

WATER SECURITY IN THE RURAL NORTH: RESPONDING TO CHANGE, ENGINEERING PERSPECTIVES, AND
COMMUNITY FOCUSED SOLUTIONS

By

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Abstract

This project explores the capacity of rural communities to manage their water resources in a changing climate, environment and society. Using water resources as a lens through which to evaluate the effects of social and environmental changes on Alaska's rural communities, and working from conversations with key community members including city planners and infrastructure operators, this research develops theoretical frameworks for increasing community capacity. The prospect of developing community capacity, and more specifically water resources management capacity, in order to respond to societal and climatic change is a present concern for rural communities, and is becoming increasingly so in today's fiscally challenged environment. Many rural water managers in Alaska are challenged by aging systems designed and built over 20 years ago, and are now operating well beyond their design life. While the configuration of existing systems varies across Alaska, a common suite of problems exists; regular breakdowns, failure to achieve regulatory standards, wide variability of raw water quality, low payment rates, and historically high electricity and fuel prices. These systems are also operating during a period of historically high deficit between community needs and available grant funding at both a State and Federal level.

Existing theoretical frameworks for exploring the impacts of change on regional water security (i.e. resilience and vulnerability) are informative heuristics for triage of impacts at the individual community level. Presently, however, there is little consideration given to water security solutions that do not involve the construction of a new system. This research proposes that the focus upon "new system solutions" limits available solutions for improving security at both the local and regional levels. Further this research seeks to understand the extent to which "new utility solutions" create additional capacity at both the community and regional level to respond to change. At the core of this work are informal interviews and participant observation research in 11 coastal communities in Bristol Bay and Northwest Arctic regions of Alaska.

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Introduction

This thesis explores the issue of water security in rural Alaska from an engineering prospective, focusing on the details of the Bristol Bay region. Water security is an environmental management, engineering and human health concern that has received increased attention from academic, governmental and non-governmental sectors over the past decade (Cook & Bakker, 2012). It is an issue of growing concern across Alaska, and it is also a “nexus” issue, in that captures the confluence of multiple social, political, ecological, and climatic issues simultaneously. Water security therefore provides an ideal lens through which to evaluate the effects of social and environmental changes on Alaska’s communities; water systems link hydrology with human communities through engineered systems and through local social, cultural practices and norms. In rural Alaska, water systems also exemplify many of the nuanced aspects of life in the north, including highly seasonal populations and lifestyles, livelihoods tightly coupled to the land, and hydrological systems in flux. These socioeconomic challenges, coupled with uncertain water security, result in an “axis of vulnerability”—a mutually reinforcing pattern of social, economic, and ecological problems.

In contrast to many areas of the world where climate change and high demand challenge local communities with water shortages and changes in hydrological cycles, the problem in Alaska relates more to a lack of infrastructure than it does to insufficient water supplies (Brubaker, Berner, Chavan, & Warren, 2011; Cozzetto et al., 2013; Brubaker, Flensburg, & Skarada, 2014). This is not to imply that climate change is not affecting hydrology in Alaska, but rather that the more immediate problem remains one of infrastructure, distribution, accessibility and water quality. Indeed, many rural Alaska homes do not enjoy “modern” piped water systems, or have in place the most basic sanitation infrastructure that one expects to find in most rural communities in the continental US and Canada (Eichelberger, 2010). In many of the smallest villages, which can be home to as few as 20 people during the winter, sanitation consists primarily of outhouses and/or ‘honey buckets’, which describe five-gallon

buckets topped with a toilet seat and lined with a trash bag that is disposed of outside the home (Eddy, 2010).

A great deal of literature is already available that examines the sociocultural and health dimensions of the limited water infrastructure in rural Alaska, addressing such issues as skin, gastrointestinal, and respiratory infections (Bjerregaard, Young, Dewailly, & Ebbesson, 2004; Martin et al., 2007; White, Gerlach, Loring, Tidwell, & Chambers, 2007; Hennessy et al., 2008; Gessner, 2008; Harper, Edge, Shuster-Wallace, Berke, & McEwen, 2011; Thomas, Bell, Bruden, Hawley, & Brubaker, 2013; Daley, Castleden, Jamieson, Furgal, & Ell, 2014). In many ways, water insecurity in rural Alaska is a manufactured problem, a nearly ubiquitous companion of the transition by Alaska Native peoples to living in fixed communities (Berardi, 1999). Rural Alaskans want access to safe, clean water and state, federal, and non-profit agencies work hard to try to support community water security (Marino, White, Schweitzer, Chambers, & Wisniewski, 2009; L. Marino, personal communication, May 27, 2014). Nevertheless, stark, and in many cases systematic challenges remain to developing water security across the state (Eichelberger, 2012).

Water security and insecurity are admittedly complex terms with shifting definitions, definitions that vary depending on the place, scale, or societal level of focus (Falkenmark, 2001; Cook & Bakker, 2012). For the purposes of this thesis, water security is defined generally, as when people have reliable access to affordable and safe water and sanitation services. By comparison, water insecurity can describe a variety of circumstances, including whether people are coping with some degree of water shortage or drought. It can also describe scenarios where people have consistent access to sufficient safe water, but the sources themselves are vulnerable to disruption. This is arguably the case for much of Alaska. Water security in Alaska also must take into account the many ways that rural people rely on rivers and other bodies of water for transportation and subsistence activities.

Thus, water security as defined here also implies a degree of control over the quality and reliability of water resources, regardless of how that water is being used. There is an important cultural dimension with respect to how control and self-sufficiency are defined. As such there are practical limits to generalizable and comparative measurable indicators of water security/insecurity and will be discussed in more detail in the following chapters.

Though universal measures and definitions for water security are rare (see Cook & Bakker, 2012), it is easy to recognize when people are not water secure, and most assessments of social and ecological challenges in the North identify water insecurity as a problem facing much of Alaska. For example, water resources figure prominently in Alaska Native Tribal Health Consortium (ANTHC)'s Center for Climate and Health climate change health impact assessments for eight communities across rural Alaska (Brubaker et al., 2014). Similarly, a recent study commissioned by the State of Alaska found that twenty-five rural communities are likely to face near-term impacts on their water and wastewater infrastructure from climate change, with another forty-four communities also identified as potentially at risk (Tetra Tech, 2010).

This paper was developed from ethnographic research done primarily with municipal workers, community leaders, and other local experts in the Bristol Bay and region of Alaska. This type of research is necessary for understanding how local experiences of climate change are embodied and acted upon (Krieger, 2001), with a goal of capturing richer stories than simple measures of vulnerability and adaptive capacity provide (Ford et al., 2010). At the core of this work are informal interviews and participant observation in six remote communities, ranging in population from 50 to more than 2400 people. Note that we do not identify these communities by name as a matter of research subject confidentiality. This study is further informed by more general observations and community input reported to one or more of the authors prior to engagement with these six communities (see e.g.,

Loring, Gerlach, Atkinson, & Murray, 2011; Gerlach, Loring, & Turner, 2011; Loring, Gerlach, & Penn, 2016). This project applied for University of Alaska Fairbanks Institutional Review Board (IRB) approval and received an exemption.

The theoretical placement of our research design is phenomenological, with the assumption being that the experiences of key individuals in these sorts of positions provide an important and informed window into the nature of climate and weather challenges at the community works and infrastructure level. In a phenomenological frame, each expert's experience is considered to be equally as informative to the nature of the phenomena being investigated. This is in contrast to research aiming to be 'representative' or 'generalizable' regarding people's opinions; as such, reporting quantitative aspects of our data (e.g., "3 people said ...") would be misleading. Equally, we have chosen to focus on the stories of community members, operators and managers ahead of a detailed study of technical engineering (e.g., construction drawings). While reviews of such technical information have some use, it is unable to capture the rich vein of human dimensions inquiry that has informed this thesis.

The goal of this thesis is to outline the issue of water security in terms of its engineering challenges. In chapter one we report that climate change is interacting with local social and environmental circumstances in ways more nuanced than are generally captured by frameworks for vulnerability analysis. Specifically, our research shows the importance of the temporal dimension of vulnerability to environmental change in rural Alaska, both in terms of temporal patterns that emerge from climate driven stressors, and also with respect to how, and under what conditions, people in rural communities may design or manage effective responses to change. To capture these interactions, we discuss two analytical concepts—community capacity and cumulative effects—and then incorporate these into a visual tool for improved planning and vulnerability analysis.

Many agree that rural communities in Alaska face challenges to their water security, as we begin to identify above, though the scale and nature of the problem is contested (Eichelberger, 2012; US Arctic Research Commission, 2015). Some academics have commented that the State of Alaska's approach to water security prioritizes economic concerns regarding operational budgets and efficiencies ahead of public health concerns; health practitioners in the state, on the other hand, acknowledge that nearly all rural households have access to safe drinking water, but caution that many still lack in-home water service; finally, data from State agencies confirms that only a fraction of rural Alaska households remain unserved. Through chapter two we explore the nature of the challenges facing both water security and community municipal infrastructure in rural Alaska, using a framework of four interrelated concepts; availability, access, utility and stability of water resources. We show that water security in rural Alaska is not a problem of access to or availability of clean water per se, and propose instead that a focus on utility and stability issues in water security is needed to address lingering water insecurity problems in the state.

Finally in chapter three, we address the concerns highlighted in both previous chapters. We caution firstly that despite the technological advances of recent decades and increased community involvement, many of the concerns about the appropriateness of complex infrastructure in rural communities remain. We propose recommendations to improve the condition of water security in rural Alaska that focus on human dimensions by avoiding over-innovation and developing modularity, and expand on existing design criteria in cold regions engineering literature. Importantly, we highlight the importance of recognising and evaluating human dimensions as part of community specific infrastructure development. This research demonstrates that infrastructure challenges all have human and social dimensions, and provides rationale for using these components to understand concepts such as community capacity, as well as infrastructure design and operation constraints that currently prevent rural water and sanitation systems operating sustainably.

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Chapter 1:

Seasons of stress: understanding the dynamic nature of people's ability to respond to change and surprise¹

Abstract

Climate change is impacting coastal communities in rural Alaska in multiple direct and indirect ways. Here, we report findings from ethnographic research done with municipal workers, community leaders, and other local experts in the Bristol Bay region of Alaska, where we find that climate change is interacting with local social and environmental circumstances in ways more nuanced than are generally captured by frameworks for vulnerability analysis. Specifically, our research shows the importance of the temporal dimension of vulnerability to environmental change in rural Alaska, both in terms of temporal patterns that emerge from climate driven stressors, and also with respect to how, and under what conditions, people in rural communities may design or manage effective responses to change. There are multiple factors that play into how rural communities will be affected by some climatic or environmental stress, and ultimately, the impacts of climatic and environmental stressors will differ depending on where, when, and how frequently they occur. To capture these interactions, we discuss two analytical concepts—community capacity and cumulative effects—and then incorporate these into a visual tool for improved planning and vulnerability analysis.

¹ Penn, H., Loring, P. A., & Gerlach, S. C. (2016). Seasons of stress: understanding the dynamic nature of people's ability to respond to change and surprise. *Weather, Climate and Society*. Retrieved from <http://journals.ametsoc.org/doi/abs/10.1175/WCAS-D-15-0061.1>

1.1. Introduction

In September of 2007 in the community of Red Salmon², Alaska, coastal erosion caused a wastewater lift station to fail, releasing untreated waste-water onto the beach adjacent to the Red Salmon river. The sewage main runs along the river; while it was formerly buried, parts of it were uncovered and left exposed as a result of weather driven erosion. The failed lift pump in particular was exposed to high water levels, weather and continued erosion. Municipal workers were able to respond to the failure quickly enough to limit the extent of environmental contamination, but in interviews, local managers expressed how fortunate they were that the failure did not occur during the height of the salmon fishing season. For one, the wastewater system would have likely been running at 150% of its designed capacity due to a seasonal increase in population from fishermen, cannery workers, and other seasonal residents. Second, a coordinated response by community workers would have been difficult at this time because some local workers would have been fishing themselves. Finally, the prospect of releasing untreated wastewater into a river when it is full of highly valued salmon raises human health and safety issues; an event such as this could have had devastating impacts on the reputation of these commercial fisheries and on the economy, health, and well-being of Red Salmon and the region as a whole.

This anecdote highlights important social and ecological dynamics that enter into how communities experience the impacts of changing weather and climate, and whether they are able to effectively respond. Specifically, we see the importance of the timing of events, fluxes in human resources, and other drivers of short-term variability in a community's vulnerability to some event or surprise. Below, we discuss these dynamics in greater detail as they relate to the many challenges facing coastal communities in rural Alaska, where both climate change and life in general, have strong seasonal

² A pseudonym, for confidentiality.

dimensions. We propose a framework for capturing these nuanced aspects of how communities are impacted by change, one based on the concepts of cumulative effects and community capacity (CEQ, 1997; Beckley, Martz, Nadeau, Wall, & Reimer, 2009). We pair these concepts with a visual, decision calendar framework (see also Corringham, Westerling, & Morehouse, 2008; Kim & Jain, 2010; Ray & Webb, 2016), which we then operationalize with the data on climate and weather impacts gleaned through interviews with municipal workers and other local experts in rural Alaska, to illustrate how these concepts provide an informative framework to help determine whether or not people are able to effectively manage environmental challenges.

