Journal of Rural and Community Development

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Citation:
Horning, D., Bauer, B. O., & Cohen, S. J. (2016). Watershed governance for rural communities: Aligning network structure with stakeholder vision. *The Journal of Rural and Community Development*, *11*(2), 45-71.

Publisher: Rural Development Institute, Brandon University.

Editor: Dr. Doug Ramsey

ISSN: 1712-8277 © Journal of Rural and Community Development
www.jrcd.ca

Watershed Governance for Rural Communities: Aligning Network Structure with Stakeholder Vision

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Abstract

Water governance often adopts one of two end-member frameworks: (a) centralized, command-control structures, or (b) distributed–collaborative networks. The former typifies the traditional style of water governance that has reigned for the past century, whereas the latter is increasingly touted as a panacea to the evolving challenges of water resource management in a time of rapidly changing drivers (e.g., climate change, urbanization). This study applies Social Network Analysis (SNA) to two case-study watersheds in south-central British Columbia in order to assess the (mis)alignment between water governance network structure and stakeholder objectives regarding adaptation to the pressures imposed by climate change. The results indicate that rural, water-scarce regions continue to be burdened by centralized, command-control style structures that reinforce the status quo in watershed governance (Neef, 2009). This reality marginalizes stakeholders at the peripheries of the network, who may represent a silent but significant voice in regard to future visions for watershed governance. The management of common-pool resources in rural areas will likely remain a difficult challenge without social networks that are designed strategically so as to become better aligned with stakeholder visions.

Keywords: adaptive; bridging; knowledge transfer; learning; social network

1.0 Introduction

Water governance can be defined as the range of political, social, economic, and administrative systems spanning different levels of society for developing, managing, and delivering water resources (Global Water Partnership, 2003). The challenges associated with management of common-pool resources are often characterized by conflicting information, theories, and social values. It is well recognized that complex ecological problems cannot be solved by enhanced scientific information alone (Fischer, 2011; Ludwig, 2014); rather, the existing body of knowledge must be translated into effective actions that are broadly accepted by society.

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Understanding social patterns of interaction and communication that enable governance systems or organizations to fulfill their mandates and to adapt to new situations is critical. Information regarding social interactions within and across groups can be an important indicator of the ability of a system to address complex ecological problems inherent in current environmental challenges (Burt, 2000; Fischer & O'Conner, 2014). For effective governance, both existing knowledge and new knowledge must be generated collectively by scientists, managers, and stakeholders and then communicated effectively to society in order to garner broad support for future initiatives (Holling, 1978; Roux, Rogers, Biggs, Ashton, & Sergeant, 2006; Fischer & O'Conner, 2014) and build the adaptive capacity increasingly required of natural systems facing climate change impacts.

Building adaptive capacity within governance systems requires a balance of structural features determined by a multitude of contextual elements, including goals, social memory, heterogeneity, redundancy (resilience), learning, adaptive capacity, and trust (Holling & Meffe, 1996; Folke et al., 2002; Schneider, Scholz, Lubell, Mindruta, & Edwardsen, 2003; Anderies, Janssen, & Ostrom, 2004; Newman & Dale, 2005; Ostrom, 2005). For example, within the water governance literature there has been a general call for transitioning current centralized water governance regimes to distributed and collaborative models more capable of addressing the increasing complexity associated with escalating climate change impacts. To transition or adapt requires the network change in some fashion, and to change requires some form of learning. Pahl-Wostl, Nilsson, Gupta, & Tockner, (2011) describe how learning within the network is a reiterative, 'triple-loop-learning' process where incremental improvement of established processes, reframing, and transforming constitute the three loops of learning respectively, and the resulting system changes enable networks to adapt.

Canada's water governance system, which includes federal, provincial, territorial, and regional actors, has been described as highly fragmented due in large part to its decentralized, multi-jurisdictional nature (Bakker & Cook, 2011). Contributing to Canada's highly dispersed water governance structure is the segmented and often isolated, yet constitutionally entrenched responsibilities that span fisheries, navigable waters, environment, federal lands, and international waters at the federal level; water resources management pertaining to supply (licensing) and water quality at the provincial/territorial level; and water delivery and infrastructure at the municipal level. Adding to this complex mix is the diverse and often overlapping context in which water issues interface with human health, ecological integrity, economic benefit, and First Nations access and control (Pahl-Wostl, Lebel, Knieper, & Nikitina, 2012; Huitema et al., 2009), especially in rural regions where access to financial resources and knowledge is sparse.

This paper investigates social network structures associated with water governance within two rural watersheds in British Columbia using Social Network Analysis (SNA). Network theory suggests that the position of an actor within the network affects the actor's ability to influence the network, and that different network typologies may be better suited to accomplish different objectives. SNA is based on the fundamental assumption that an understanding of network relationships and associated interdependencies is required to explain individual and collective behaviours (Fischer, 2011). The interactions may be formally established through structured organizations (i.e., committees or advisory boards) or enabled by informal communication pathways (e.g., social media). Use of SNA facilitates the development of a holistic understanding of the knowledge exchange, learning capacity, and adaptability that exists at the actor, institutional, and network levels within a water governance regime. SNA may be employed to examine additional forms of exchange within a network as demonstrated by Kelly, Cooper & Pinkerton (2014) in their study of currency circulation.

Communication linkages within the two watershed planning processes are examined, focusing specifically on the (mis)alignment between network structure and established watershed planning goals. The primary questions being investigated are: (a) what types of network typologies and characteristics have evolved within these two rural watershed planning processes? and (b) Considering the contextual challenges and goals inherent in these watershed planning processes, are the network structures consistent with optimizing water governance objectives according to governance network theory? Network structure and characteristics are quantified through the use of network-theory-based quantitative metrics (i.e., reachability, closeness centrality, and clustering) identified in Bodin, Crona & Ernstson (2006).

2.0 Rural Water Governance and the Subsidiarity Challenge

Recently, there has been an unchallenged promotion of 'localized' governance solutions. Subsidiarity theory states that decision-making with concern for water resources should be made at the lowest possible level or level closest to where the resource is being used (Nowlan & Bakker, 2007). While 'local' is very context specific, localization and localism draw upon subsidiarity principles that are defined in broad terms as "decentralizing each task (governance) to the lowest level with capacity [and political authority] to conduct it satisfactorily" (Marshal, 2007, p. 93), subject to the corollary that, "complementary high-level institutions are established to address tasks that span multiple levels" (Garrick, Bark, Connor, & Banerjee, 2012, p. 917). The underlying philosophy posits that in order for local communities to achieve social and economic self-determination, governance must be developed on principles of effectiveness, responsiveness, representation, and legitimacy, thereby enabling communities to take advantage of environmental opportunities and protect the community against threats and challenges (Hunt & Smith, 2005).

Subsidiarity reveals two separate and possibly competing frames of reference: (a) an economic frame in which subsidiarity is viewed as decentralization for the purposes of efficiency that requires divesture of powers to lower levels in order to create competitive pressure, to maximize preference satisfaction, and to minimize circulation problems (see Charles Tiebout, 1956); or (b) a religious (teleological) frame that recognizes uniqueness and multiscale nature of individual social spheres and that each social sphere would have a power configuration aligned to the needs and purpose of that specific sphere (Blank, 2010). In the case of the economic framing of subsidiarity, there are potentially an unlimited number of social and political entities that could take on responsibilities and perform various governance functions. This can lead to the creation of new entities or special purpose governments (SPGs) at scales that provide the most efficient management of resources (Blank, 2010). The religious framing decentralizes power, responsibility, and authority to a limited and pre-existing number of entities (e.g., provinces, regions, cities, or towns). The free forming economic version of subsidiarity is driven primarily by efficient management of resources for the maximization of wealth, whereas in the religious framing, "the fit between a sphere and an activity (or function) is a result of the essence of the sphere and the nature of the activity at hand" (Blank, 2010, p. 542).

