations described more outgoing ties with other organizations. In addition, organizations that work with water information describe more incoming and outgoing ties than organization that do not use water information. Organizations that utilize water information are also more central to the network.

Table 5: Centrality Measures by Information Type

Primary Info Type	N	Avg Out	Avg In	Avg BonPwr	Avg Eigen	Avg Between
Technical Info	5	3.00	6.00	580.92	0.29	49.75
General Info	4	3.25	2.25	117.91	0.09	17.38
Water Info	6	3.50	5.33	561.54	0.26	49.79
Non-Water Info	3	2.33	2.33	2.33	0.07	6.50

6. CONCLUSION AND POLICY RECOMMENDATIONS

Rogers (1962) introduced a theory for the diffusion of innovations, which highlights the role of the characteristics of the innovation, communication channels between participants, time, and social systems to the flow of knowledge. Wejnert (2002) expands upon Rogers' theory by creating a framework where the environmental context, as well as characteristics of the innovation and innovator dictate the diffusion of innovations. Wejnert's diffusion framework provides a lens with which to examine the network of organizations identified in the Big Wood Alternative Futures Project. Using formal network analysis and qualitative interview data, Wejnert's framework brings forth a number of interesting results from the data.

Viewing the environmental context as the organization network by which diffusion occurs, the network identified in the data proves to be one that is loosely connected. Analysis shows the network to be largely dependent upon three central organizations, the USDA Natural Resource Conservation Service, Idaho Department of Water Resources, and Idaho Power. Each of these organizations is shown to exhibit a large degree of centrality in the network, providing network ties to 16 organizations that would otherwise exist outside network (Figure 6). Despite having fewer ties than the three central organizations mentioned above, NOAA plays an important role in diffusion by connecting to influential organizations in the network. Despite having few network ties, organizations that conduct or share research, such as universities, federal labs, and professional conferences are also shown to exhibit an above average potential to influence the network by connecting to central network organizations (Table 4).

Diffusion within the network appears to be dependent upon the type of organization through which climate information flows. State agencies, private organizations, and local governments tend to absorb more information than they distribute, while federal agencies and non-profits distribute more than they absorb. A look at the relationship between federal and state agencies shows a largely hierarchical, or vertical, structure with climate information flowing from federal to state agencies (Figure 8). In the case of non-profits, climate information primarily flows horizontally, between non-profit organizations (Figure 7).

Characteristics of the innovation, or the type of climate information shared, appears to also play a role in the diffusion of climate knowledge. In this analysis, technical climate information like quantitative model data is distinguished from more general information, such as long-term climate trends (e.g. water availability will decrease over the next 50 years). Organizations that work with more technical climate information tend to have more incoming and less outgoing ties compared to organizations that use more general climate information (Table 5). Organizations using technical information also exhibit a greater degree of centrality in the network. Use of water related climate information appears to also be an important factor in diffusion. Organizations working with water related climate data have more incoming and outgoing ties, while also exhibiting greater centrality than organizations that do not work with water related climate information.

6.1 *Policy Recommendations*

Findings from the Big Wood Alternative Futures Project suggest a number of policy recommendation to improve the diffusion of climate knowledge within the Big Wood network. Perhaps the most evident result of this analysis is the importance of water to the network. Central network organizations that work with water related climate data have a large capacity to diffuse climate knowledge within the network. The USDA Natural Resource Conservation Service, Idaho Department of Water Resources, and Idaho Power all work extensively with water related climate information and exhibit a large degree of centrality within the network. Water related climate data that can is absorbed by these three organizations has a much greater chance of diffusion through the network when compared to other network organizations. Focusing the presentation of new and novel climate information on these organizations would improve the efficiency of diffusion by focusing effort on organizations known to diffuse climate information widely within the network.

In addition to organizations central to diffusion, several organizations in the analysis are shown to have a significant influence over diffusion through secondary ties. These organizations tend to be sources of research on climate, including universities, federal labs, and professional conferences and meetings. Despite the ability for these organizations to influence diffusion, their ability is limited by the number of direct ties these organizations have to the network. Creating direct ties between these research organizations and federal and state agencies operating in the study area has the potential to increase the diffusion of climate knowledge within the network.

The creation of these ties should also take into consideration the hierarchical structure of federal and state agencies in the network, as information directed toward the top of the hierarchy will have greater opportunity for diffusion. Additionally, creating ties between research organizations and non-profits would improve the likelihood of diffusion within the network. Currently, non-profit organizations exist on the periphery of the network, acquiring information from other non-profit organizations. Forming direct ties between research organizations and non-profits would increase the diffusion of climate knowledge within the network, providing these organizations with new and novel information to share with network partners.