Our study is thus situated within the general area of vulnerability analysis, which has emerged as an important and popular framework for thinking about the impacts of climate change (e.g., Cutter, 1996; Adger, 1999; Turner II et al., 2003; Adger, 2006; Ford, Smit, & Wandel, 2006; Gallopin, 2006; Smit & Wandel, 2006; Hinkel, 2011; Haalboom & Natcher, 2012). As we discuss below, vulnerability analysis and other analytical frameworks that attend to climate change do not always specifically address the nuanced temporal dynamics highlighted in the story above (Ray & Webb, 2016). The decision calendar framework we present here provides both a vocabulary and a compelling visual tool for examining the place-based complexities of how communities experience and respond to change (Garfin & Parris, 2016).

1.2. Methods

This paper was developed from ethnographic research done primarily with municipal workers, community leaders, and other local experts in the Bristol Bay and region of Alaska (Figure 1). This type of research is necessary for understanding how local experiences of climate change are embodied and acted upon (Krieger, 2001), with a goal of capturing richer stories than simple measures of vulnerability and adaptive capacity provide (Ford et al., 2010). At the core of this work are informal interviews and

participant observation in six remote communities, ranging in population from 50 to more than 2400 people. Note that we do not identify these communities by name as a matter of research subject confidentiality. This study is further informed by more general observations and community input reported to one or more of the authors prior to engagement with these six communities (see e.g., Loring, Gerlach, Atkinson, & Murray, 2011; Gerlach, Loring, & Turner, 2011; Loring, Gerlach, & Penn, 2016)

Our research involved semi-structured interviews and community tours with a total of twelve city managers and planners, public works managers, and water and sanitation infrastructure operators. Interviews were done with individuals and small groups, and were informal, guided only by general talking points about the challenges facing community infrastructure, management, and planning. Direct observation of and work with people carrying out their daily duties often took the form of community tours and time spent shadowing participants as they attended to their daily responsibilities. Happenstance encounters with additional individuals in diverse venues such as tribal offices and restaurants were also common and informative.

The core six communities where the research took place were initially chosen based on the types of public works infrastructure in operation for drinking water, sanitation, and solid waste, to provide a representative sample of infrastructure challenges within a single region. Community officials and representatives from regional tribal government consortia and health care providers were then consulted to verify the appropriateness and importance of research in an identified community, and for help in identifying key community research partners. Our selection of Bristol Bay for a strategic case study region is thanks primarily to interest in these issues among our local collaborators.

For the semi-structured interviews, we developed a community capacity inventory tool in close collaboration with our community partners, to provide talking points and assess the assets (i.e., capital)

present in each community, as well as the resources at people's disposal for managing day-to-day concerns (e.g., infrastructure operation and maintenance) and surprises such as a severe winter storm or an infrastructure failure. The survey was divided into five sections based on the Department for International Development livelihood assets (DFID, 1999); human capital, natural capital, financial capital, physical capital, social capital. For any given section, the aim was to identify where the capacity to respond to change and surprise exists, and when and why that capacity would be diminished. Table 1 identifies a sample talking point for each survey section.

Our research approach also remained flexible, given the need to adapt to local needs and concerns. Depending on the community member consulted or even the community itself, we used judgment to determine when and how data were collected (Huntington, 1998). Simply put, we employed a 'listen first, question second' approach. The process was particularly useful when consulting with members of the communities who are not normally contacted by researchers (e.g., water treatment plant operators). Where appropriate, the community capacity inventory was used as a source of talking points for interviews. For each community, one complete survey was compiled as an aggregation of all the responses recorded.

The theoretical placement of our research design is phenomenological, with the assumption being that the experiences of key individuals in these sorts of positions provide an important and informed window into the nature of climate and weather challenges at the community works and infrastructure level. This is in contrast to research aiming to be 'representative' or 'generalizable' regarding people's opinions; as such, reporting quantitative aspects of our data (e.g., "3 people said ...") would be misleading. In a phenomenological frame, each expert's experience is considered to be equally as informative to the nature of the phenomena being investigated. It is worth noting here two additional features of this approach: first is that the amount of information collected differed for each community

depending on who the researcher was able to communicate with, their knowledge, or in some cases, simply the information kept by the community (this was particularly true of financial information); second is the surplus of valuable, but sometimes ‘anecdotal’ information. Alongside explicit answers to the questions described above, we recorded local evidence of climate change, people’s opinions of state and federal agency practices, and general comments about the practicalities of living in rural Alaska through happenstance interactions, all of which progressively inform how we interpret and report these data (Vayda, 1983; Agar, 2013)

1.3. The Seasonality of Climate Change and Life in Rural Alaska

Climate change is already affecting people in Alaska and the rest of the circumpolar North through a variety of meteorological and environmental changes in annual precipitation, form and patterns of precipitation (i.e., rain vs. snow), snow and winter frost depth, the distribution, movement and quality of near-shore sea ice, and growing season length (Markon, Trainor, & Chapin, III, 2012). The frequency, intensity and seasonality of marine storms are also increasing, and these bring both heavy waves and water level surges that can worsen coastal erosion (Atkinson, Schweitzer, Smith, & Norris, 2011). Land cover changes are also occurring, including permafrost thaw, expansion of shrubs in the tundra, and a northward and westward drift of the arctic tree line (Markon et al., 2012). Along with other impacts, continuation of these trends could increase water loss due to evapotranspiration and result in overall drier seasonal and annual means for Alaska in the future (Scenarios Network for Alaska Planning, 2011).

Many of the changes expected in high latitudes, including but not limited to the ones mentioned above, pose risks for rural and urban communities in these regions, and in many cases, these changes and their associated risks are playing out with a distinctive seasonal signal. Strong fall storms are the norm now; seasonal sea ice cover can protect coastal communities from these storms by buffering wave action, but declines in sea ice extent and changes in the timing of freeze up can make communities more

vulnerable to surge and erosion (Overeem et al., 2011). Likewise, the timing and duration of rapid and often dramatic “break up” and “freeze up” seasons, that is, the period of time during which coastal or river ice is transitioning from open to frozen or vice versa, is also changing. In recent years uncertainty about “break up” and “freeze up” has complicated shipping and travel along rivers, and in many cases has resulted in large ice dams and severe spring flooding (Hopkins, 2013; Friedman, 2013).

Many aspects of life in rural Alaska are also marked by a distinct seasonal pattern. These remote rural communities are peopled by cultures very familiar with the highs and lows of seasonal resource productivity and seasonally-mobile lifestyles. Historically, Indigenous people across Alaska moved from summer fish camps to fall hunting and spring trapping camps (Nelson, 1969, 1986). Today, hunting, fishing and the country food harvest remain very important to local culture and food security though people are less mobile and trips are often shorter than in the past (Loring & Gerlach, 2009; Gerlach et al., 2011). Other seasonal aspects of life in coastal communities include winter constraints on shipping; in communities where sea ice or river ice is a factor, barge service may only be available for a few months per year. Commercial fisheries, sport fisheries, and other tourism activities also contribute a seasonal rhythm to life in many coastal communities. Finally, many men from these communities also take seasonal employment, working in summers for firefighting crews or mining companies, for example. As we discuss below, many of these seasonal aspects of life in rural Alaska factor directly into how climate and weather impacts are experienced.

1.4. Results

Given the various seasonal facets of life in the North, it is perhaps not surprising that people reported to us in this research that their ability to respond to climate and weather-driven challenges varies seasonally (See also Corringham et al., 2008)). Indeed, interviewees provided information to us about a number of seasonal challenges that they regularly cope with and that impact their ability to

respond to climatic change in one or more ways (Table 2). In winter, for example, interviewees explain that extreme cold and extended darkness can make it difficult or impossible to work outdoors on failed infrastructure. Another seasonal stress reported in multiple villages is the seasonal influx of non-resident laborers for jobs in fisheries, mining, and other industries such as hospitality and tourism. These spikes in local population put extreme but short-term stress on community infrastructure, and as we describe below, this is generally at times when community offices are understaffed because local people are busy with subsistence activities or commercial fishing. Similarly, some respondents noted how increased severity of winter weather and reduced sea ice cover, impacts the summer window during which supplies, equipment, and fuel can be reliably shipped to rural communities. One particularly high profile example of this involved unseasonably early sea ice blocking the coastal community of Nome and interfering with the winter's shipment of fuel oil (DeMarban, 2011; Burke, 2012). Multiple interviewees also noted how disruptions in shipping can delay important municipal projects for one or more years because of important supplies being stuck in Seattle or elsewhere, diminishing their ability to respond to unexpected and unplanned for infrastructure failures during the winter (see also Gerlach et al., 2011).

The following three quotes from respondents exemplify the various ways that local people communicated to us the importance of timing and seasonality in the challenges they face operating and maintaining their community infrastructure.

"If somethings going to fail, it's going to happen when it's coldest, or during a bad storm, in either case at a time when it's hardest to get out there and fix it. Water only freezes in the winter, you know? Things break at 40 below if you even look at them funny." *City Manager*

"There's only a relatively small window each year that we can barge equipment here from [Seattle]. If something happens and the barge doesn't sail, we may be waiting until next year, even for something as simple as a part for our backhoe." *City Water Manager*

“I feel like I’m always on my back foot and when it rains it pours. Trouble seems to cluster, and I think that’s because when things happen out there they happen fast. We have maps of how the river bank has eroded, and it’s a lot each year, but I tell you that happens in a matter of weeks.” *City Planner*

Another way that seasonality presented itself in these interviews included comments by interviewees regarding administrative challenges and mismatches among fiscal calendars, reporting, and grant deadlines, which can create gluts of desk work for local municipal workers during a short period of time. One city manager explained that in times of stress or crisis the first activities to be “sacrificed” are planning and grant writing, and that this causes complications for them in the future by impacting their ability to obtain new funding. Another puts the challenge this way,

Why the state [of Alaska] makes us submit these in summer I have no idea. We have to write our grant proposals and reports when people are out on the land. They know what life is like out here, so why they don’t let us work on these things in winter I have no idea.

A final way that timing emerged as an issue is with respect to people’s ability to respond to climate change impacts, and while not exclusively a seasonal signal, it still involves limits to human resources, a perceived or real tendency for surprises to cluster, and the generally high level of effort it takes for local people to keep old and failing community infrastructure running under even normal circumstances (Loring et al., 2016). “I’m always standing on my back foot,” explained one city manager, “... it takes most of my day and all of my employees’ time to keep [things] running.”

Indeed, in every community we visited we encountered a similar challenge, where one or a few people were already working at, near or beyond their capacity to maintain just the day-to-day status quo. In many cases, this was because they were coping with infrastructure that is old or inadequately built for the nuances of the remote North, especially during times of rapid and unplanned for shifts in

climate and weather. In others, it was simply a matter of staff shortages or inadequate training to work with unnecessarily complex systems. In one community, we observed a “top priorities” list on a city manager’s whiteboard that listed items such as training, equipment repairs and so-on. The last space on the list was empty, and the city manager explained that he leaves it empty because some issue emerges nearly every day to fill the spot:

I try to keep an empty space on my whiteboard for whatever new break-down is going to happen, but take winter time, for example. Winters don’t go by without water problems. That’s when we can’t get new parts if we need them, so it doesn’t matter if my list is empty or full.

Taxed as they are with this baseline level of work for simple operation and maintenance (O&M), several interviewees also reported feeling unequipped to attend to a surprise or crisis. More than one interviewee also shared a similar sentiment regarding climate change in general that while they know climate change is important; it is nevertheless in some ways the least of their problems:

I have a lot of things going on here, a lot of things on my to-do list. Climate change is not on there. We see it here better than most people. We just do not want to be [focused on] climate change because we have a lot of other things to be working on.

1.5. Discussion

A comprehensive framework for understanding how communities will be impacted by climate change needs to account for the experiences described above. The role of timing, seasonality, and human resources issues all interact in these communities in complex ways that as we argue must be explicitly accounted for in order to effectively assess climate change vulnerability at the community or regional level. Below, we discuss how the concepts of cumulative effects and community capacity can improve vulnerability approaches to these issues.