Ideally, localized water governance would include local and regional government agencies, First Nations, non-governmental organizations, and other SPGs such as regional water boards and watershed stewardship groups, in addition to provincial and federal levels of government that typically dominate the jurisdictional hierarchy or in essence 'government trumping governance' (see Zirul, Halseth, Markey, & Ryser, 2015). The new British Columbia Water Sustainability Act (Bill 18), for example, supports in principle the expansion of powers and responsibilities at the local level through 'place-based' strategies and alternative governance models, although details regarding how such transfers of responsibility are to be resourced and where authority rests remain largely unspecified. There are evident ramifications for rural communities that involve the degree to which decision-making responsibility is supported by appropriate sharing of financial resources and jurisdictional authority.

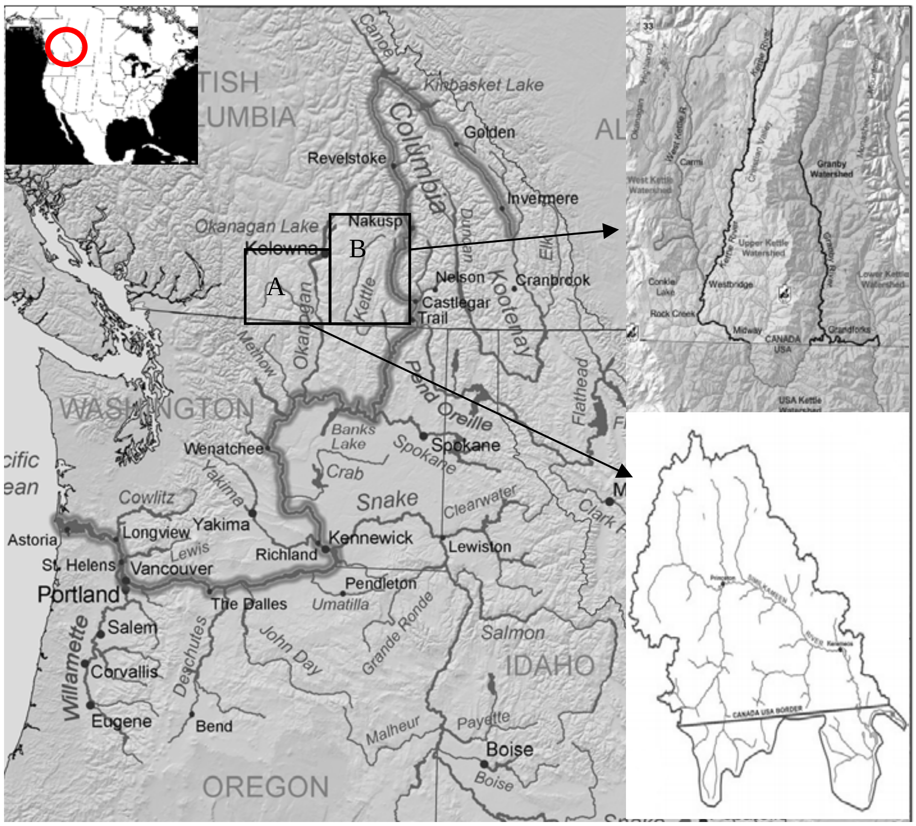
The challenges associated with the complex and nested nature of water governance is widely recognized (Cook, 2014; Morgan, Patrick & Bowden, 2014). The Organization for Economic Cooperation and Development (OECD, 2011), for example, identified the following key challenges: institutional and territorial fragmentation, badly managed multi-level governance, limited local capacity, unclear roles and responsibilities, and questionable or insufficient resource allocation. Other issues, including poor and inconsistent financial management, poor economic regulations, poorly drafted legislation, and the lack of long term strategic planning were also identified as significant challenges to the development of sustainable water practices (OECD, 2009). Often the capacity to address water related issues is lacking at the local level, and whatever capacity does exist is often fragmented due to varied viewpoints, values, and norms (Dewulf, Mancero, Cardenas & Sucozhanay, 2011). Dispersed and sparse rural populations with limited communication abilities are particularly susceptible to high levels of fragmentation (Bakker & Cook, 2011). One critical form of fragmentation is the absence of intra- and inter-agency communication linkages that are essential for effective water governance (OECD, 2009, 2011; Dewulf et al., 2011).

In response to these issues, compounded by the increasing complexity associated with climate change impacts, there has been a growing demand for more collaborative and adaptive forms of governance (e.g. adaptive co-management). Adaptive governance approaches allow management systems to engage in a form of experimental learning through a reiterative process, leading to increased societal learning and ultimately increased adaptive capacity and improved water related outcomes (Adger, 2009; Pahl-Wostl, 2009; Booth & Halseth, 2011; Pahl-Wostl et al., 2011).

3.0 Case Study Regions

The Similkameen Valley Watershed (SVW) and the Kettle River Watershed (KRW) (see Figure 1) were investigated using Social Network Analysis (SNA) to map and analyze the socio-ecological relationships that contributed to their water governance planning processes. The investigation involved mapping social relationships (i.e., network attributes) that developed among water actors participating in the planning process. The two case study watersheds were selected based upon having similar regulatory, environmental, and socio-economic contexts, as well as strong parallels in the underlying drivers that initiated watershed planning (i.e., increasing demand, changing supply, and conflicting views on legislative and regulating roles). Two case studies were undertaken (rather than one) to provide some sense of whether there can be variance among different watersheds in regard to the network typology that evolves, given that the actors differ. Limited resources precluded additional case studies, although this would be essential in order to make robust conclusions about the likely range of variance that characterizes rural watershed planning processes in British Columbia and other water scarce regions.

Figure 1: (A) Similkameen Valley Watershed, (B) Kettle River Watershed.



Source: https://upload.wikimedia.org/wikipedia/commons/e/e4/Columbiarivermap.png

3.1 Similkameen Valley Watershed (SVW)

The Similkameen River is a tributary of the Okanagan River, forming part of the larger Columbia River system. The majority of the SVW is located in Canada with a portion of the headwaters and lower portion located in the United States. The Canadian portion of the watershed is 7,600 km^2 in size (Hamilton 2011). The SVW is the largest watershed within the Okanagan drainage system, contributing 75% of the flow of the Okanagan River. The SVW is governed via multiple jurisdictional authorities including international (Canada/USA), federal, provincial, regional (Regional District of Okanagan-Similkameen), local municipalities (Town of Princeton, Village of Keremeos), First Nations (Upper Similkameen and Lower Similkameen Indian Bands), and six irrigation and improvement districts.

The main drivers for creating a SVW Plan include widespread concerns for water availability, water quality, ecosystem requirements, population growth (amenity migration), economic development activities, transnational concerns (hydro production and water use), and climate change impacts (Glorioso & Moss, 2010; Hamilton, 2012). Virtually all cropland in the SVW depends on irrigation, and all surface water was considered fully licensed by the mid-1980s. With limited flow in the critical late summer months, increasing populations (5.9% between 2001 and 2006), expanding recreation facilities (e.g. Apex Ski Resort), and increasing mining activity, residents have demonstrated heightened awareness of future uncertainties with regard to water resources management.