6.2 *Future Research*

Moving forward, additional research on the networks of climate information should expand its scope, focusing on large study populations in different areas of the country and world. The results of this study are limited by the size of the study population and sample, as well as the unique nature of the study area. The results of this network analysis should be explored in other study areas to determine if similar network characteristics exist. In particular, the interactions between non-profits, as well as state and federal agencies should be explored. Methods used in this study could also be improved upon. This study exclusively uses interview data to construct and analyze the network of organizations. A more efficient approach might include surveying the study population, asking where participants receive and share climate information in order to construct a baseline network. This survey technique could then be supplemented by semi-structured interviews focusing on the nature of network ties, including the type of information shared between network members. The combination of survey and interview techniques could lead the researcher to identify a larger network, while still acquiring qualitative data from network participants.

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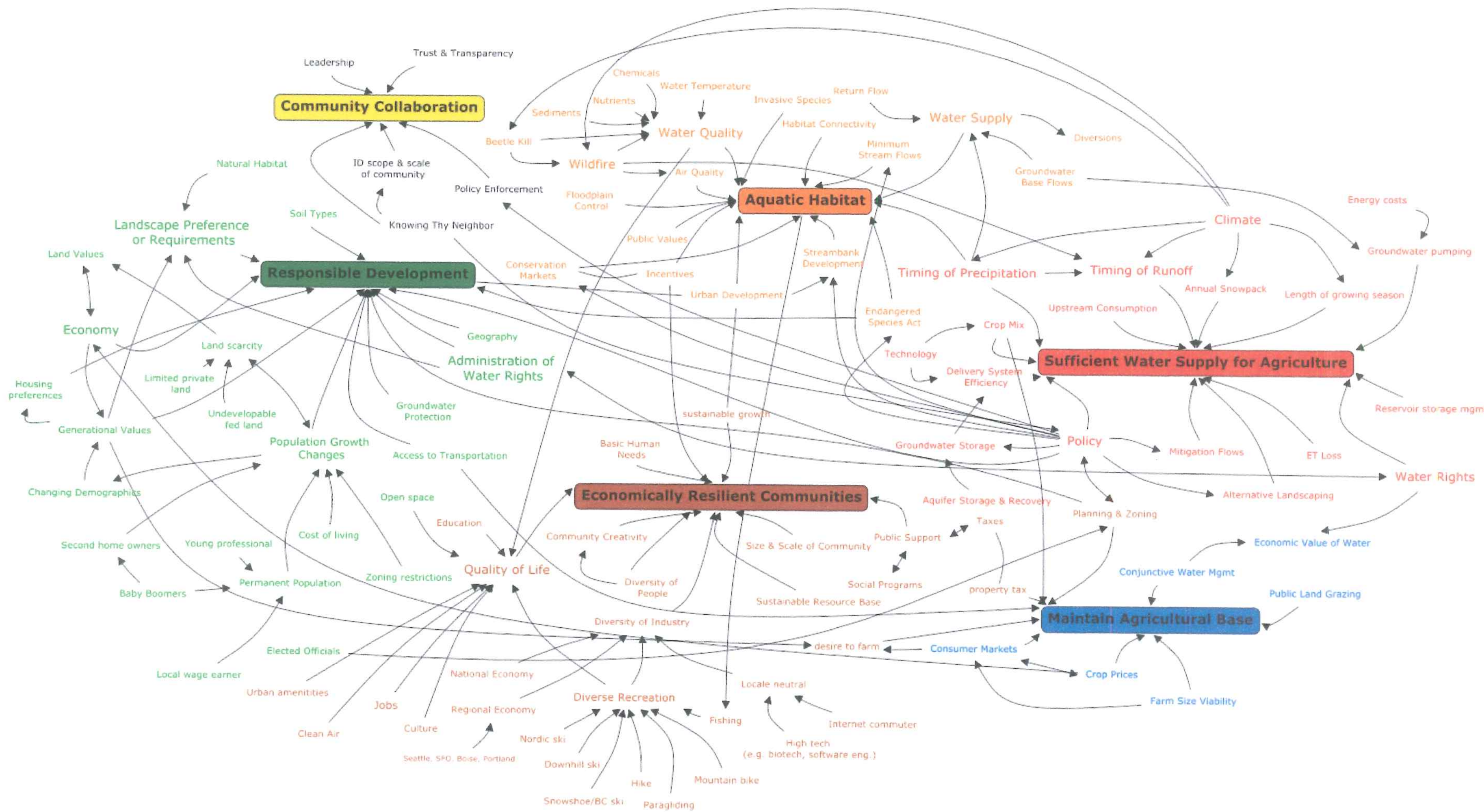
Appendix A: Concept map of future endpoints identified by stakeholders