1.5.1. Vulnerability

There are numerous extensive reviews available of the concept of vulnerability (e.g., Cutter, 1996; Adger, 1999; Turner II et al., 2003; Adger, 2006; Ford et al., 2006; Gallopin, 2006; Smit & Wandel, 2006; Hinkel, 2011; Haalboom & Natcher, 2012). In general, most vulnerability frameworks employ a set of three independent concepts for describing a system's vulnerability: exposure, sensitivity, and ability to respond. The first, exposure, relates to a community's proximity to a hazardous location or activity (Dow, 1992): are people in the path of a storm or flood, for example. The second variable, sensitivity, relates to the extent to which communities would experience harm if exposed to that stressor. Sensitivity is generally determined by pre-existing social, economic and environmental conditions (Kelly & Adger, 2000; Oliver-Smith, 2013). Sensitivity can also depend on whether or not a community is already experiencing or coping with some other condition. For example, a community may be more sensitive to a severe storm if they only just recently experienced another severe storm or catastrophic event. Finally, the third component of vulnerability is the system's ability to respond to harm or disruption (Ford et al., 2006). This has been described as both resilience (ability to recover), and adaptability (ability to respond in a way that reduces future vulnerability).

Vulnerability analyses are often spatially explicit, representing comparatively the vulnerability of nations, regions and/or communities (e.g., Allison et al., 2008; Himes-Cornell & Kasperski, 2015). With respect to the temporal dimension, however, most vulnerability frameworks are more limited, attending primarily to pre-, peri-, and post-impact states, treating communities as generally static at the time of 'impact', and emphasizing the nature of the hazard or crisis over local societal processes and trends (Fazzino & Loring, 2009; Oliver-Smith, 2013). That is not to say that the temporal aspect of vulnerability has not been discussed; Ford and colleagues, for example, describe it thus,

Climate-related conditions include magnitude, frequency, spatial dispersion, duration, speed of onset, timing, and temporal spacing of conditions. ... In Arctic communities, different species will

be harvested in different locations at different times of the year on account of individuals' knowledge of the environment, past experience, differential time constraints, and access to technology. ... Exposure-sensitivity is clearly dynamic, changing as the community changes its characteristics relative to the climatic conditions and changing as the stimuli themselves change. (p. 147)

Other work on climate change and vulnerability identifies the importance of the temporal dimension (Sönmez, Kömüscü, Erkan, & Turgu, 2005). Yet, as Ray and Webb (2016) note, writing specifically about the needs of communities facing climate change, "many analytical frameworks lack a temporal dimension of use of products and information" (p. 29). Our goal in the sections that follow is to offer a decision framework for capturing the temporal dimension, focusing specifically on how a community's ability to respond changes over time as a result of myriad local social and ecological circumstances and processes.

1.5.2. Community Capacity

Whereas vulnerability analyses are generally oriented to the system-level responses to change and perturbations, they also often emphasize the importance of a community's capacity to respond to change--the capabilities and resources that actors in communities can draw on for the practice of managing environmental systems and needs (Scoones, 1998; Beckley et al., 2009; Speranza, Kiteme, & Wiesmann, 2008; Loring et al., 2016). Sometimes called community capital (DFID, 1999), capacity-oriented frameworks have also been used for some time in the international development policy literature. Community capacity as we use it here is borrowed as a metaphor from the ecological concept of carrying capacity (Brush, 1975) to describe the cumulative abilities of people in a community to manage their day-to-day lives and responsibilities (Figure 2a), while also coping with external stresses and disturbances as a result of social, economic and environmental changes (Loring, Gerlach, & Huntington, 2013).

Community capacity is generally understood to have five dimensions: natural, human, built, social, and financial (DFID, 1999). Natural capital describes the environmental resources upon which people rely, resources that include but are not limited to fresh water sources. Human capital represents the ability of people to perform management tasks and to respond to problems, with this measured by experience, expertise, and education. Built capital represents the existing infrastructure with which people have to work when managing the environment, whether water treatment facilities, seawalls, or airports and seaports. Social capital includes organizations for regional collaboration and strategic plans for development or disaster mitigation. Finally, financial capital represents the finances available, and can include local revenues as well as grants and federal transfers that are necessary to manage existing systems and to promote effective responses to change, even if this is too often a short-term approach to both long and short-term problems.

What the various local experts in the Bristol Bay communities have impressed upon us is that their community capacity is not static (Figure 2b). For example, when public works employees are absent during subsistence activities there is less capacity to respond to infrastructure challenges. Similarly, turnover in many community sectors (health, teaching, public works) is high, and while replacements can be employed their level of training, experience and importantly local knowledge can greatly change the capacity available. Community capacity thus changes over time in ways that are seasonal or cyclical, and in ways that are directional, especially where small events slowly accumulate over time and erode their capacity to attend to ongoing operation and management issues. One city manager, for example, noted his concern regarding the ways in which a series of wastewater infrastructure failures was impacting community morale; “it’s hard to keep people in jobs where they get [human waste] all over them. Eventually, they walk away.” As we discuss below, these temporal dynamics are an essential component of how we understand the cumulative effects of environmental and climate challenges on communities.

1.5.3. Cumulative Effects

The cumulative effects framework was originally developed by the US White House Council on Environmental Quality (CEQ), for use in environmental impact assessments associated with the National Environmental Policy (NEPA) act of 1970. The CEQ (1997) defines cumulative effects as “the impact... which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions” (pg. V, CEQ, 1997). Cumulative effects as originally written was concerned with predicting the short term and cumulative impacts and adverse effects (the language at the time) of large-scale development projects (e.g., oil, gas, mining, etc.) and was tied to NEPA, the Antiquities Act, and a variety of federal funding streams. What a cumulative effects approach brings instead to the matter of vulnerability is a holistic perspective that expects that new climate and weather-driven challenges will interact with one another and with other social and cultural factors, and accumulate, additively or synergistically over time. The cumulative effects approach also focuses not just on the short-term but also on the long-term impacts, and accounts not just for proximate or immediate causes, but anticipates the accumulation of stressors toward the potential for thresholds and ‘tipping points’ beyond which an entirely new suite of negative impacts may appear (Natural Resources Council, 2003).

Cumulative effects describe the feedbacks that either amplify or suppress vulnerability. Those feedbacks can be connected temporally, such that, for example, a storm in November that knocks out power and requires expenditures to fix could deplete the financial resources necessary to fix the next power outage. In the simplest terms, cumulative effects arise from single or multiple drivers, whether climatic or non-climatic, and that in combination result in additive or interactive effects on communities. One way that the cumulative effects perspective is complementary to traditional vulnerability approaches is that it provides language for incorporating spatial and temporal crowding of environmental perturbations as well as synergistic effects among the various perturbations:

- Temporal crowding occurs when the interval between perturbations is less than the time required for an environmental system to recover from each perturbation. The rate of temporal crowding may be continuous, periodic, or irregular and occur over short or long time frames.
- Spatial crowding is analogous to temporal crowding but where spatial proximity between perturbations is smaller than the distance required to mitigate or disperse the effects of each perturbation. Spatial accumulation may be characterized by scale (local, regional, global), density (clustered, scattered) and configuration (point, linear, areal).
- Synergistic effects are those cases where stressors do not merely accumulate in an additive way, but complex interactions among environmental stressors and other local circumstances, whether economic, demographic, or cultural, create outcomes that are often complex, non-linear, and unanticipated.

With the popularization in the last few years of health impact assessments, uses of the cumulative effects concept have evolved from a focus just on human impacts on the environment, to how environmental changes impact people through health and food security (Bhatia & Wernham, 2008; Fazzino & Loring, 2009). Here, we argue that the concept has important analytical power for thinking about people's collective ability to respond to climate and weather-driven impacts on their households and communities. The 'near miss' anecdote at the beginning of this paper provides an informative example. The people of Red Salmon were fortunate; the cumulative effect of the various circumstances could have been disastrous by comparison had the failure happened during the fishing season and, while a failure could very well occur at any time, it is not unreasonable to expect that failures are more likely when the system is under higher operating load as it is during salmon fishing season (June to September) when a community population can double. Coastal erosion, another process that played a role in the Red Salmon example, is also intensified in the region during spring and fall storm events.

1.5.4. Developing Our Seasonal Approach

As explained above, a great many aspects of life in rural Alaska have strong seasonal characteristics, and whether and how a community will be impacted by some climatic or environmental stress is related to this temporal dimension. Accordingly, seasonal calendars have emerged as one innovative way for communities and environmental managers to plan for environmental variability and change (Corringham et al., 2008; Kim & Shaleen Jain, 2010; Ray & Webb, 2016). In conversations with our community collaborators, we likewise found it informative to adopt a seasonal time scale for our analysis of community capacity and cumulative effects, as it is reflective of the various features of northern life noted earlier: important hunting and fishing activities that take place during certain times of the year, rapid and often dramatic “break up” and “freeze up” seasons, and strongly seasonal weather patterns.

Figures 3 and 4 offer a visual representation of both community capacity and the cumulative effects of multiple climatic and non-climatic stressors on a seasonal time scale. We adapted the circular visual style from the traditional calendars of subsistence practices that are common for Alaska Natives and indigenous groups around the world (e.g., (Atlla, 1996; Hoogenraad & Robertson, 1997). Our goal is to provide a culturally-relevant framework and visual tool for capturing and communicating data on the timing and seasonality of potential hazards, as well as sociocultural details such as planning cycles, fiscal years, and seasonal changes in human resources (Goddard et al., 2010; Dilling & Lemos, 2011). Table 2 provides additional detail about how the stresses marked on the seasonal calendar in Figure 3 are categorically organized.

Especially evident in Figure 3 is the temporal crowding of challenges reported by interviewees. The cumulative effect of these various factors, for example in the month of June, is evident: public works operators must manage both the increased population for fishing season and the stresses put on the wastewater system, as well as perform triage repairs with reduced staffing because people are away

and fishing themselves. Community members have likewise reported to us and to others an increase in both severity and frequency of summer storms and the dramatic effect this can have on river and sea coast lines, leading to challenges such as those described above for Red Salmon (Atkinson et al., 2011). Finally, many state organizations are balancing future budgets at this time, and the community itself is completing the necessary financial planning to ensure continued grant funding. While community managers concede that they have no choice but to respond to these challenges, they recognise that the response required to the accumulation of these stresses often exceeds the various physical, human and financial resources at their disposal. Managers, too, express concern about the trade-offs and inherent vulnerability in being over-committed and too often under-resourced:

I was asked if we'd want a new water plant here, and sure, why not, why wouldn't you want the latest and greatest? But frankly, that's a headache I just don't have time for. We have clean water. We don't have a working backhoe, though. We barely have enough people to keep the existing water system running in winter time.

Not all activities that a community routinely manages are included in Figure 3, but these are the most often-reported concerns that we encountered through this research. For example, when responding to the question "what keeps you up at night?," one public works manager specified that operating the wastewater system during salmon season (mid-summer for most Alaskan communities) was their greatest concern at that time of the year. Clearly, if an additional surprise event occurred people would do what they could to respond, but what must be sacrificed as a result is an important consideration, as is whether people are functioning so far over capacity that they must implement short-term fixes that are not durable, and may even erode their capacity moving forward.

Figure 4 illustrates how the seasonal calendars complement vulnerability analysis through the addition of an explicit temporal dimension, and especially participatory approaches to vulnerability (e.g.,

Gadamas, 2013). With the help of local experts, exposure to stress, sensitivity to stress, and the community capacity to respond can be mapped on the seasonal calendar for one or even multiple stressors. The tool could also inform research, guiding needs assessment interviews, for example, by asking local experts to rate when exposure or sensitivity is highest, or when ability to respond is low. Hence, a community and researchers could use this framework to collaboratively generate an understanding of vulnerability to stress on a local temporal scale.

1.6. Conclusion

Rural Alaskans are keenly aware of climate change and are actively searching for innovative and effective solutions that complement rather than detract from community plans for development and prosperity (Cochran et al., 2013; Loring et al., 2016). Intuitively, we all understand that people are creative—that they experiment and innovate in different ways, and therefore we should expect that no two communities can or will mobilize resources in the same manner. Our attempt with this paper is to shed further light on how communities mobilize resources and to craft a robust framework for visualizing how communities will be impacted by change or surprise.

One of the most important findings in this research is the importance of the temporal aspect of environmental change in rural Alaska, with this perhaps overshadowing the spatial dimension that is so commonly emphasized in vulnerability research. Indeed, when we started this research, our operating premise was that spatial variation of community vulnerability to climate change would be pronounced, and we had to abandon this premise rather quickly. To be sure, there are multiple factors that play into whether and how a community will be impacted by some climatic or environmental stress, both spatial and temporal, but in rural Alaska at least, the seasonal pattern is the most visible. The cumulative effects framework employed here draws attention to this temporal dimension; we propose that the seasonality aspect may also be important outside remote high latitudes as well, and other researchers

have observed seasonal rhythms in rural livelihoods around the world (Ulijaszek & Strickland, 2009). Regardless of whether the temporal aspects are more dominant than spatial, we argue that a focus on community capacity and cumulative effects significantly improves researchers' and policy makers' toolkit for examining and addressing vulnerability to extreme weather and climate change. The next step with this framework is to evaluate its applicability elsewhere in the North, but also in notably different geographic and decision-making contexts, through participatory action research. Ultimately, the most important indicator of the durable value of this or any framework is whether it presents information in a way that enables people to make informed and successful responses to change.