3.2 Kettle River Watershed (KRW)

The Kettle River, one of British Columbia's Heritage Rivers, lies between the Okanagan and Columbia River valleys in the central part of southern British Columbia. Approximately 75% (8,230 km^2) of the total KWR (11,000 km^2) is located within Canada, with the remaining drainage area (2,650 km^2) within northern Washington State (Regional District Kootenay Boundary, 2010). As with the Similkameen River and most other interior rivers in British Columbia, flow discharge is high during the spring freshet as a result of snowmelt but there is significant reduction by mid to late summer when demand from water users is substantial (Hamilton, 2012).

The residents within the KRW have expressed concern with respect to diminishing flows, adequate water supplies for communities, sufficient flow for fish survival, water quality, and health of riparian ecosystems, particularly during mid and late summer months (Glorioso & Moss, 2010; Hamilton, 2012). These concerns are exacerbated by uncertainty surrounding the implications of climate change. The Kettle River is ranked as the most endangered river in BC (Angelo, 2011), primarily due to the seasonal low flows and current development demands associated with water extraction (Regional District Kootenay Boundary, 2010). Prominent among the proposed developments is a water use application from a major ski resort requiring 400 million gallons of clean water annually to accommodate planned resort expansion. If approved, water extraction licences would add further pressure to the oversubscribed river, with 994 current licences (at 826 points-of-diversion) for surface water in the Canadian portion of the watershed (with 1,100+ more in the US). Crop irrigation remains the largest licensed volume for extraction, followed by domestic use.

4.0 Methodology

4.1 Social Network Analysis

Social Network Analysis (SNA) was used to identify patterns (network structures) that assist and restrain individual actors' ability to influence water-related decisions. Ultimately, properties of the social system that support decision-making are exposed (Wasserman & Faust, 1994; Diani & McAdam, 2003; Borgatti, Mehra, Brass & Labianca, 2009; Stein, Ernstson & Barron, 2011). Specifically, the sociograph (SNA mapping outcome) makes implicit social elements, such as 'communities of practice', explicit via a visual representation of the network structure. The implicit components of the network are often associated with pockets of specialized local knowledge or shared interests that have developed over time and place, but they may not be widely known beyond the immediate participants (e.g., community-based conservation efforts). SNA helps to identify the relevant actors likely to interact and learn from each other through their tight connections. Conversely, there may be communication deficiencies that result in knowledge gaps. Isolationism and fragmentation, for example, can be measured to identify potential nodes of innovation that exist on the periphery of the network, which, if more strongly connected, could advance the agenda of the whole network via more efficient knowledge exchange.

A social network is comprised of a set of actors, whether individuals or aggregated groups, linked through one or more relationships (Scott, 2000; Marin & Wellman, 2011; Stein et al., 2011). Actors are referred to as 'vertices' or 'nodes' and the relationships between actors, referred to as 'edges' or 'links', are associated with communication mechanisms or information exchange pathways. SNA is used to characterize the relative arrangement of these network components and the strength of their interaction via a series of quantifiable metrics.

4.2 Watershed Network Bounding Survey

An observational case-study design was implemented to analyze the communication patterns associated with the watershed planning processes for the SVW and the KWR. A semi-structured bounding survey and interviews (phone and in-person) were employed to collect relational data used to characterize the networks. Consent was obtained prior to conducting interviews. Each of the watersheds' planning process followed similar stages, beginning with technical assessment of the watershed and followed by the watershed plan development. The watershed plan development involved stakeholder committees and steering committees. Participants in the Steering Committee were usually volunteers and local government appointments, whereas members of the Technical Committee were local government appointees. A local consulting firm was selected to conduct the initial technical reports for each of the watersheds. The watershed planning committee members consisted of local, provincial, and federal government representatives, First Nations, and local non-government stakeholders including resort owners, farmers, and energy development groups. In the SVW a pre-watershed planning process conducted by the Similkameen Valley Planning Society (SVPS) provided an existing group of local government representatives and other non-government representatives to populate the watershed planning committees. In KRW the planning process also consisted of a Technical Committee and a Stakeholders Committee as well as a Steering Committee.

In order to capture the entirety of each network a relation-based approach, referred to as *expanded selection*, was utilized to define the final network limits (network bounding) by drawing on the identified network actors' knowledge of their egocentric network limits (Doreian & Woodard, 1994; Marsden, 2005). The expanded selection is an abbreviated form of referral sampling that allows informal actors to be identified and included, providing a more accurate bounding of the watershed planning network. All individuals identified by the regional governments as formally participating in the watershed planning process were included in the initial bounding list for the process. Each of the formal members was requested to list up to five additional members with whom they had meaningful engagement within the development of the plan. These additional participants were considered the informal participants. Follow-up interviews were conducted to (a) ensure all participants were given the opportunity to respond to survey, (b) ensure a high response rate could be achieved, and (c) allow for richer responses through the interview process. The end result was a bounded network based upon the collective knowledge of the network participants (Stein et al., 2011). Each interview was recorded (with approval) and later transcribed. The challenges associated with SNA emanate from the requirement that respondents divulge personal information that may have (or be perceived as having) associated risks, such as implications for current employment or negative implications for existing working relationships. Thus, participation rate in the survey can suffer.

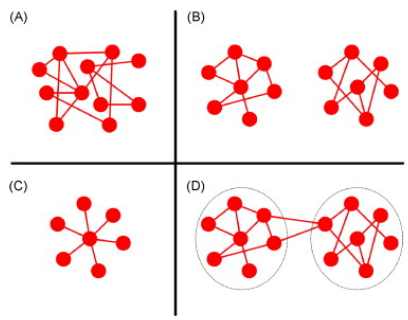
Structurally speaking, network learning is enhanced through strong links within a group (Granovetter, 1983), which is achieved through high modularity. High modularity enables the transfer of tacit knowledge (Reagans & McEvily, 2003) and complex knowledge relevant to the increasing unpredictability of water resource management (Bodin et al., 2006). It should be noted that some degree of separation of these groups is required in order to maintain heterogeneity within the network. Having high 'reachability' or shortest hops to many actors, privileges the network with expanded knowledge repositories, enhancing potential for innovative solutions. High centrality among few actors may, however, lead to a continued dependence upon centralized governance models (Bodin et al., 2006) and negatively impact network learning due to restricted access to the broadest possible grouping of actors and their varied knowledge repositories (Crona & Boden, 2006). To quantify the level of grouping within a network requires cluster analysis.

Building on adaptation research carried out by Newman and Dale (2005) and Bodin et al. (2006), this research focused on social network structural characteristics, measured through social network metrics: reachability, centrality, and clustering coefficient. Both reachability and centrality have been identified as being positively correlated to the adaptive capacity of a social network. The clustering coefficient metric is used to quantify the learning capacity, which has been identified as a fundamental component of the adaptive capacity of a social network (Pahl-Wostl et al., 2011). The structural characteristics of the planning networks were examined and contrasted to better understand the existing adaptive capacity embedded within rural watershed planning networks and to investigate how the network structures may or may not be aligned with the objectives and vision of the stakeholder groups.