Appendix B: Project proposal for the Big Wood Alternative Futures Project

Pacific Northwest Climate Impacts Research Consortium
pnwclimate.org

Project Proposal – Big Wood River Basin, Idaho

Objectives

- Convene a group of water users and managers within the Big Wood River Basin to identify and collaboratively produce relevant information needed to make decisions about the water resources of the basin.
- Explore a range of potential impacts to water resources due to human and natural drivers of change over the next 30-40 years.

Proposed Research Questions

Based on information obtained from local water users and managers through discussions and workshops, the following research questions are proposed for study:

- How are drivers of change, both natural and human, likely to affect the quantity and timing of water for agriculture, fish habitat, and municipal uses in the Big Wood Basin?
- Where and when is water scarcity most likely to occur in the Big Wood Basin under projected future conditions?
- What policies and strategies would be most effective for achieving the desired endpoints for the basin?

A parallel research question posed by the Climate Impacts Research Consortium is:

- Does the collaborative development of information lead to more useful and useable information for resource managers?

Proposed Methods

1. Develop a conceptual model of the Big Wood Basin. (completed during August 2010 workshop)
    a. Identify the primary endpoints[1], components[2], influences[3], and drivers of change within the Basin. Integrate these components into a conceptual model.
2. Develop a system dynamics model of the Big Wood Basin.
    a. Using the information from the conceptual model, develop a system dynamics model using the VenSim platform (http://www.vensim.com/).
    b. Use the system dynamics model to explore relationships, feedbacks, and system responses to changing inputs.
3. Integrate the conceptual and system dynamics models into a spatially explicit alternative futures scenario analysis model.
    a. Couple natural and human models and data sets to represent the primary elements of the Big Wood Basin within Envision, a scenario analysis and modeling tool (http://envision.bioe.orst.edu/).
    b. Using the Envision platform, develop baseline and alternative scenarios with the collaborative group to explore impacts of land and water management decisions on landscape change and patterns of water use.

[1] Endpoints: centerpieces of the conceptual model; what is important to understand within the system
[2] Components: elements of the system that relate to the endpoints
[3] Influences: relationships within the system; used to indicate how components affect other components or endpoints

This work is supported by NOAA's Climate Program Office with funding from the Regional Integrated Sciences & Assessments (RISA) program.

4. Facilitate information sharing within the collaborative group.
    a. Conduct in-person meetings, workshops, and webinars as necessary to exchange information and achieve project objectives.
    b. Maintain a website containing project information, workshop or meeting notes, and other relevant information.
5. Engage the collaborative group in an analysis of the effects of decision alternatives to the identified endpoints.
6. Conduct surveys, interviews, or other assessments throughout the project to evaluate the utility of these methods and approaches.

Proposed Timeline

Approximate Date	Activity
August 2012	**Meeting 1:** *Workshop to identify issues, system, sources of information* **Develop conceptual model**
August – Nov 2012	**Ongoing stakeholder outreach** **Develop System Dynamics model**
Nov 2012 – Feb 2013	**Webinar series (approximately 90 minutes each)** • Webinar 1 (Nov): Presentation of preliminary system dynamics model • Webinar 2 (Jan): Regional climate model projections for the Big Wood Basin • Webinar 3 (Feb): Land use **Ongoing System Dynamics model development**
March 2013	**Meeting 2:** *Workshop to identify scenario elements and narratives*
March – June 2013	**Develop Alternative Futures Scenario Analysis Model**
June 2013	**Meeting 3:** *Review initial scenario results; finalize alternative scenarios*
August 2013	**Meeting 4:** *Final scenario review; exploration of tradeoffs*

Planned Deliverables

1. Conceptual model of endpoints, components, and influences within the Big Wood Basin identified by the collaborative group.
2. System Dynamics model representing the major elements of the conceptual model.
3. Alternative scenario narratives and spatially explicit model outputs of scenario simulations.
4. All models and input datasets used in the analyses.