1.7. Figures



Figure 1: Map of Bristol Bay, Alaska, with major communities highlighted.

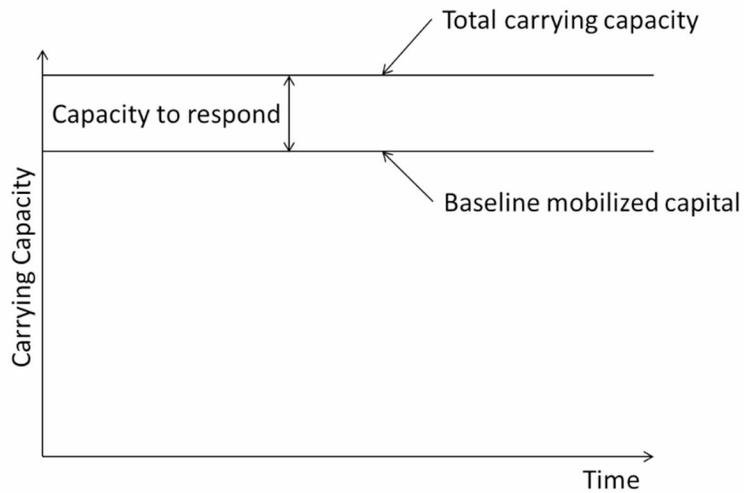


Figure 2a: A schematic representation of community carrying capacity. The area mobilized capital demonstrates the extent of the total carrying capacity that is currently employed by the community in some way to manage an existing need or challenge. The capacity that is available beyond this baseline i.e., once existing needs are meet, and up to the point where all capacity is exhausted, represents the capacity to respond, or in operational terms; the ability to respond. Putting time on the x-axis allows for the visualization of how capacity changes over time.

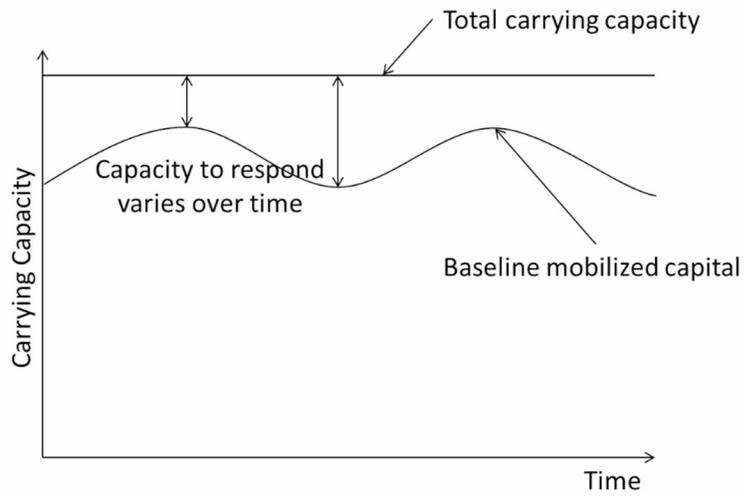


Figure 2b: A schematic representation of community carrying capacity. The area representing the capacity to respond – between mobilized capital and total capacity – is temporally dynamic and changes over time in ways that are often seasonal.

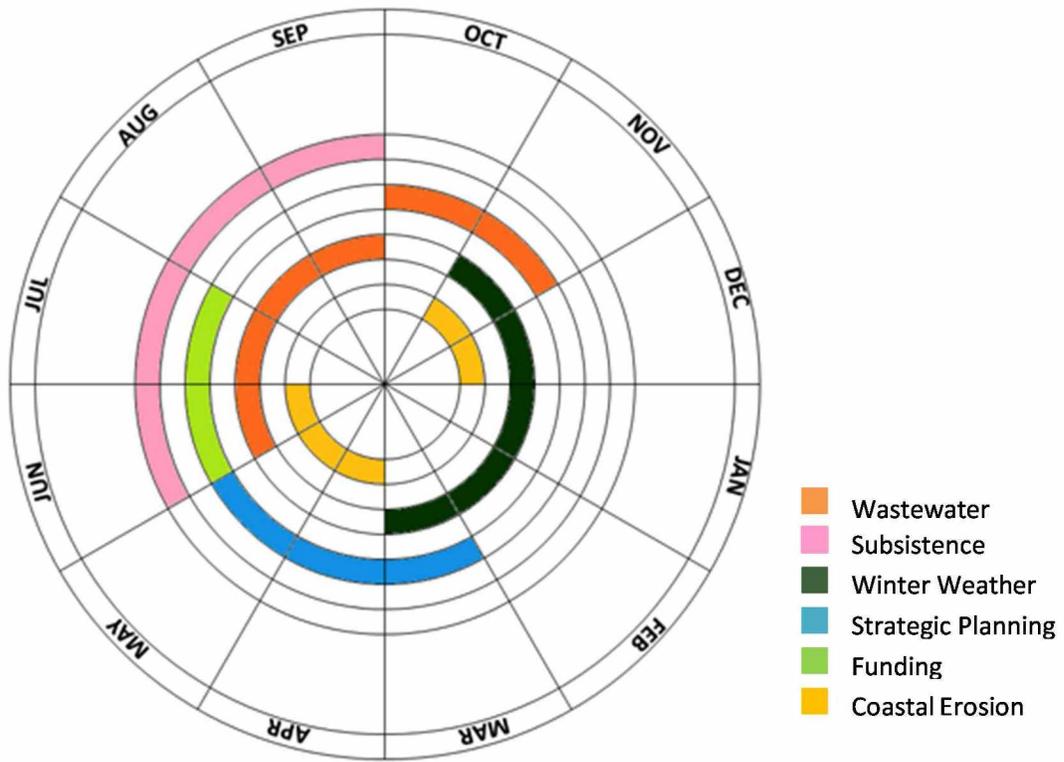


Figure 3: The seasonality calendar displays the seasons in which climatic and non-climatic stresses impact a coastal Alaskan community based on stresses reported in Table 2.

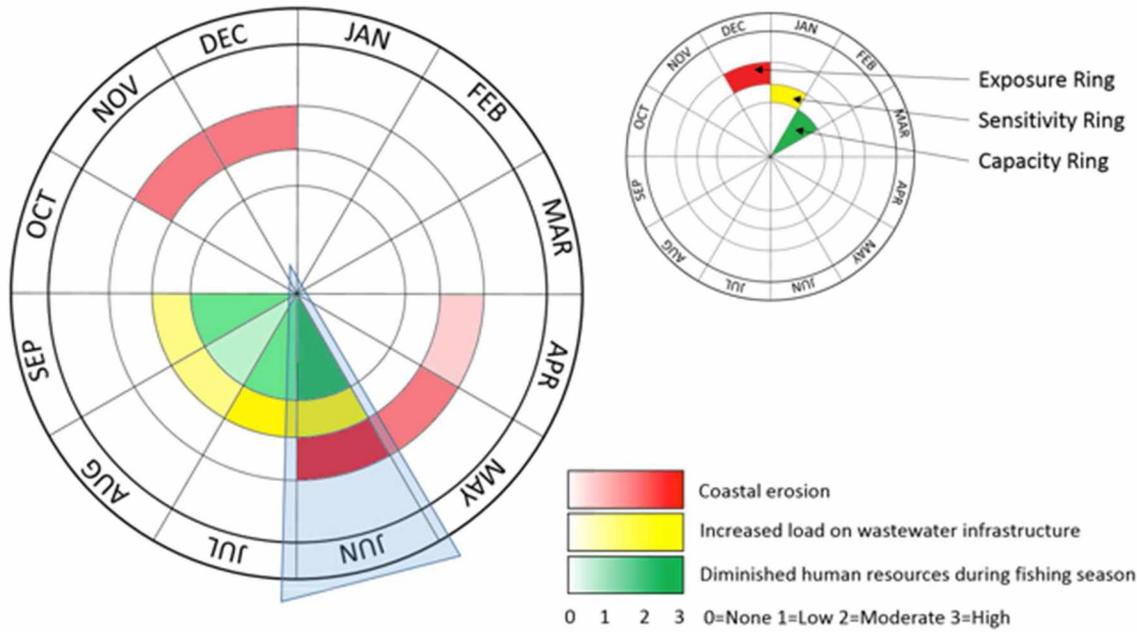


Figure 4: Simple seasonal stress calendar showing how a vulnerability approach can be given a temporal dimension, focusing on the example of a community’s vulnerability to wastewater systems failure and taking into account coastal erosion, usage of wastewater infrastructure, and seasonal variability in human resources. When viewed together, late spring appears to be the time when the community is most vulnerable.

1.8. Tables

Table 1: Sample questions for each category of the community inventory survey tool employed in six remote communities.

Community inventory survey category	Sample questions
Human capital	How many funded municipal employees are currently trained on water/wastewater management, monitoring, and infrastructures? How many years' experience does each of the primary employees have working on these areas?
Social capital	Does your community/borough have a disaster response plan? Does your community/borough have a climate change adaptation plan?
Financial capital	What are the current sources of permanent funding that support the management of water/wastewater facilities? What grants do you currently receive for water/wastewater issues?
Natural capital	What is your primary source of potable water? What are your concerns with respect to the source water used for the drinking water system?
Built capital	What is the class/configuration of water treatment infrastructure in your community? What percentage of households/public buildings have operational piped water systems?

Table 2: Description of the seasonal stresses that are impacting rural Alaska water systems based on community reporting.

Seasonal stress	Description	Challenge
Wastewater treatment system	The calendar identifies the seasons when usage is highest due to seasonal population increase (Jun-Sep), and when effluent quality is lowest (Oct-Nov) as a result of high use during the summer months. The high use season overwhelms and degrades the treatment process.	Seasonal increases in population stress community infrastructure, particular water systems, and result in regular break-downs. Due to increase usage, treatment system effectiveness is reduced, which reduced the resultant effluent quality. In some communities effluent did not achieve regulatory standard
Subsistence activities	This refers specifically to a typical salmon fishing season	The coincidence of increased local population, regular breakdowns of public infrastructure, and absence of workforce members whom are themselves fishing. The net effect is that response to breakdowns is slow.

Table 2 continued

Winter weather	Season when exposure to severe winter weather storms is greatest, thus most negatively impacts operational ability and efficiency	Severe winter weather can prevent community members from responding to surprises. Further if equipment or materials are needed they cannot be delivered by barge during the winter. Instead expense airfreight is used, further challenging capacity.
Strategic planning	Season when communities typically complete planning, resource allocations or community elections.	Much like the challenges stemming from subsistence activities, planning activities tie up community members during the short season where yearly maintenance can occur. Without planning though, communities may not get the grants that sustain many of the public systems.
Community funding activities	Season in which many agency funding application deadlines are situated	Much like the planning activities, paperwork activities reduce the capacity of the community to attend to surprises or attend to improvement projects.
Coastal erosion	Season when exposure to coastal erosion is greatest	Many community public infrastructure pieces (i.e. sanitation lagoon) are located near coast/shore lines. Fish camps are likewise located in areas challenged by erosion. A significant erosion event that threatens infrastructure or property will be attended ahead of everything else challenging the community.

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Chapter 2:

Diagnosing water security in the rural North with an environmental security framework.¹

Abstract

This study explores the nature of water security challenges in rural Alaska, using a framework for environmental security that entails four interrelated concepts: availability, access, utility and stability of water resources. Many researchers and professionals agree that water insecurity is a problem in rural Alaska, although the scale and nature of the problem is contested. Some academics have argued that the problem is systemic, and rooted in an approach to water security by the state that prioritizes economic concerns over public health concerns; health practitioners and state agencies, on the other hand, contend that much progress has been made, and that nearly all rural households have access to safe drinking water, though many do still lack 'modern' in-home water service. Here, we draw on ethnographic research alongside data from State agencies to show that the persistent water insecurity problems in rural Alaska are not a problem of access to or availability of clean water, or a lack of 'modern' infrastructure, but instead are rooted in complex human dimensions of water resources management, including the political legacies of state and federal clean water regulations and community development schemes that did not fully account for local needs and challenges. The diagnostic approach we implement here helps to identify solutions to these challenges, which accordingly focus on place-based needs and empowering local actors. The framework likewise proves to be broadly applicable to exploring water security concerns elsewhere in the world.