4.3 Network Structure Typology

Figure 2 shows four idealized networks (based on Bodin & Crona, 2009), each with inherent advantages and disadvantages with regard to watershed governance. For example, it has been argued that the mesh network typology (A) is preferable for adaptive governance due to more effective communication along multiple edges and increased levels of trust, thereby facilitating greater access to a wide variety of knowledge within the network (Currall & Judge, 1995; McLain & Hackman, 1996; Rathwell & Peterson, 2012). Ultimately, this leads to greater trust. Collaborative and distributed network typologies such as (A) appear better suited to address complex tasks due to the increased level of innovation resulting from a diversity of interconnected actors (Bodin & Crona, 2009; Ernstson, Sörlin & Elmqvist, 2009; Crona & Hubacek, 2010; Bodin & Prell, 2011; Stein et al., 2011, Weiss, Hamann, Kinney & Marsh, 2012; Lienert, Schnetzer & Ingold, 2013). In contrast, the core-periphery network typology (C) is characterized by centralized decision-making and restricted communication pathways, leading to limited knowledge diversity and homogeneous values (Boden & Crona, 2009).

Figure 2: Social Archetypical Network Typologies. (Adapted from Bodin & Crona, 2009, p. 369).



4.4 Network Metrics

Common to both case-study watersheds was the importance placed upon the need to adapt to climate change impacts, as a planning objective (Glorioso & Moss, 2010; Newig, Gunther & Pahl-Wostl, 2010; Hamilton, 2012). Therefore, network metrics associated with adaptive capacity were deemed critically important, specifically, reachability and centrality (Bodin et al., 2006). In social network analysis, 'centrality' and 'community' are quite often the focus, however, few studies have looked at both of these structural properties together (Obradovi & Rueger, 2011), so we have added a cluster analysis to reveal the community structures embedded in the networks.

4.4.1 Reachability. Reachability is defined as the number of independent 'components' (e.g. sub-networks) within a broader network for which all vertices in the sub-network are directly or indirectly in contact with each other, but not with other sub-network vertices (Bodin et al., 2006, p. 37; Janssen et al., 2006). Scott (2000,) defines a component as, "a subgraph where all points can reach one another through one or more paths but no paths run to points outside the component" (p. 101). If a network consists of more than one component (e.g., Typology B in Figure 2), it is considered fragmented. The degree of fragmentation can be quantified by measuring the number of components, with large reachability values indicating greater degrees of fragmentation (Bodin et al., 2006, p. 37). Network fragmentation creates barriers to knowledge transfer, learning, adaptive capacity, and overall network collaboration essential to adaptive and resilient governance models (Dietz, Ostrom & Stern, 2003; Lee, 2004; Folke, Hahn, Olsson & Norberg, 2005; Lautze, de Silva, Giordano & Sanford, 2011; Tan, Bowmer & Baldwin, 2012; Green, Cosens & Garmestani, 2013). Identifying and understanding the number, size, and pattern of the components provides insight into the opportunities and obstacles to effective communication and, ultimately, collective action (Scott, 2000).

4.1.2 Closeness centrality. The 'closeness centrality' metric provides insight into network inter-connectivity because it measures the shortest (geodesic) distance between a vertex of interest and all other vertices within the network (Sabidussi, 1966; Knoke & Yang, 2008). The closeness centrality score of a vertex indicates the structural positioning of that vertex as well as the relative importance of that vertex within the network or sub-network. Hansen, Shneiderman & Smith (2011) describe the closeness centrality score as a distance because it is proportional to the number of steps between any two vertices of interest. The closeness centrality of a vertex impacts the distribution of knowledge, the transfer rates of information, and the mediated nature of knowledge because it accounts for the numbers of actors and knowledge repositories between distal and proximal vertices in the network. Typically, small closeness centrality scores denote greater inter-connectivity of a particular actor and subsequently greater structural importance to network communication (Hansen et al., 2011). Hansen et al. (2011) refer to closeness centrality as a paradoxical measure of distance. The SNA program employed for this study (Smith et al., 2009; Hansen et al., 2011) utilizes a scoring system where larger values of closeness centrality indicate greater connection to other vertices. The index of an actor's closeness centrality is calculated as the inverse of the sum of the geodesic distance (i.e., the shortest distance between pairs of vertices) between an actor and all other actors (Knoke & Yang, 2008). Values are normalized to remove network size influence and to allow for comparison across various network sizes. A fully connected node will have a value of 1, whereas isolates are identified with 0.

4.1.3 Cluster analysis. Identifying groups or clusters within a social network and mapping their relationship to one another enables insight into communication patterns and knowledge flows within a network. Cluster analysis involves the process of identifying communities of densely connected vertices that are only weakly connected to other communities (Hansen et al., 2011), as shown in Typology D in Figure 2. The Girvan and Newman (2002) clustering algorithm is designed to detect tightly clustered nodes or communities within a network by progressively removing edges between low centrality—sparsely connected—vertices. For example, Typology D in Figure 2 will reduce to Typology B—two independent sub-networks as identified by the reachability metric— with the elimination of only two edges. Girvan and Newman (2002) define 'edge-betweeness' as the number of shortest paths (edges) between pairs of vertices (dyads). The edges that connect communities will have high edge-betweeness values, and their removal will result in the identification of those communities as isolated clusters (Girvan & Newman, 2002).

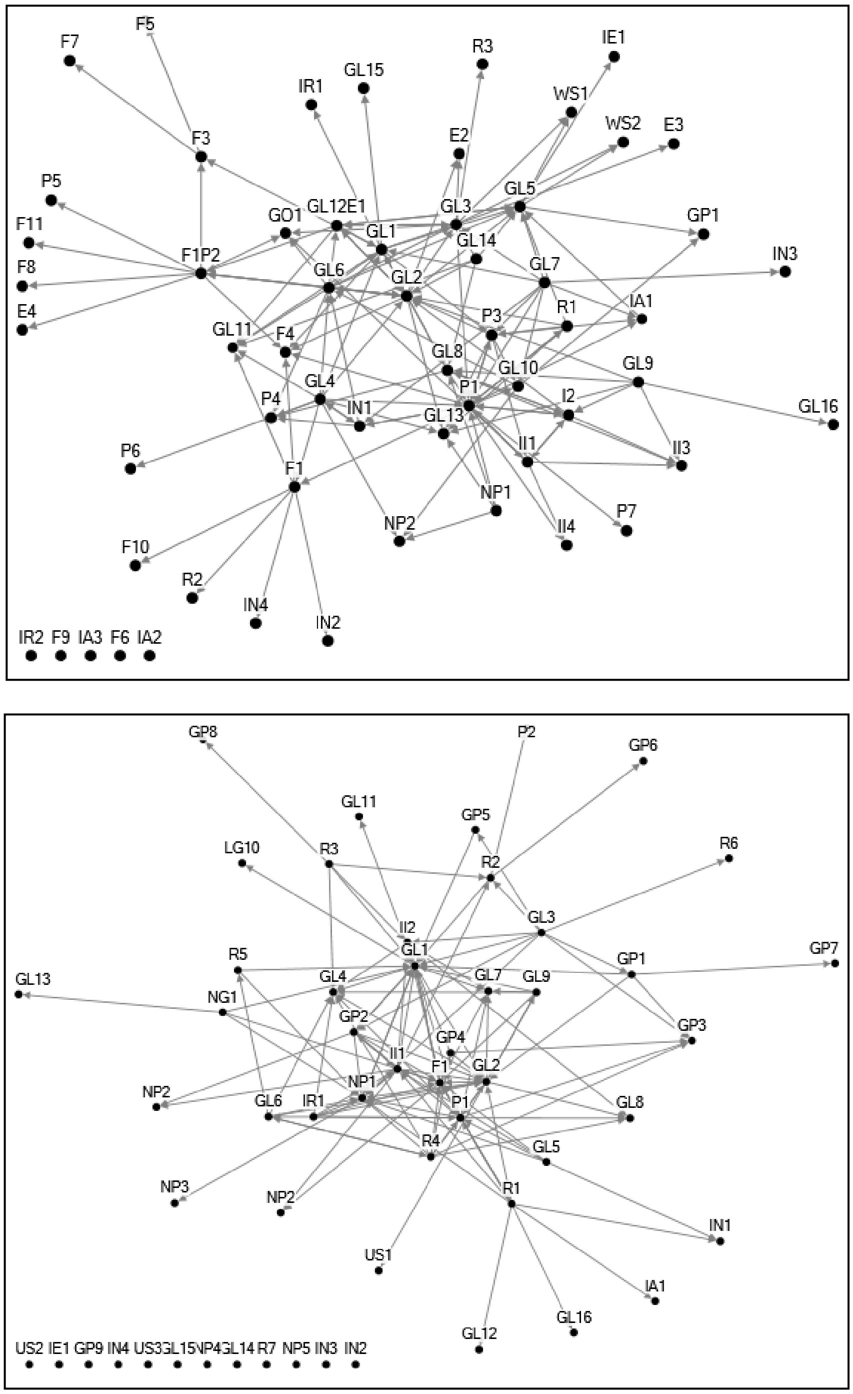
The communities that are revealed within a network through cluster analysis are often quite different from formalized structures imposed on the network, such as organizational hierarchies (e.g., local, regional, provincial, and federal governments). Indeed, the clusters may be based solely upon informal communication patterns motivated by other elements including trust, mutual gain, and accessibility (Loftus, 2009; McEvily & Tortoriello, 2010).