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Appendix C: Draft Scenarios created following a June 2013 meeting with stakeholders

DRAFT Scenario Narratives for Big Wood Alternative Futures: 6/28/13

Tourism Boom – More Management

Water Use:

Under a tourism boom – more management scenario, increased demand for recreational water uses, and increased policies to promote high efficiency water use is assumed. Water use in agriculture will become more efficient. Incentives for shifting existing agricultural water rights to non-agricultural uses will be utilized. Agricultural systems will shift to more drought tolerant crops. More storage will be developed, and a 24 hour rule will be enforced *(what is this?)*. In this scenario, development will be limited by water availability. Conservation practices will be required for all municipal and private uses. The domestic exemption will be reduced (from X to Y). If water becomes scarce residential and recreational uses are given preference over agricultural uses. Increased in-stream flows will be used to meet water quality targets.

Land Use:

This scenario assumes limited conversion of agricultural land to conservation reserves, resorts, and spas will take place; Increased zoning and easements will protect prime farmland. No new development on public lands will be considered. In urban areas, effort will be placed into infill development emphasizing higher density in and around existing towns. Ninety percent of new population growth will be allocated to urban areas. Buffer zones will also be put in place to separate agricultural land from residential areas. Incentives to convert private lands into conservation uses will be provided such as increased riparian buffers, and wetland setbacks.

Tourism Boom – Less Management

Water Use:

Under a tourism boom – less management scenario, increased demand for recreational water uses is assumed through both increased snowmaking and increased instream flows *(others?)*. Both residential and agricultural water efficiency policies will be relaxed. Existing agricultural crop patterns will be maintained. Limited changes to water storage are assumed. The domestic exemption will be maintained. If water becomes scarce residential and recreational uses are given preference over agricultural uses.

Land Use:

This scenario assumes significant conversion of agricultural land to conservation reserves, resorts, and spas will take place; Limited zoning and easement protections will be provided to prime farmland. Some public lands will be developed as resorts. Urban density will remain at the status quo, while urban boundaries will be expanded. In rural areas, fewer development constraints will allow for more rural residential, commercial, and industrial development.

Agricultural Boom – More Management

Water Use:

Under an agricultural boom – more storage will be developed and water use in agriculture will become more efficient. Agricultural systems will shift to more drought tolerant crops. Development will be limited by water availability in this scenario. Conservation practices will be required for all municipal and private uses. The domestic exemption will be reduced (from X to Y). If water becomes scarce, agricultural uses are given preference over residential and recreational uses. No new in-stream water rights will be developed.

Land Use:

This scenario assumes increased zoning and easements to protect prime farmland. In urban areas, effort will be placed into infill development emphasizing higher density in and around existing towns. Ninety percent of new population growth will be allocated to urban areas. Buffer zones will also be put in place to separate agricultural land from residential areas.

Agricultural Boom – Less Management

Water Use:

Under an agricultural boom - less managed scenario, efficiency of water use in agriculture will remain at the status-quo. Agriculture will shift to more water intensive cropping patterns and limited changes to water storage are assumed. The domestic exemption will remain at its current level. No new in-stream water rights will be developed.

Land Use:

This scenario assumes significant expansion of agriculture through conversion of non-agricultural private and public land. In rural areas, fewer development constraints will allow for more rural residential, commercial, and industrial development. Urban density will remain at the status quo. Roughly half of new population growth will be allocated to urban areas and half to rural areas.

Appendix D: Interview Outline

Verbal Consent Guide

- This study involves research on climate knowledge networks. You will be participating in a semi-structured interview that lasts about 30 minutes about your climate network. This interview will be recorded for the purpose of analysis.

- Names will be used during the interview process to identify members of the network. Upon completion of interviews, names will be replaced with identifiers to be used in the analysis process. A list of names and identifiers will be kept during the analysis process, but will be destroyed upon completion of the study.

- You may contact the PI, Denise Lach via email or phone with any questions or concerns regarding this research:

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- Participation in this study in voluntary, refusal to participate will involve not penalty or loss of benefits. You may discontinue participation in the study at any time, and you may skip any questions you do not wish to answer.

- Are there any questions can I answer for you?

Interview Outline

1. How do you use climate info, do you use climate info to help manage or make decisions in your work? Decisions outside of work?

2. Where do you currently get climate information?
   - People
     - How do you know this contact?
     - Do you provide information to this contact?
   - Organizations
     - How did you come to know this organization?
     - How do you use this organization?
   - Media

3. For each of these sources (Q2), let me know (how do they assess)
    - Value/usefulness
    - Frequency
    - Trust/reliability

4. Who comes to you for climate information?
    - Who comes to you with questions?
    - How do you know those who come to you?
    - How do you give them information?
        - Email?
        - In person?
        - Phone?
    - Does that person also share climate information with you?

5. Info about you
    - Position (title), Organization
    - Farmers: other organizations? Position?
    - Gender: note
    - Age: Brackets
    - Education: highest degree obtained