¹ Penn, H.J.F., and Loring, P.A.,

2.1. Introduction

Water security is generally defined as involving stable and affordable access to clean water in sufficient quality and quantities for maintaining health and enacting livelihoods (Cook & Bakker, 2012). In rural Alaska, water security at the household and community level has emerged as an important societal problem, though there's growing debate about both the nature and the relative scale of the issue, and these disagreements have led to different perspectives on the most appropriate solutions (US Arctic Research Commission, 2015). In contrast to many areas of the world where local communities are challenged by water shortages and changing hydrological cycles (Vörösmarty et al., 2010; Wheeler & Gober, 2015), the problem facing household water security in rural Alaska relates primarily to infrastructure (i.e., water and wastewater treatment facilities) and community development policies than it does to insufficient water supplies. Reports about the severity and extent of the problems vary, however; it has become a regular anecdote, for example, to claim that it is not uncommon for homes in rural Alaska to lack piped water and sewer (Eichelberger, 2014). Conversely, official sources show that as of 2000, 93.7% of all Alaskan households had access to complete sanitation (US Census Bureau, 2000), and health practitioners in the state contend that "nearly all villages have access to safe drinking water" (Hennessy et al., 2008). These findings notwithstanding, public health outcomes such as rates of water washed diseases remain high (Hennessy et al., 2008; Gessner, 2008), and climate-change is also impacting water infrastructure in a way that threatens its sustainability. As such, water security remains, at least to some extent, a problem.

The purpose of this paper is to tease apart these divergent narratives regarding the state of water security in rural Alaska, and diagnose existing challenges such that effective and sustainable solutions can be identified. To this end, we apply a four-dimensional framework for environmental security proposed by Loring, Gerlach & Huntington (2013) (See also Grumbine, 2014; Hossain, Loring, & Marsik, 2016) with data from new ethnographic research in rural communities in the Bristol Bay and Kotzebue

Sound regions of Alaska. Our analysis highlights key human dimensions such as the role of policy and social narratives regarding modernization. We identify key points of intervention for improving water security in the region, and propose a paradigm shift away from large-scale projects oriented around new infrastructure construction, and instead toward community empowerment as a way to improve the efficiency and stability of water systems, whether old or new. Our analysis also illustrates the effectiveness of the environmental security framework for unpacking the endogenous human dimensions of water security at the community and household level, which Wheeler and Gober (2015) identify as a priority for water security research. As such, we conclude with a discussion of the relevance of this work to water security issues around the world.

2.2. Water Security in Rural Alaska

In rural Alaska, household and community water security is an ongoing and possibly worsening concern, albeit a relatively new one considering that until the last 50 years or so, Alaska Natives were generally environmentally secure (Hossain et al., 2016), and had free access to plentiful clean water (Berardi, 1999b). Now that life in rural Alaska is based in fixed and more densely populated villages, water and wastewater management systems are essential (Berardi, 1999b). Contemporary water security issues are in part due to the environmental challenges of engineering water systems suitable for remote arctic conditions, which have driven even expensively engineered systems into disrepair (Berardi, 1998; Berardi, 1999a). Inadequate and/or failing facilities and infrastructure, and the impacts of climate change on infrastructure rather than on the availability of water, are likewise principle challenges (Brubaker, Berner, Chavan, & Warren, 2011; Cozzetto et al., 2013; Brubaker, Flensburg, & Skarada, 2014).

As noted above, the vast majority of Alaskan households has access to complete sanitation and safe drinking water (US Census Bureau, 2000; Hennessy et al., 2008). The systems that provide these utilities

vary in design and source of water; some communities have pressurized piped water to homes, and those who do not typically haul their water in 5-gallon (19-L) plastic containers from community-based “washeterias”, which also often offer shared laundry and showers. As of 2000, one third of rural Alaska residents obtained water this way (Alaska DEC, 2000). This is a common practice for many urban residents as well, and indeed all three authors have hauled water in this manner while living in Fairbanks.

There are still gaps in service, however; 33 communities in rural Alaska lack any sanitation services at the time of writing (Alaska DEC, 2015a). These communities, and the approximately 3300 households they represent, account for 17.2% of the total number of rural communities statewide (Alaska DEC, 2015b). In several of the rural communities that do have water systems, climatic change is interfering with this infrastructure, which is often aging, and increasing both operating costs and the incidences of temporary losses of service (Cozzetto et al., 2013). Thus, despite Alaska making huge strides in address rural water insecurity since the 1950s, water insecurity remains a problem. Public health outcomes such as high infection rates, and particularly among infants, children and the elderly, underscore this problem (Gessner, 2008), as the absence of in-home water service is generally associated with high rates of water washed diseases, including respiratory tract and skin infections (Chambers, Ford, White, Barnes, & Schiewer, 2008; Gessner, 2008; Hennessy et al., 2008; Laderach, 2006).

State-led water and sanitation infrastructure improvement projects have been the *du jour* approach for attending to issues of water insecurity in Alaska since 1972 (Village Safe Water, 2015), supported by both by health practitioners and politicians, but in the last 10+ years, infrastructure projects have faced a growing funding deficit that now exceeds \$660M USD (Alaska DEC, 2015a), and this makes it increasingly unlikely that the existing, capital-projects based approach to water security will not continue. Indeed, the state is exploring alternative, lower cost approaches such as in-home water

treatment (Alaska DEC, 2015a). The state has been critiqued, however, for possibly prioritizing solutions for local water challenges that are fiscally sustainable but sacrifice public health and social justice (Eichelberger, 2014). Nevertheless, approaches that focus on efficiencies in household water management, even in the absence of 'modern' piped systems, are producing improved health outcomes in the state (Laderach, 2006).

2.3. Conceptual Framework and Methods

2.3.1. The Four-dimensional Water Security Framework

There are multiple research fields that share a goal of understanding and addressing water security issues, including eco-health, hydro-sociology, socio-hydrology, and integrated water resources management (IWRM) (GWP, 2000; Sivakumar, 2012; Sivapalan, Savenije, & Blöschl, 2012). To date, and despite widespread attention to these areas by researchers and policymakers, research and action on water security remains constrained by differences in how water security and water resources management paradigms are conceived and implemented (Cook & Bakker, 2012). These include differences in the organizational levels and/or spatial scales of interest, and in the benchmarks and metrics chosen and prioritized for analysis and management (Rahaman, Varis, & Kajander, 2004; Sullivan & Meigh, 2007). Socio-hydrology, for example, generally focuses on the availability and stability of water at the landscape or basin-scale; IWRM, on the other hand, emphasizes water management practices and such embedded issues as technology, capacity, and expertise among managers. Likewise, human dimensions are often treated as merely external forcing factors in hydrological systems, as opposed to recognizing the roles of people and communities within socio-hydrological systems as agents in identifying possible solutions (Wheater and Gober 2015). In other words, water security suffers from similar challenges associated with the implementation of other complex yet high profile environmental policy concerns, such as food and energy security and natural resource management more generally (Falkenmark, 2001; Loring, 2013; Giampietro, Aspinall, Ramos-Martin, & Bukkens, 2014).

Despite the various differences that exist among paradigms for water security, some common themes have been identified (Cook & Bakker, 2012; Loring et al., 2013; Giampietro et al., 2014). Cook and Bakker (2012), for example, discuss four prominent themes in existing water security research: quantity and availability of water, water-related hazards and vulnerability, 'human needs', which covers a broad range of issues including development related concerns, and sustainability. Loring and colleagues (2013) likewise suggest four core dimensions for water security that transcend these varied fields and paradigms, dimensions they contend are especially useful because of their congruence with the dimensions of food and energy security (see e.g., Ericksen, 2008; Hossain et al., 2016). These are: 1) the availability of water resources (i.e., source water supply); 2) access to water resources (i.e., distribution and affordability); 3) the utility of water resources (i.e., water resources sufficient to household and livelihood needs); and finally, 4) the stability of the preceding three factors over time. Stability, the fourth dimension, reflects the necessity of thinking about water security as a process rather than as an outcome or state condition, one that can have important temporal features such as seasonal variation (Kim & Jain, 2010; Penn, Loring, & Gerlach, 2016).

Taken together, these four dimensions support a multi-scale definition of water security that encompasses both the household and community level, recognizing that it is difficult and perhaps unwise to try to disentangle the two (as has likewise been argued for food security). As Loring and colleagues (2013, their Table 1) show, these four dimensions are also broad enough to capture the themes in research identified by Cook and Bakker (Cook & Bakker, 2012): availability is concerned with extractions and the quantity of water available to a household or community; access incorporates human needs such as quantities for drinking and sanitation; water hazards and vulnerabilities, whether with respect to droughts or floods, are included in utility; and, stability incorporates sustainability of water resources over time. As we illustrate below, the framework also enables analysts to move beyond approaches that focus solely on water resources as a hydrological phenomenon where people are

simply exogenous drivers of change, to also evaluate the importance of endogenous human dimensions such as municipal management, distribution, quality control, equity, economic sustainability, and the role of water Utility² institutions in managing these various issues over time.

2.3.2. Methods

We apply this framework as a diagnostic heuristic (c.f., Ostrom, 2007) for unpacking water security challenges in rural Alaska. Data for this undertaking are drawn from both existing literature and ethnographic fieldwork with twelve municipal water managers and community health administrators in eleven rural communities in the Bristol Bay and Kotzebue Sound regions of the state. From 2012 to 2014, we conducted unstructured interviews, participated in community tours, and observed these workers performing day-to-day “community work” (Loring, Gerlach, & Penn, 2016). The topics of these interviews included the challenges facing community water systems, including concerns regarding climate change, funding, planning, and human resources. In addition to these interviews, happenstance encounters with other local experts were frequent, and these informal discussions also inform how we interpret our data. Following our initial visits and analysis, we presented preliminary findings back to key participants and also to panels of experts and water resource managers at professional meetings, to refine and ensure the validity of our findings.

2.4. Results

2.4.1. Availability

The first issue at hand is whether availability of fresh water is a constraint for community water security in rural Alaska. Generally, groundwater is a source of drinking water for about 50 percent of

² To disambiguate the notion of ‘a Water Utility’ as a service provider from the concept of utility as introduced in the water security framework described above, the former will be capitalized throughout the paper. In other words, a Water Utility is the formal social institution charged with ensuring the utility and stability aspects of water security.

Alaska's population (Alaska DEC, 2008). In northern Alaska, where permafrost (a layer of soil that remains frozen year-round) prevents groundwater usage, communities instead draw drinking water from streams, rivers, lakes, and rainwater catchments. In Alaska, groundwater aquifers, and to a certain extent surface water sources, are recharged primarily by snowmelt. As such, climate change may pose a threat to the availability of water. Scenarios for climate change effects in Alaska suggest a general statewide trend of later freeze up and earlier snowmelt due to an increase in annual temperature. Annual evapotranspiration and precipitation are also predicted to increase, with the proportion of snowfall in annual precipitation decreasing on average. However, increases in effective precipitation have been predicted to be great enough to sustain sufficient groundwater recharge (Clilverd, White, Tidwell, & Rawlins, 2011).

In 2010, the State of Alaska convened an Immediate Action Working Group to compile a report of "imperiled community water resources" (Tetra Tech, 2010). The security of community critical infrastructure, which included water and sanitation infrastructure, was evaluated against likely climatic impacts (e.g., precipitation, temperature changes). The group found that infrastructure in many rural communities is threatened by and facing worsening climatic impacts, particularly from increasing coastal and riverine erosion. However, of the 25 communities that were assessed, none were found to "face near term climate change related impacts" to the availability of drinking water.

Thus, whilst we recognize that the effects of climate change are already being experienced in diverse and complex ways in rural communities, generally, the availability dimension of water security is not imperiled. However, as we discuss in the next section, availability does not guarantee access or water security on its own.

2.4.2. Access

There are over 200 remote rural communities in Alaska, most of which are not on a statewide road system and employ water management practices that some would describe as underdeveloped. In the smallest communities, which can be home to as few as twenty to one hundred people, fresh water is often gathered manually from rivers and streams or rainfall in the summers or from lake or river ice in winters and stored in plastic trash-cans or similar containers. In these and other communities, households often transport raw wastewater to central sewage lagoons in 5-gallon “honeybuckets”. For the larger rural communities with more robust water and wastewater infrastructure there is greater diversity in design and function, with some communities relying on groundwater wells, others relying primarily on water pumped from rivers and streams, and others relying on water drawn from tundra lakes.

As already noted, 93.7% of Alaskan homes had complete sanitation as of the year 2000, and although many rural residents obtain water from a community based watering point, health practitioners have reported that “nearly all villages have access to safe drinking water” (Hennessy et al., 2008). However, access is still a challenge for some in rural Alaska. The cost of water and sanitation in rural communities is often over \$100 per month, which is cost prohibitive for many residents. Employment opportunities are limited in these small communities, and while cash is important, local economies are still largely based on a subsistence economy (BurnSilver, Magdanz, Stotts, Berman, Kofinas, G. 2016).

In communities where pressurized water distribution is not available, self-haul is the prominent method of water collection. This can be problematic for seniors, though support through social networks is generally very strong in these communities. Some choose self-haul or rainwater collection despite the existence of distribution infrastructure, perhaps because of the cost or just because they do not like the taste of treated water. Regardless of the cause, limited access to sufficient clean water is still a problem

for some, as evidenced by high respiratory and skin infection rates across much of Alaska (Hennessy et al., 2008).