5.0 Results

Survey response rates reached 82% for the SVW and 70% for the KRW networks. Sociographs for the two watershed networks are presented in Figure 3 with the associated actor code table (see Table 1). The Fast Multiscale Layout Algorithm of Harel and Koren (2001) was used to create these sociographs because it is a force-directed algorithm designed to make all lines (edges) representing a communication connection the same length to enhance the readability of the graph. Such graphical portrayals of the network provide a visual assessment of the degree to which these networks align with the traditional typologies presented in Figure 2.

Table 2 provides a summary of general network metrics calculated for the SVW and KRW Planning networks using NodeXL software (Hansen 2011). The total number of actors or network vertices for the SVW and KRW watersheds was n=59 and n=54, respectively. The total number of unique communication pathways (i.e., edges) for the SVW was 143, and for the KRW watershed it was 126. Pairs of actors (dyads) that identified each other as import for bi-lateral communication—quantified by the 'reciprocated vertex pair ratio' (VPR)—were slightly greater in the SVW (VPR=0.11) than in the KRW (VPR=0.08). The larger the VPR value, the greater the opportunity for knowledge transfer within the network.

Figure 3: Watershed Sociographs, Similkameen (Top) and Kettle (Bottom).



Source: Author.

5.1 Reachability

The 'average geodesic distance' refers to the average number of steps between all dyads in the graph (Wasserman & Faust, 1996). The 'maximum geodesic distance' is the maximum number of steps required to connect any two vertices. While the maximum geodesic distance of both case-study watershed networks is the same (5), the SVW network had an average geodesic distance of 2.64, marginally larger than the KRW (2.35).

The larger the geodesic distance between any two vertices, the weaker the linkage between these actors, resulting in a smaller likelihood that they will communicate with each other. The geodesic distance has implications for knowledge transfer, trust building, and ultimately decision-making. Despite a slightly larger average geodesic distance between vertices in the SVW, the overall level of fragmentation was relatively small with more than 91% of the vertices being connected (54 of 59). The KRW network was more fragmented with only 78% of the vertices being connected (42 of 54). The KRW had twice the number (12) of 'isolates'—single-vertex connected components—than the SVW (5). Isolates are vertices that are unconnected to the rest of the network, and the number of isolates gives additional insight into the level of fragmentation within a network. The KRW network therefore suffers from an inability to access potentially useful knowledge at the peripheries.

Table 2 indicates that the KRW network had more than twice the number of sub-networks or 'connected components' (13) than the SVW network (6). Note that the number of isolates—single-vertex-connected components—in the SVW (5) and the KRW (12) accounted for all but one of the connected components in each of the watersheds. This indicates that both networks are comprised of a single, dominant, 'super' component with several marginalized actors (isolates) along the periphery (more so in the case of the KRW). Evidently, there were no cliques—small groups of actors sitting in semi-isolation—within either network.

5.2 Closeness Centrality

Connectivity was measured in each of the networks via the 'closeness centrality' metric (see Table 3). As before, several 'isolates' or completely disconnected vertices with closeness centrality values of 0 can be identified. The majority of the vertices in each network, however, are connected to each other to varying degrees. The closeness centrality scores for the SVW are generally smaller (0.005–0.01) than for the KRW (0.008-0.015) with median centrality scores of 0.007 and 0.009 respectively.

Recall that a low closeness centrality score means that the actor is connected to most other actors in the network—although not necessarily through a direct link—which is consistent with the core-periphery structure of both networks. In contrast a mesh-like, randomized network of n=59 produces a median centrality of 0.014 due to the much higher number of edges (1731). Although the differences between the median scores for the SVW and KRW networks are small, in part due to the relative differences in size and complexity of the networks, they suggest that the KRW network has, on average, stronger connectivity between dyads, despite the larger proportion of isolates (12 of 53) that are included in the calculation of the overall network statistics in Table 3.

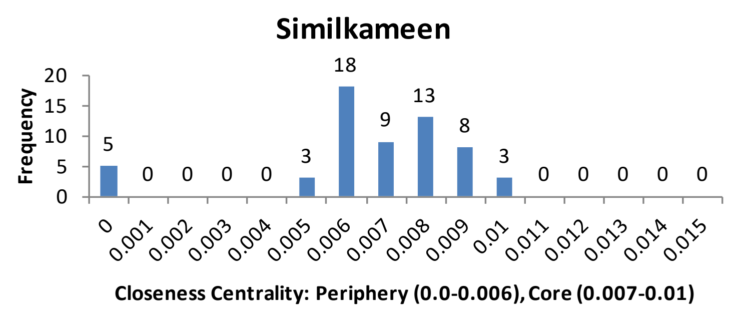
Table 1. *Sociograph Code Table*

E	Education:	education and researcher
F	First Nations:	Self-identifying and representing
G	Government:	**L**–local; **P**–provincial; **F**–federal; **O**-organization assisting gov.
I	Industry:	**A**–agriculture; **E**–energy producer; **I**–irrigation district; **N**–natural resource extraction; **R**–recreation and tourism
NG	Non-government:	gov. related or focused
NP	Non-profit:	environmental, advocacy groups
P	Private consultant	
R	Watershed resident no affiliation	
US	United States actor	
WS	Watershed representative:	alt. watershed (Kettle, Nicola, Similkameen.)