2.4.3. Utility

The utility dimension of water security involves whether water and water systems meet people's needs, expectations, and preferences for water provisioning and use. This includes the quality of drinking water and the systems by which it is treated, transported, distributed, and also the manner and efficacy by which wastewater is managed. Generally, it would seem reasonable to assume that the presence of modern water and wastewater infrastructures and trained personnel (collectively, the Water Utility), would improve water security for rural Alaskans, but in many cases we heard from interviewees that the reverse is true (see also Marino, White, Schweitzer, Chambers, & Wisniewski, 2009). Each community we visited in rural Alaska operates a relatively unique water treatment system that was built with one-time capital improvement grants from state or federal agencies. Moreover, this is a pattern that is replicated across the state (Marino, personal communication, May 27, 2014; US Arctic Research Commission, 2015). Due to limited availability of funds for operation and maintenance (O&M) (typically communities have small fee payer economies and limited cash economies), and trained personnel (operators reported to us that there is not normally money available for them to travel to training opportunities), these systems are in various states of repair, and are often have been in operation long past their planned end-of-life (Marino, personal communication, May 27, 2014). This was the case for six of the villages we visited. Indeed, many interviewees discussed how their community struggles to afford the expensive operations, maintenance, and repair of water and sewer infrastructures that are subject to harsh seasonal conditions, including extremely cold temperatures, flooding, and high source water turbidity that requires a greater level of treatment (Wiita & Haley, 2003; Marino et al., 2009; ARUC, 2014; US Arctic Research Commission, 2015). In other words, these large-

scale engineered systems are in many cases proving to be ill-fit for the unique needs of the North, failing the test of utility as defined above see also (Wiita & Haley, 2003; Marino et al., 2009).

2.4.4. Stability

Stability is concerned with the sustainability of the first three framework dimensions, how they change individually or in concert over time. In other words, stability is a condition of the interfaces and interconnections between availability, access and utility, and is driven both by hydrologic and climatic processes as well as by the success of the Water Utility to manage and distribute water resources and respond to change and surprise.

While our experiences with community water systems, and their operators and managers tells us that systems are challenged on almost a weekly basis (Marino, personal communication, May 27, 2014), exact numbers are hard to quantify. The Remote Maintenance Worker's (RMWs) program (Alaska DEC, 2016) arguably attends to more community water systems than any other organization in Alaska. During SFY 15, RMWs collectively made 338 routine community trips, but were employed for 61 additional trips to provide emergency assistance to system failures or malfunctions. However, context is important; we have not heard of system failures lasting for more than a few days, which is almost always within the water storage capacity that the community system provides. Additionally, system failures are not unique to, and should not just be associated with small, rural communities in Alaska; the University of Alaska Fairbanks had to switch its water provider in 2015 following successive exceedance of the federal drinking water limits for total trihalomethanes (UAF, 2015).

2.5. Discussion

Above, we recount our understanding of water security challenges being faced across rural Alaska, using the four-dimensional framework as a guide to characterize the problems people face. What the exercise reveals, and what interviewees have repeatedly expressed to us in interviews, is that the

problem is not availability of water, but the challenge of sustainably providing water to all households in an affordable manner. Many communities are operating aged systems for water and wastewater management that are well past their planned end of life, that are expensive to operate and challenging to maintain, and that were not designed with the nuances of arctic landscapes and climate in mind. Climate change enters here as well, creating additional pressures by further complicating operations and driving up operating expenses.

2.5.1. The Water Utility

The framework we use above for water security treats it as a primarily socially constructed phenomenon; that is, beyond the simple hydrological availability of water, various human infrastructures and practices are implicated in whether people have access, whether that water meets their needs (utility), and whether it is reliable over time (stability). Collectively, these human infrastructures and practices can be understood as the Utility: the social institutions and organizations responsible for maintaining infrastructure, providing water services, (and often charging a fee for that service), and more generally, making sure people's needs are met. In remote regions in Africa the Utility can be as simple as a shared water pump; in North America Utilities are far more complicated, and function through the commodification of water as a public service. In rural Alaska, a rural community Utility is at most staffed by one or a few local persons who must determine and report rates of payment, and enforce household accountability.

Since the introduction of water systems into rural communities, the concept of the Water Utility has been challenged. Initially, there was little support or guidance, following the introduction of rural water systems, for communities to develop a Water Utility after the ownership of the system was passed to them (State of Alaska, 1972). Moreover, the commodification of a public need runs orthogonal to local cultural values, which place emphasis on sharing, reciprocity, and a shared commitment to help neighbors when they are in need (Wenzel, 1995; Eichelberger, 2012). Enforcing bill payment, for

example, is a difficult proposition when the “delinquent” person is a relative or elder and the commodity is considered an entitlement.

Thus, while there is a persistent problem with people in many communities not having sufficient access to clean water, the bottleneck ultimately resides in the utility and stability dimensions, which as we explain above are the domain of the Water Utility. To be clear, we are not locating fault with specific individuals; much to the contrary we find that local workers are lynch-pins in keeping their communities running (Loring et al., 2016). Simply put, these people in most cases have inherited systems that are ill-fit to local cultural and bio-geographies, and as such they lock people into a pattern of crisis mitigation, and out of a path toward developing more secure solutions.

As described above, the dominant paradigm for water security interventions in rural Alaska is centered on attending to access with system improvements to the existing infrastructure with the aim of connecting all community residents to a centralized system (Marino, personal communication, May 27, 2014). The rationale for using new infrastructure to attend to water security challenges seems sound; a new system uncouples the community from the burden of old or outdated systems, and community members who are without in-home service can be connected to a centralized system, which attends directly to the condition of public health (Hennessy et al., 2008). However, there are multiple concerns with installing new systems to attend to water security challenges. New water systems are complicated technology advanced operations required to achieve comprehensive and strict Federal drinking water standards. Typical technological systems are designed to treat water in environmental conditions similar to the temperate Lower 48, not the harsh Arctic; regular winter temperatures of -40 degrees Fahrenheit, alongside winter storms and variable source water quality, all of which are regularly reported as the cause of breakdowns. Further, complicated, technology rich systems are energy intensive and hence expensive to operate; with the increased operating costs requiring user fees to increase accordingly.

Voluntary disconnections from water systems are prevalent in communities with high user rates (Eichelberger, 2010; Marino, 2014). Disconnections not only compound the small fee payer base, but also return those community members back to water security challenges the new system was intended to alleviate. Finally, transporting equipment and materials to the community (often by barge) from Anchorage or Seattle, and managing the practicalities of constructing in the North (short construction season, permafrost, expensive workforce) make constructing new systems in the rural North very expensive.

A stable and sustainable Utility is one where the revenue from community members is equal to the cost of operation and management, plus some profit that can attend to 'surprises' (i.e., breakdowns, emergencies). In our experiences with communities, Utilities with this level of security are rare and found only in the largest regional hubs. The reason for this is twofold. Firstly, as we alluded to earlier, water systems in rural Alaska are expensive to operate, old, outdated, and not designed for the Arctic environment. They fail in some manner regularly, and attending to breakdowns is an expensive and time-consuming proposition with materials and parts having to travel long distances. In communities where sea ice or river ice is a factor, barge service may only be available for a few months per year. Secondly, even though user rates are in most cases set with some level of community involvement, many are set too low to generate the revenue required for operation and management activities (ARUC, 2013, 2014). This is something of a catch-22, among the cost of the water systems, local economic circumstance, and in some cases the small number of residents in a community.

2.5.2. Empowering the Rural Water Utility

The premise that emerges from our analysis is that the most strategic point of intervention for improving water security in the North is the Utility. Ostensibly, the goal for improving water security based on the specifics of the challenges identified above should be to reduce operating costs and increase operational efficiency and self-reliance, to make available and generate financial capital that

can be used to address access challenges and public health concerns in a sustainable way and reduce dependence on overarching State level financial support. This approach does not necessarily have to entail a trade-off between fiscal viability and health as some scholars have suggested (Eichelberger, 2014). Rather, we argue that it is possible to move community water systems away from the locked-in condition of State funding dependence and towards a model that attends to self-reliance as part of a broader improvement of water security.

As we describe it above, a rural Water Utility has two roles. The Utility is the system of water security governance that maintains and supports the stability and sustainability of water availability, access and utility. The Utility also embodies the total ability of the community to manage and attend to existing and future water security challenges. In other words, community water and sanitation systems cannot operate beyond the carrying capacity of the Utility (Penn et al., 2016). For example, an operator cannot attend to a system for which they have had no training, and maintenance can only be completed up to the value of user rates collection (after operational costs; and ignoring outside funding).

As such, the Water Utility is an essential and central component for managing water security challenges at a community level. While State lead initiatives to water security challenges has increased the number of Alaska communities that have water and sanitation infrastructure, little has been done to address the challenges facing rural water Utilities. This methodology would appear counter intuitive, because by not addressing the limiting factor – the total ability of the Water Utility – new initiatives either simply test the Water Utility in a different way (for example; a new technological problem) or compound existing conditions by further exceeding the Water Utility ability (e.g., increasing operating costs, increasing treatment standards).

Once a Water Utility is improved and has the systems in place to manage infrastructure operation and management, be fiscally sustainable, and has reduced energy inefficiencies, the total ability of the

Water Utility can be quantified (i.e., operator training level, value of Water Utility user fees), and used as a yardstick for future whole scale infrastructure projects. Below we outline two features of an improved Utility for rural Alaska: reduction in energy expenses and increasing operational efficiency.

2.5.3. Efficiencies as Points of Intervention

As much as 39% of rural Alaska water and sanitation operating expenses are associated with energy (ARUC, 2013). According to municipal financial statements, water and sewer systems are the single largest energy consumer in rural villages (Eichelberger, 2010). The two biggest expenses for water systems are process costs (i.e., chemicals or filters) and energy costs. While attempts to reduce the process costs require extremely costly changes to the treatment train, opportunities exist for reducing operating costs through relatively low cost small scale efficiency upgrades, inter-community bulk fuel orders, and by switching to renewable energy technologies.

Increasing efficiency involves extending the useful life of the system through prevention and maintenance, thereby saving money in replacement costs. Much like the infrastructure itself (e.g., treatment system), auxiliary systems are typically old and inefficient, having been installed at the same time. For example, heating boilers and building insulation can both be replaced for a relatively low cost but dramatically reduce the cost of energy by increasing operational efficiency (ARUC, 2014).

Gasoline prices in rural Alaska are the highest in the State – average \$6.04/gallon – compared to a National average price of \$2.23 (DCCED, 2015). Gasoline and heating fuel is delivered to rural communities by ship or barge during the summer months when shipping lanes and rivers are ice free. The high price fuel is a factor of the delivery cost, but also is the small amount of fuel purchased; the population in most rural communities is less than 300 people. Communities who organize within their region to order fuel in sufficient bulk quantities to meet all needs are able to reduce cost of fuel

dramatically (ARUC, 2013; 2014). In some communities we have observed a \$0.50/gallon price reduction.

Renewable energy is becoming more and more prevalent in rural Alaska (Konkel, 2013), with wind and solar being the two main sources (ARUC, 2013, 2014). Since 1999 the Denali Commission has been supporting alternative and renewable energy projects in rural communities. However, it is only in recent years that the nexus between energy and water has been used as an opportunity to address water security challenges. Renewable energy even used alongside traditional oil operations reduces fuel dependence and usage, and therefore saves money.

Operational efficiency refers to the fiscal management of the Utility; user rates and labor costs. The concept of operating a utility was introduced to Alaska communities in accordance with Village Safe Water (VSW) Act in 1972 (State of Alaska, 1972). While the idea and function is a common place concept for peoples elsewhere in the world, a-pay-for-use service violates the traditional sharing culture of Alaska Natives (Wenzel, 1995), which lead to historically low bill paying rates (Eichelberger, 2014), and the utility operating without a revenue stream that could be used for maintenance, repairs and ‘surprises’. User fees are an unavoidable component of a utility, and the user fee must be set at a value that is self-supporting. However, community members must be involved in rate setting and provided information that details the rationale for user fees. A long term view of user fee collection is imperative to sustainably attending to access conditions.

2.5.4. Solutions in Progress in Rural Alaska

A new Water Utility solution that is a departure from State-led approach – the “new system” solution as we have called it here - towards community stewardship of water security challenges, requires a long term view to existing access, public health and water security concerns. Certainly, the new system solution has been significant in the improvements of water and sanitation conditions in

rural Alaska, but now the low hanging fruit has been picked, a new model is needed. The challenge, however, for any new model of rural development is to demonstrate its viability (Stein & Valters, 2012).