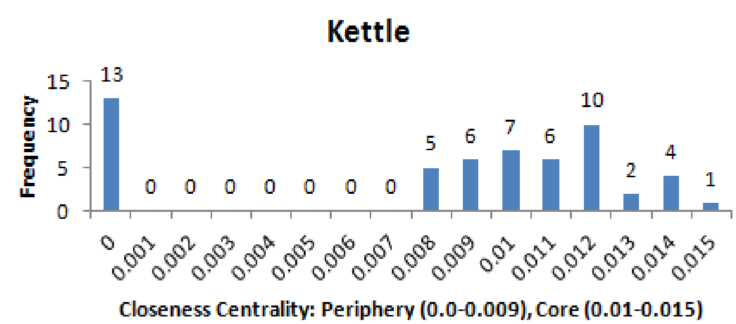
Table 2. *SNA Statistics for SVW and KRW Networks*

Watershed Network Summary Statistics		
Graph Metrics	**Similkameen**	**Kettle**
Vertices	59	54
Unique Edges	143	126
Reciprocated Vertex Pair Ratio	0.11	0.08
Connected Components (Sub-networks)	6	13
Isolates (Single-Vertex Connected Components)	5	12
Maximum Vertices in a Connected Component	54	42
Maximum Geodesic Distance (diameter)	5	5
Average Geodesic Distance	2.64	2.35

Table 3: *Closeness Centrality Metrics* (Note: NODEXL calculates small scores for low centrality and large scores for high centrality)



Minimum Closeness Centrality	0.000
Maximum Closeness Centrality	0.010
Average Closeness Centrality	0.007
Median Closeness Centrality	0.007



Minimum Closeness Centrality	0.000
Maximum Closeness Centrality	0.015
Average Closeness Centrality	0.008
Median Closeness Centrality	0.009

The 'super' component (i.e., the only sub-network with multiple vertices) in the KRW serves very much as a centralized core, with several actors isolated on the periphery without any connections to the core. This core-periphery distinction is much less evident in the SVW, suggesting that the network is more distributed and less core-reliant in terms of information exchange.

5.3 Cluster Analysis

The structure of ‘communities’ within the SVW and KRW networks is derived through a cluster analysis, as shown in Figures 4 and 5, respectively. Statistics for the clustering coefficient accompanying the analysis are presented in Table 4. The standard cluster graphs use a color scheme to designate different communities (see Figures 4 and 5). In order to provide better clarity regarding the community structure, the clusters were aggregated (collapsed) with relative size corresponding to the number of nodes in the cluster (see Figures 4 and 5).

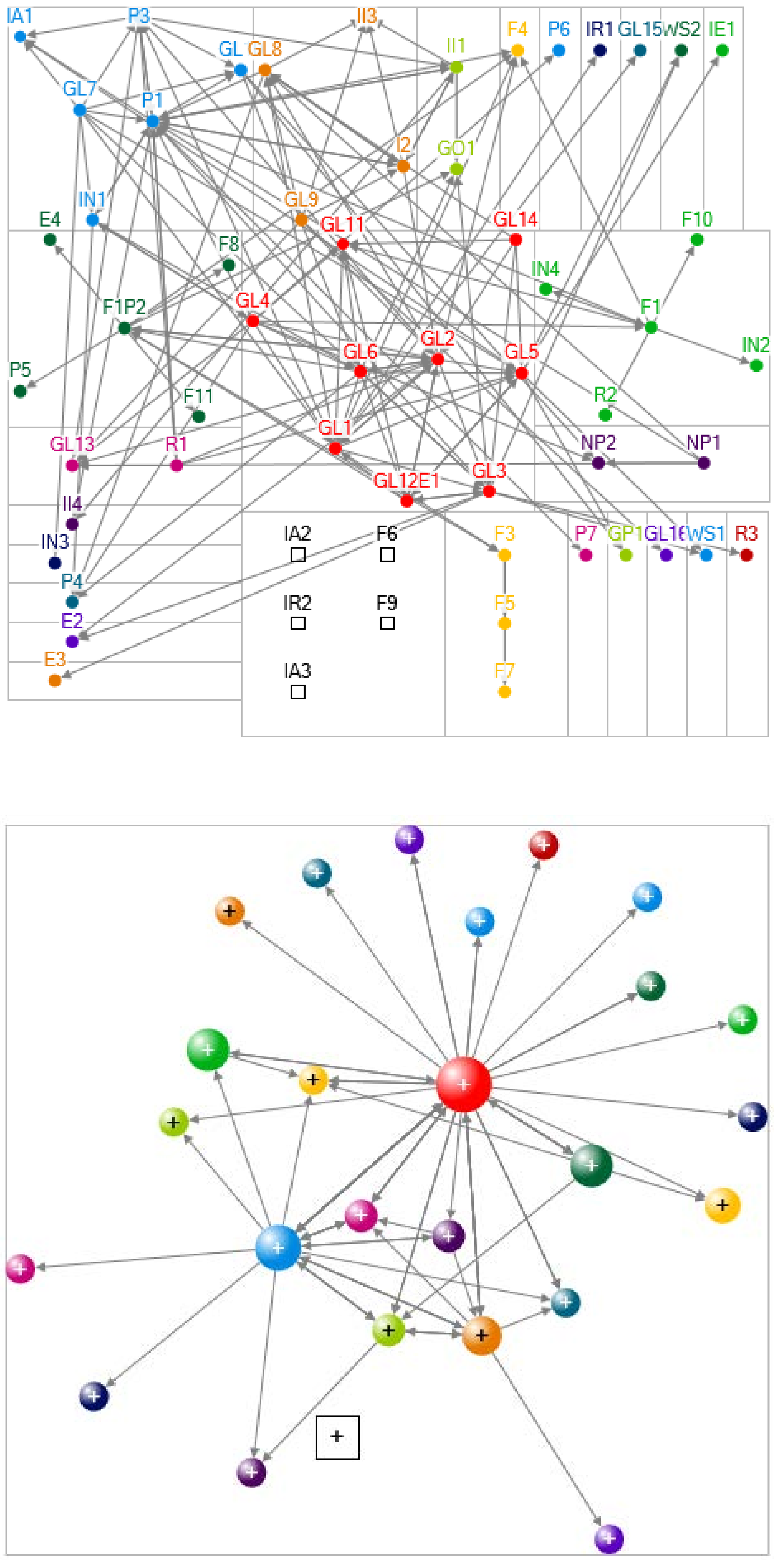
The total number of clusters for the SVW network was larger (c=26) than for the KRW network (c=20). However, the most striking difference is the relative complexity of the SVW network (see Figure 4) in comparison to the KRW (see Figure 5). The SVW has one cluster that is slightly larger than the others, but it also has several medium-sized clusters that are of similar size. In contrast, the KRW has one dominant cluster containing the majority of connected vertices and only two other multi-node clusters that are much smaller. The remaining clusters consist of single dyads (with one connection) or isolates (disconnected vertices). Borgatti and Everett (1999) describe core-periphery typologies as “cohesive subgraphs in which actors are connected to each other in some maximal sense and a second class of actors that are loosely connected to the cohesive subgraph but lack any maximal cohesion with the core” (p. 377). It is evident from the cluster analysis that actors on the periphery of the KRW network who are not totally isolated (i.e., 12 of 54 vertices) are more strongly connected to the core cluster—reinforced by greater median closeness centrality scores and by smaller average geodesic distance scores—than is the case in the SVW.

In the SVW there are multiple communities of influence, each with a relatively tightly connected group of actors that are only weakly connected to other clusters. There was also a smaller number of isolates, suggesting that the SVW enjoys a more inclusive, distributed network structure than the KRW. The cluster coefficients for all the network vertices in the SVP and KRW are presented in Table 4, and they range from 1.0 (fully integrated) to 0 (totally isolated). In both networks, there are multiple isolates. Of note are the larger average and median cluster coefficient values for the KRW network (0.155 and 0.13) in comparison to the SVW (0.121 and 0.078). These reaffirm that the KRW can be characterized as displaying stronger centralized integration within a core, and a network structure that is closer to the idealized core-periphery typology (see Figure 2). The SVW network also displays core-periphery characteristics, but with weaker clustering and a more distributed nature.

6.0 Discussion

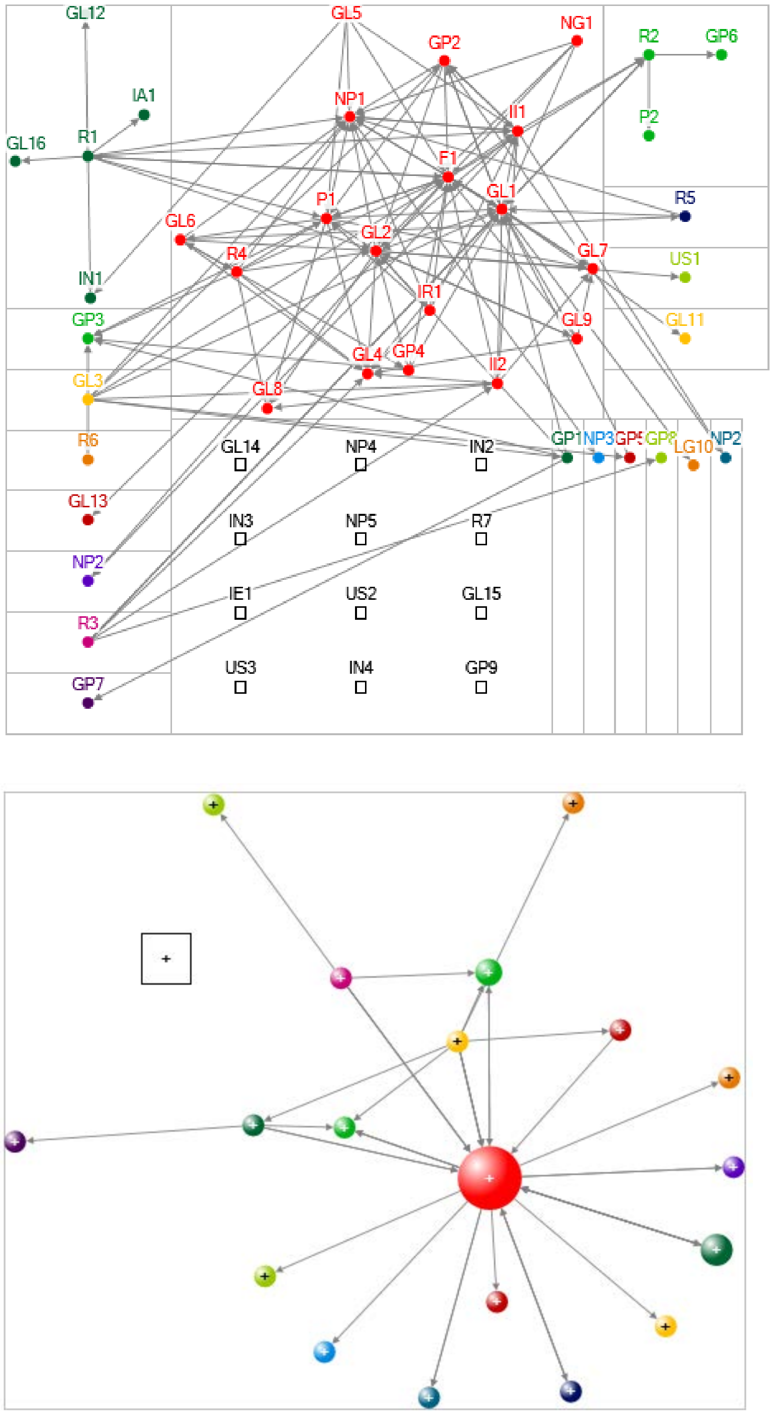
Despite increasingly strong calls for watershed governance systems that are distributed, collaborative, and localized (Brandes, O’Riordan, O'Riordan, & Brandes, 2014), the network structures of the SVW and KRW were more closely aligned with a core-periphery—hub and spoke—typology (see Figure 2). The SVW core cluster consisted of predominantly local government representatives (87.5%) but from a whole network perspective was somewhat more balanced in representation.

Figure 4: SVW Watershed Cluster Network (top), collapsed cluster (bottom).



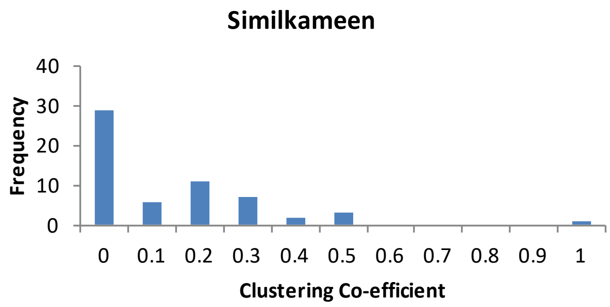
Source: Author.

Figure 5: KRW Cluster Network (top), Collapsed Cluster (bottom).

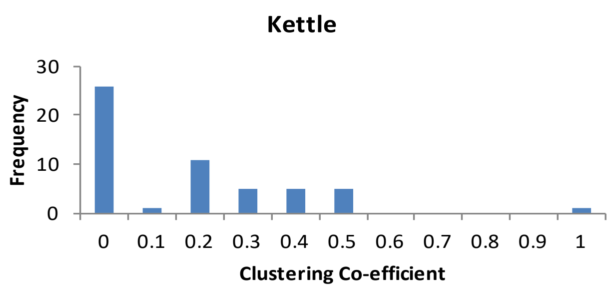


Source: Author.

Table 4: *Clustering Co-efficient Histogram and Measures*



Minimum Clustering Coefficient	0.000
Maximum Clustering Coefficient	1.000
Average Clustering Coefficient	0.121
Median Clustering Coefficient	0.078



Minimum Clustering Coefficient	0.000
Maximum Clustering Coefficient	1.000
Average Clustering Coefficient	0.155
Median Clustering Coefficient	0.131

The core cluster constituted only 15% of the entire network, and the other large clusters consisted of a greater variety of actors. There was also communication between periphery actors within the SVW network. In contrast, the core cluster within the KRW was comprised of 56% local government staff and politicians. While there was some representation within the core from other fields—watershed residents, irrigation districts, etc.—the core cluster had a far greater influence over the network with the cluster comprising 44% of the total number of vertices. The actors on the peripheries were either weakly linked directly to the core or were completely isolated, including industry representatives, environmental groups, First Nation members, and senior government appointees from the watershed planning process. Notably missing within the KRW was any significant trans-boundary communication linkage, given that the watershed is part of the greater Columbia River Basin Watershed. There was one trans-boundary communication link in the SVW. Arguably, these are significant omissions considering that one of the largest transnational water treaties—the Columbia River Treaty—involving the US and Canada is entering a phase of renegotiation.

The limited or non-engagement of First Nation actors within the watershed planning process also appeared to be a significant deficiency in the process. There has been a long debate surrounding the ongoing exclusion and limited engagement with First Nations Bands in British Columbia with respect to resource use and planning (Booth & Halseth, 2011). First Nations groups, who are often treated as a homogenous group of actors, have played limited roles within the formal process of watershed governance, both generally and in regard to the case-study watersheds. For example, of the ten actors in the SVW network who self-identified—or were identified by other actors—as First Nations, six were structurally located within the periphery (closeness centrality score less than 0.006) or not at all connected to other actors in the network. The opportunity to connect to broader, more diverse knowledge bases of First Nations actor networks is not being utilized effectively in these planning processes.