Since 2012 the Alaska Native Tribal Health Consortium has been experimenting with ways to improve and support Utilities in rural communities through a rural Utility collaborative (Alaska Rural Utility Collaborative, or ARUC). ARUC was developed to manage water and sewer systems in partnership with rural Alaska communities. ARUC sets rates with community council input and each community's rates are set to be self-supporting, and ARUC purchases all fuel, parts, electricity, etc. for water and sanitation systems with money collected from water and sanitation customers. Further, ARUC carries out water system audits to identify opportunities for addressing small scale energy inefficiencies, and also facilitates integration of renewable energy where feasible. In 2015 ARUC, managed 28 community Utilities to a combined annual profit, and continued the three year trend of reducing both overall energy expenses and user fee rates.

Thus, ARUC has begun to demonstrate the potential for addressing water security challenges without developing new system solutions. However, ARUC management is not without its challenges. The ARUC experiment has only be running for a small number of years, and is yet to demonstrate that such a model is capable of generating the financial capital required to address the access concerns identified here. Moreover, Even successful rural Utilities managed by ARUC, in the eventually of a major breakdown, will be supported by a State level organization (ANTHC), if not the State itself. This raises governance concerns; if a Utility is operated by the community, managed by ARUC, and financially underwritten by the State; does the community truly have ownership of their Utility? However, the ARUC experiment has demonstrated that rural Utilities in both large and small communities can be operated stably and sustainably.

2.6. Conclusion

There are myriad challenges facing Alaska's rural communities in the management of freshwater resources. Overall, circumstances are good, though challenged by the unique social, cultural, and geographic parameters of the North as well as legacies of colonialism, in the specific form of community and infrastructure development programs that did not account for Northern issues when water and wastewater systems were being deployed across the rural parts of the state. What we've argued for here is a discussion of water security in rural Alaska that moves beyond the typical focus on access and availability concerns. Instead, we argue that the best gains to water security in these regions can be had through improving local Utilities.

We recognize that despite many years and many dollars spent, access to water and sanitation is still a concern for some rural Alaska communities. There is no doubt that people in communities without water systems, or with failing systems, or where washed water health problems are being experienced, need a solution. The word of caution that we identify here is that newly constructed water systems can compound existing insecurity by increasing energy demand and user fees. We propose that rather in places with existing systems, new systems may be less ideal than focusing on developing Utilities that are both sustainable and self-supporting. ARUC is currently managing 28 community Utilities in this way, but there is always the possibility that third party management can jeopardize self-determination.

Finally, our analysis illustrates the benefits of addressing water security through the four dimensional framework derived from the food security literature. The human dimensions of water security extends well beyond anthropogenic impacts on source water and hydrological regimes; like food security, social, political, and economic factors feature centrally in whether people have reliable access to sufficient and safe water to enact their lives and livelihoods. In this way we have operationalised water security at a management level to provide local context and use, but also opportunities to include IWRM good governance strategies. Indeed, this framework has directed our

attention to key points of intervention, many of which have a distinct, place-based nature, for improving rural water security in Alaska, but all of which are arguably relevant to northern regions in rural Canada, and at a more general level, to water issues around the world. Many parts of the rural North are challenged by both public health concerns; due to inadequate in-home water quantity, and decreasing State level financial support (Howard & Bartram, 2003; Bjerregaard, Young, Dewailly, & Ebbesson, 2004; Ellis, Miron, Gallant, Phypers, & Scholten, 2007; White, Gerlach, Loring, Tidwell, & Chambers, 2007; Martin et al., 2007; Goodman, Jacobson, & Veldhuyzen van Zanten, 2008; Daloo et al., 2008; Harper, Edge, Shuster-Wallace, Berke, & McEwen, 2011; Carraher, Chang, Munday, Goodman, & CANHelp Working Group, 2013; Bakker, 2013; Daley, Castleden, Jamieson, Furgal, & Ell, 2014). While further investigation is needed, improving the Water Utility as a route to attending to water insecurity concerns may prove a more sustainable and empowering solution.

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Chapter 3:

Stop Trying to Fix Rurality, and Start Designing for it: Challenging the Complexity of Rural Water Infrastructure in the North¹

Abstract

The introduction of treated water and sanitation systems in Alaska villages emerged out of a decades-old effort by the state to improve Alaska Native health. From the beginning, however, water and sanitation projects encountered environmental factors that intersected with social, political and economic ones to create significant challenges. Recent critiques have argued that the original infrastructure were not designed to withstand the Arctic environment, which has contributed to the existing conditions; typically characterized by regular malfunctions and failure to achieve regulatory standards. Here we draw on our research experiences with municipal workers in rural Alaska communities, who are managing the impacts of failing infrastructure, and the challenges of newly developed systems. We outline the infrastructure challenges of the 1970s and 1980s, and caution that despite improved technology and great community involvement, many of the concerns about the appropriateness of complex infrastructure in rural communities remain. We propose recommendations to attend to these concerns that focus on human dimensions by avoiding over-innovation and developing modularity, and expand on existing design criteria in cold regions engineering literature. We conclude by highlighting the importance of recognising and evaluating human dimensions as part of community specific infrastructure development.

¹ Penn, H.J.F., Gearheard, S.F., Loring, P.A., and Schnabel, W.E.

3.1. Introduction

Developing modern water and sanitation infrastructure in Alaska and other Northern regions has challenged communities, engineers, and governments for decades. In most cases problems existed from their inception, due in part to the sheer engineering feat involved in designing small systems that could withstand the cold, remote locations (Marino, White, Schweitzer, Chambers, & Wisniewski, 2009). Indeed, the Arctic environment poses a particular challenge to centralized drinking water systems. Conventional deep burial water distribution mains are often not practical or possible in the Arctic because of permafrost, so water mains are often laid on top of the ground, exposed to harsh winter temperatures (Marino et al., 2009). These water lines can be insulated and heated to prevent freezing, but only at exceptional cost. In an environment where power is intermittent and expensive, freezing failure is inevitable, and frequently the cause of ultimate system failure (Wiita & Haley, 2003; Marino et al., 2009). Further, engineers who design these systems are faced with complex federal regulations in addition to all the challenges posed by the Arctic environment. As a result, modern, newly designed systems have the potential to be too complicated or too expensive for a community to maintain (Marino et al., 2009; Marino, personal communication, May 27, 2014; US Arctic Research Commission, 2015).

In rural Alaska, not all of rural communities enjoy “modern” piped water systems that one would expect even for rural communities in the continental US (Figure 1). Outside of the largest municipalities of Anchorage, Fairbanks and Juneau, most communities in Alaska are small and relatively isolated, with populations ranging from 20-4,000 people, and not on a road system, but rather accessible only by small aircraft or barge and river boat in the summer, and dog team, snowmobile and aircraft in the winter. In many of the smallest villages, which can be home to as few as twenty people during the winter, sanitation consists primarily of outhouses and/or ‘honeybuckets’, the term for five-gallon buckets topped with a toilet seat and lined with a trash bag. In such communities, fresh water is often gathered manually from rivers and streams or rainfall in the summers or from ice in winters, to be stored in clean

trash-cans or similar containers. For slightly larger communities of one to a few hundred people, households may transport honey bucket waste to central sewage lagoons, or even to local solid waste facilities. For those larger rural communities with more robust water and wastewater infrastructure, there is a great diversity in design and function, with some communities relying on groundwater wells, others relying on temporary or permanent intakes located on rivers and streams or tundra ponds, and others still relying on water drawn from tundra lakes.

In our experience, each community operates relatively unique systems that were built with one-time capital improvement grants (Berardi, 1999; Eichelberger, 2010). Due to limited availability of funds for operation and maintenance (O&M) and trained personnel, however, these are regularly in various states of repair, and are often in operation long past their planned end-of-life (Wiita & Haley, 2003; Marino et al., 2009; ARUC, 2014; US Arctic Research Commission, 2015). Broadly though, there are four categories of water and sewer infrastructure in rural Alaska (Alaska DEC, 2015), which we describe generally throughout as ‘systems’: Washeterias and central watering points, which describe locations where treated drinking water is delivered to a single service connection and people must use their own containers to collect drinking water; individual wells and septic systems; water and sewer truck or trailer haul system, which delivers water to and removes sewage from the home; and piped water and sewer systems, which provides centralized treatment, storage and piped distribution directly to homes.

In this commentary we explore the historical decisions, alongside the environmental and political landscape, that established the current condition of water and sanitation infrastructure in rural Alaska. We also present insights from some Canadian northern communities where similar water and sanitation infrastructure challenges exist. We compare these historic engineering and development considerations both alongside those apparent in recent water and sanitation projects in Alaska communities, and to infrastructure development recommendations in prominent cold regions engineering literature. We

identify that, despite existing research, human dimensions are not being sufficiently accounted for during water and sanitation infrastructure development, which is preserving many of the challenges that communities have contented with since water and sanitation infrastructure was first introduced in rural communities. We conclude with recommendations for policy makers charged with developing future water and sanitation infrastructure projects that expand on existing cold regions design criteria to include avoiding over-innovation and developing modularity.

3.2. Historical Decisions

Two landmark passages of legislation; the Alaska Native Claims Settlement Act (ANCSA) and the Village Safe Water (VSW) Act (both passed in 1972), created the current landscape of water and sanitation infrastructure in rural Alaska communities. The objective of the latter VSW Act was “to provide safe water and hygienic sewage disposal facilities in villages in the state” that would “be available for use by the public and... designed to assure year-round use” (State of Alaska, 1972). The purpose of the VSW act was to provide access to water and sanitation for rural communities, and coupled with the revenue from the newly constructed oil pipeline, produced unprecedented levels of infrastructure development across Alaska during the late 1970s and 1980s (Marino et al., 2009; Eichelberger, 2014).

Cornerstone to both pieces of legislation were the ideals of community participation and self-determination (Bergman, Grossman, Erdrich, Todd, & Forquera, 1999; Case & Voluck, 2002; Eichelberger, 2012). Yet from the beginning these principles were challenged by a nexus of engineering, environmental and political factors (Berardi, 1999; Eichelberger, 2012). Indeed, many of the concerns communities have with existing infrastructure stem in large part from two historic circumstances: firstly, communities were given little opportunity to provide substantive input on the infrastructure they received, and secondly, the installed water infrastructures were either not adequately designed to

withstand Arctic conditions, or to be manageable within the context of remoteness which they serve (Eichelberger, 2012; US Arctic Research Commission, 2015).

On the first circumstance, we have heard from multiple community members, as other researchers have also reported (e.g., Eichelberger, 2012), that during the development of the 1970s and 1980s, visitors would suddenly arrive in their villages encouraging expensive experimental infrastructure projects. Village councils often had to approve the designs, in many cases with few choices and little substantive input, if they wanted any system at all (Eichelberger, 2012; Marino, 2014). Further, the VSW Act, forces responsibility for facility operations and maintenance on the community by stipulating that construction cannot occur without "satisfactory assurances...that [the community] will, upon completion of a facility, accept ownership and responsibility" (State of Alaska, 1972; Eichelberger, 2012).

Without substantive local input and collaboration, designs of the 1970s and 1980s created a variety of challenges that communities are still struggling to manage (Alaska DEC, 2015). Initially, the newly developed infrastructure failed to provide dependable treated water without additional and expensive upgrades (Eichelberger, 2012). However, despite the additional attention and decades more since, water and sanitation systems are still characterized by inadequate and/or failing facilities and infrastructure (Brubaker, Berner, Chavan, & Warren, 2011; Brubaker, Flensburg, & Skarada, 2014; Cozzetto et al., 2013). Further, many villages continue to struggle to afford the expensive operations, maintenance, and repairs of water and sewer infrastructure that are subject to harsh seasonal conditions (Eichelberger, 2012). Equally, as we have encountered working in this research with rural water operators from around the state, regular breakdowns of infrastructure, particularly in smaller satellite communities that have little cash economy and small fee payer operations, are especially challenging because even small scale repairs or replacements can be extremely costly and difficult logistically. That is, materials and equipment have to travel long distances, typically by barge, from

Anchorage or Seattle, and those barges only run for part of the year to many communities because of seasonal sea and river ice.

3.3. Methods

This essay is informed by ethnographic research conducted primarily with municipal workers, community leaders, and other local experts in the Bristol Bay region of Alaska (Figure 2). Such research has shown to be essential for developing an understanding of experiences of local change beyond what simple measures of vulnerability and adaptive capacity can provide (Ford et al., 2010). At the core of this work are informal interviews and participant observation in six remote communities, ranging in population from 50 to more than 3000 people. Note that here and throughout the manuscript we don't identify communities as a matter of research subject confidentiality. Interviews were informal and guided only by general talking points about the challenges facing community infrastructure, management, and planning. Direct observation of people carrying out their daily duties often took the form of community tours, and time spent shadowing participants as they attended to their daily responsibilities.