While both case-study networks manifest a core-periphery structure, the SVW appears to have adopted a less centralized structure containing a larger number of communities (clusters) and fewer isolated actors on the periphery. In contrast, the KRW has assumed a more centralized core cluster that was tightly integrated but with large numbers of isolates on the periphery (i.e., greater degree of fragmentation). The average geodesic distance within the KRW was shorter, indicating that the actors connected to each other are also tightly connected to the core, thereby forming a dominant, interconnected community or sub-network. Decision-making therefore remains strongly centralized in this sub-network (see Figure 4 versus Figure 5). The central cluster in the KRW network is of substantially larger size than all other clusters. The remaining periphery actors were connected directly to the core with few intermediaries, or not connected at all to the network (i.e., ignoring the isolates), reinforcing the centralized nature of the potential decision-making that is typical of command-control style governance structures. The SVW network, while maintaining an overall core-periphery structure, also contained structural characteristics that were more distributed (mesh-like) in nature, indicating a more balanced whole network with multiple communities of engagement and more interconnections amongst periphery actors. One possible reason for this difference was the significant amount of pre-watershed planning interaction and trust building that occurred in the SVW during the development of the Strategy for a Sustainable Similkameen Valley (2011-2020) initially coordinated by the Similkameen Valley Planning Society (SVPS)—a not-for-profit organization composed of local government bodies including local municipalities, regional districts, electoral areas, and Indian Bands.

The SNA and cluster analysis results indicate that the KRW is dominated by a core community of local government actors and therefore government-to-government communication at the local level dominates the exchange of information. Actors on the periphery have limited access and opportunity to infuse new knowledge and innovative ideas into the dialogue. In the SVW network, while the core community is also dominated by local government representatives, the core only accounted for a small portion of the overall the network. In essence, the SVW planning process is being shaped by a greater diversity of actors contributing a greater diversity of knowledge from which to develop water management solutions (Ostrom, 2010). The more distributed nature of the SVW network is tempered, however, by the general absence of provincial and federal representation within the planning process. The

KRW network does include several provincial representatives, although these key actors remain marginalized at the periphery. In both cases, access to critical resources and jurisdictional authority that reside at the senior government level is preempted by the structural nature of these networks.

In order to establish adaptive capacity, especially in regard to the pressures imposed by climate change on water sustainability, Bodin et al. (2006) recommend that networks should be characterized by a high level of reachability (i.e., minimal number of steps between actors), a dispersed mesh typology (see Figure 2), and a high degree of connectivity. These are difficult objectives to achieve in tandem, and often the network evolves in a manner that favours one metric to the detriment of another. For example, the more dispersed and mesh-like the network, the larger the number of small communities (clusters) and the longer the average geodetic distance (i.e., decreased reachability). This creates potential tensions between the oft-touted benefits of collaborative-distributive mesh-type typologies and the desired efficiency of communication pathways needed for adaptive capacity. Complex, mesh-like networks may indeed be inclusive of multiple voices, but the increasing complexity of communication pathways also leads to challenges as regards information accuracy and knowledge exchange. Regardless of end-member typology, then, it becomes critical to build effective information pathways into the network and to enable access to knowledge that may reside at the periphery.

The core-periphery typology of the two case study watershed networks indicates a degree of structural misalignment between the evolved network and the planning goals, which are focused on adapting to the impacts of climate change. The centralized nature of decision-making imposes a structural barrier to communication and knowledge exchange that involves peripheral actors and thereby reduces the likelihood of innovation with regard to novel water policy instruments intended to stimulate collective action. Thus, the very nature of the planning process, which will lead to watershed planning recommendations, may face limited buy-in and legitimacy challenges that stem from the exclusion—whether forced or voluntary—of key stakeholders such as First Nations and industry representatives. Increased normalization tendencies associated with high levels of centrality will likely reinforce existing institutional inertia and the status quo (Bollig & Menestrey Schwieger, 2014; von Tunzelmann, 2010).

7.0 Conclusions

Recent prescriptions for effective water governance regimes has privileged collaborative, adaptive, and distributed (CAD) water governance models (Gupta & Pahl-Wostl, 2013) with a tendency to delegate planning and management responsibilities to local levels according to principles of subsidiarity. Theoretically, such a system should mobilize localized knowledge and enable diverse stakeholder input to water related decisions. Such prescriptions are in response to the perceived failings of traditional hierarchical command-control styles of water governance, which are pervasive throughout North America. There are, however, many challenges associated with transitioning to a localized—place-based—model of water governance. Increasing diversity amongst water actors and decision makers leads to louder demands for inclusion, increased complexity, and broader heterogeneity of purpose and vision.

Through the use of Social Network Analysis, this research has quantified the sociological relationships that define the evolving networks in two case-study watersheds while providing insight into the associated challenges that enable or hinder the achievement of effective water governance. Specifically, the study focused on metrics of inter-connectivity and, in so doing, revealed the structural topology of the watershed planning networks under study. Despite the popularized movement toward collaborative and distributed systems of watershed governance, both the SVW and KRW evolved network structures that were largely centralized, reflecting the idealized core-periphery typology described by Bodin and Crona (2009) and Borgatti and Everett (1999). The result is a potential misalignment between the network structure and the stated watershed planning goal of climate change adaptation. Although climate change impacts are widely recognized and accepted as key threats to the immediate and long term sustainability of the respective watersheds, there remains little understanding of the importance of, or capacity to, develop truly localized models of water governance based upon genuine collaboration, effective communication, and equitable distribution of decision-making authority.

While localization continues to dominate the rhetoric of senior governments, there is limited evidence supporting the effective implementation of these CAD governance systems. In the Province of British Columbia, the new Water Sustainability Act encourages such localization even in the absence of planning strategies or policy, which acknowledges and addresses the many challenges of implementation, particularly in a rural water scarce context. The absence of key industry, government, and First Nations actors in the case-study watersheds, for example, raises issues of legitimacy of the process. Inattention to proper structuring of the network, including efficient communication mechanisms, will likely further entrench the status quo and lead to outcomes that remain ineffective (Vorosmarty et al., 2010).

This research, while revealing implicit governance network information (Cross, Borgatti & Parker, 2002), highlights many important areas in network analysis requiring further investigation. For instance, additional understanding of the bridging services provided by specific actors and organizations in reducing network fragmentation and increasing network connectivity is required. Other areas of emerging research that hold promise include the role of 'negative connections'—edges that have a negative influence—and 'active non-participation' in which a potentially important stakeholder makes an explicit decision not to participate in the planning process due to perceived risk (e.g. loss of water rights or increased costs) or affinity for the status quo. Incorporation of negative and null ties, in addition to positive connections, would enable a more robust investigation of water governance processes in light of a continued non-participatory position taken by industry representatives, First Nations groups, and senior levels of government (Huitsing et al., 2012).

Acknowledgements

We would like to thank the following for their financial support for conducting this research: University of British Columbia Okanagan; the Water Economics, Policy and Governance Network; the Regional District of Okanagan Similkameen; and the Regional District of Kootenay Boundary. We also thank the watershed network participants who donated their time and effort to respond to surveys, and the reviewers for their constructive critique.

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