Communities in this study were chosen based on the types of water and sanitation infrastructure each operated to provide a representative regional sample of infrastructure challenges alongside more generalisable social and environmental concerns. Community officials or similar representatives from regional tribal government consortia and health care providers were then consulted to both verify the appropriateness of research in an identified community and help identify key informants. The selection of individual communities as a strategic case studies were thanks primarily to interest in these issues among our various local collaborators. To add further context to information gleaned in interviews, we consulted Alaska state organisations such as Village Safe Water (VSW), Department of Environmental

Conversation (DEC), Alaska Native Tribal Health Consortium (ANTHC), and private construction and consultancy companies. Communication was again conducted through informal interviews.

In developing our recommendations, we reviewed interview and consultation responses with respect to existing design criteria presented in the Cold Regions Utility Monography (CRUM) (Smith & Low, 1996); a prominent cold regions engineering manual and source of good engineering guidance.

3.4. Recent Decisions

During the early development of water and sanitation (~1970–1980), the motivation behind providing water utilities was largely focused on the convenience aspect related to having water in the home, as opposed to the beneficial health effects (US Arctic Research Commission, 2015). Since ~2005, peer-reviewed studies linking the effects of hand washing on respiratory and skin diseases in rural Alaska and other remote locations have emerged (Bjerregaard, Young, Dewailly, & Ebbesson, 2004; Martin et al., 2007; White, Gerlach, Loring, Tidwell, & Chambers, 2007; Hennessy et al., 2008; Gessner, 2008; Harper, Edge, Shuster-Wallace, Berke, & McEwen, 2011; Thomas, Bell, Bruden, Hawley, & Brubaker, 2013; Daley, Castleden, Jamieson, Furgal, & Ell, 2014). The advent of these research findings focused VSW, engineers and health practitioners on improving community health through the provision of modern sanitation infrastructure (Gessner, 2008; Hennessy et al., 2008). While there are clearly many benefits to having modern sanitation infrastructure, this research has observed a number of difficulties in terms of the parameters used for design, the implementation of those designs, and the operational challenges communities have to manage.

Firstly, centralized systems are extremely expensive, in part, due to the sheer engineering exercise involved in designing and constructing small systems that can withstand the cold, remote locations. In the past five years, the state has paid over \$50million to construct water and sanitation infrastructure, which in some cases this has been the equivalent to as much as \$100,000 per person (Alaska DEC, 2015).

Such high construction costs are the main reason why the VSW program is, at the time of writing, managing a deficit of over \$600million between available funding and the needs of communities for water and sanitation infrastructure (Alaska DEC, 2015).

The high cost of construction and funding deficit are creating a funding environment in which communities are required to be economically sustainable before the state will provide funding for new infrastructure. This raises concerns about how funding agencies balance the importance of economic sustainability and public health (Eichelberger, 2014). Since 2005, yearly community applications for VSW grants are scored based on the proposed project's ability to address assessed critical public health needs and the communities' demonstrated capacity to operate and maintain the facilities (Murkowski, 2005). Communities must also meet sustainability standards focused on local cost recovery mechanisms (through user fees), low-cost infrastructure projects, and demonstrations of financial commitments (both past and present) (State of Alaska, 1972; Eichelberger, 2012, 2014). Grants are awarded for the highest ranking projects, and since individual villages compete with each other for limited funding, these village specific economic measurements carry more weight in these assessments than health criteria, even if the public health importance of clean water and sanitation are widely recognized (Eichelberger, 2014). Increasingly, these types of arrangements are particularly important to the state of Alaska as it currently tries to manage an unprecedented deficit in the state budget.

Secondly, engineers who design these systems are faced with complex federal regulations, as well as all the challenges posed by the Arctic environment. As a result, more often than not, engineers have in some cases designed systems that are too complicated or too expensive for a community to maintain (Wiita & Haley, 2003; Marino, personal communication, May 27, 2014; Nelson, personal communication, May 19, 2014). Equally, the cost to build, operate and maintain the system is also increasing, and some now fear that an overly complex system may increase the likelihood of failure due

to inadequate operation and maintenance (Wiita & Haley, 2003; Marino et al., 2009; Eichelberger, 2014; Nelson, personal communication, May 19, 2014; Marino, personal communication, May 27, 2014). Both instances place an additional burden on communities to train infrastructure operators to ensure the local capacity to operate and maintain the system is increasing at the same rate as the complexity; that is, complexity increases the knowledge required to run the system.

Secondary standards, or those that account for the aesthetic quality of water, are also problematic for the community. Concerns with secondary standards typically involve the taste of treated water. A well-known but perhaps under-reported dispute from community members is that they prefer the taste of water from untreated (e.g., from rivers, lakes) compared to centralized sources (Marino et al., 2009; Marino, personal communication, May 27, 2014; Ritter et al., 2014). While some have called for further education efforts to teach communities about the benefits of treated water, local, culturally specific ideas about health and acceptable drinking water quality must be taken into account for infrastructure to be successful. (Marino et al., 2009).

Finally, centralized systems are expensive for the users. As much as 39% of rural Alaska water and sanitation operating expenses are associated with energy (ARUC, 2013), and as we alluded to above, the complexity of the infrastructure is a significant determinant of the overall expense. Indeed, according to municipal financial statements, water and sewer systems are the single largest energy consumer in rural villages (Eichelberger, 2010). Alongside operational expenses, financial arrangements for the construction of new systems also greatly impact user fees. Due in part to state financial sustainability requirements, communities often leverage user fees to generate funding to pay-off lenders. For example, while raising the funding for a new \$60million water, sanitation and solid waste infrastructure project, the City of Unalaska projected a \$44.94 increase in monthly user fees over three years from \$251 to \$296 (Paulin, J., 2013). The high cost of user fees is compounded by the lack of economies of

scale. In a small community there are simply too few households to reduce the expense of operating community infrastructure to a level affordable in a small cash economy.

3.5. Shared Experience from the Canadian North

In northern regions of Canada, as in Alaska, extreme Arctic conditions combine with other economic and social factors to create infrastructure challenges. Also like Alaska, Canadian Arctic communities are small and remote, and the state of water systems in these communities differs greatly.

'Water security' in Canadian studies has been defined similarly, such as 'consistent availability of sufficient water for good health from sources and through means that are culturally appropriate, financially non-burdensome, and otherwise' (Hanrahan, Sarkar, & Hudson, 2014). There have been few water security studies in the Canadian Arctic, and most have focused on drinking water quality, as opposed to water infrastructure and access to quantity (Daley et al., 2014), but increasingly, studies are looking more at water access, availability, and desirability in the context of environmental and other changes (Loring, Gerlach, & Huntington, 2013; Goldhar, Bell, & Wolf, 2012).

In Canada, responsibility for providing water services generally falls on the territorial and provincial governments, with federal voluntary drinking-water guidelines (Hanrahan et al., 2014). Challenges of planning, constructing, funding, and maintaining infrastructure in Canada's northern communities is considerable. While there may be water standards, criteria, laws, and other protocols in place for defining rights and access to safe and adequate water, the realities of providing water (and other services such as sewage treatment, etc.) in most communities make it a serious challenge (Gerlak & Wilder, 2012). Water quality and access vary greatly from community to community, but a look at a few case studies illuminates some of the main issues at play.

For example, Hanrahan and colleagues (2014) provide a case study of water insecurity in the Indigenous community of Black Tickle-Domino in Labrador. In this community, water access is severely

compromised. Water is available from a potable water dispensing unit (PWDU), with no water distribution system. Residents come to the PWDU where they can purchase drinking water for \$2 per liter and/or collect general use (non-potable) water for free. While the province installed the PWDU (in 2004), it has failed to fund operations consistently. If there is funding, an operator is able to maintain the small buildings and heating system that make up the PWDU. In years when there has been no funding, community volunteers have attempted to keep up operations, but struggled with breakdowns and other problems. As a result, the PWDU is not well utilized. Residents report obtaining drinking water from local ponds and scattered, unmonitored wells in the settlement. One of the important factors for why the PWDU is not used is that residents distrust the treated water (especially with its inconsistent operation), preferring untreated water from ponds and brooks which they consider to be clean and pure; strong cultural attachment to untreated-water sources is an important element to water security in the community.

In another Canadian study, Daley et al. 2014 explored municipal water quantities and health in the Nunavut community of Coral Harbor. Their study examined the trucked water distribution system that is used in most Nunavut and other northern communities. Here, the authors provided a different view of water security – moving away from the usual look at water quality, to available water quantity, a critical element of human health and well-being. Daley et al. (2014) found that although the trucked water system is an improvement over reliance on individual haul systems, there are still distribution system challenges and some households are not receiving adequate quantities of water. The research highlighted that the current recommended minimum of 100 liters per capita per day was inadequate in some cases and households experienced in-home water shortages. Reasons included issues with the delivery systems (e.g., delays due to blizzards, mechanical problems, holidays, etc.), but moreover, a key issue was the under-estimation and improper characterization of the average household. The minimum standard of water quantity assumes a stable number of people in a home, but the research highlights

that household numbers can change (at times even day to day). Overcrowding in households, a key area of concern in many Nunavut communities, puts strain on available water – larger families use more water, and large families with small children tend to use more water (Daley et al., 2014).

3.6. Discussion

The Canadian cases presented highlight some of the interrelated issues of water, health, regulations, cultural and household considerations, capacity, and other aspects of water security also found in the Alaska context. In both regions, there are wide gaps in water security from urban to rural areas, and Indigenous communities suffer disproportionately from access to clean water, a situation occurring globally (Gerlak & Wilder, 2012). Across rural Alaska, the historic landscape of water and sanitation infrastructure was borne from insufficient community involvement and the development of infrastructure that were—in many cases—not suitable for the Arctic and remote communities (Eichelberger, 2012). In the four decades that have followed, state agencies and engineers have made significant improvements in working with communities while delivering new infrastructure. Further, and as technology has improved, infrastructure can now be developed that can withstand the harsh Arctic environment. However, little has been done to address the appropriateness and sustainability of modern sanitation infrastructure in remote, rural communities with respect to the design considerations exercised and consequently the extent to which human dimensions are accounted for. The attempt to simply design around or ‘fix’ rurality has created a number of concerns as we identified above, and also sustained the historic challenges of infrastructure operation and maintenance, as well as the paternalistic approach to new system development.

In Canada, Alaska, and indeed globally, there is a “need to develop context-specific and appropriately targeted water management solutions that recognize specificity of place and culture and meaningfully engage local communities in resolving these issues” (Gerlak & Wilder, 2012: 15). This

means moving beyond the tradition engineering approach, which often accounts simply for the infrastructure design, and towards a more holistic understanding of water and sanitation infrastructure that captures the fundamentals of system operation and maintenance in rural locations. While some examples of such infrastructure design have emerged in recent years (Alaska DEC, 2015), in our experience, community level infrastructure design is certainly not the norm. We provide here a series of recommendations under two broad topics; avoiding over-innovation, and developing modularity, based on our experiences with water and sanitation infrastructure in rural communities. We also draw on the CRUM (Smith & Low, 1996) as an example of prominent engineering literature to demonstrate that far from being new concepts, design considerations that embrace rurality and human dimensions have been available for the past decade, but have struggled to be implemented.

3.6.1. Avoiding Over-innovation

Over-innovation describes when decisions are made to make use of technologies, usually cutting edge, that do not make notable contributions toward whether an engineered system meets place-based design criteria. Community operators with whom we worked were quick to demonstrate to us where new products or technologies installed in their systems had unnecessarily increased their workload. Operators called such devices “black boxes”; referring to a typically sealed unit that when broken could not be fixed in the community, was shipped to an outside company, and returned many months later at great expense. Examples included newer models of heavy equipment (e.g., front loaders) as well as state of the art HVAC equipment in water treatment facilities. Whilst community operators recognized that new technologies can in many cases increase local capacity, they cautioned that without proper installation and consideration of their additional O&M burden, these new technologies are more often a nuisance or worse.

In most of the communities we have visited, key informants also noted that there are no local mechanisms in place to fund maintenance, and ultimately the community does not have the capacity to

do the work. Indeed, in many communities replacement parts are rarely back-stocked for future emergencies. Reliability of equipment and facilities is therefore important because of the expense to replace or repair items in remote areas and because of the severe consequences of failures (Smith & Low, 1996). Reliability must be a major consideration in selecting components and equipment and should also include the availability of parts and services.

An additional burden as the complexity of infrastructure has increased, is communities have become further removed from the design process as it progresses and addresses the technical aspects of the system. This sustains historic concerns, not only about the level of community involvement in new development, but that the residents may not understand the system sufficiently to be sure it meets their needs. Hence, systems and equipment that are relatively simple to understand and service are more likely to be repaired with minimum disruption and damage (Smith & Low, 1996). In this regard, simplicity and reliability are somewhat synonymous. Systems or equipment that requires servicing by specialized tradespeople or require parts that are difficult to obtain, are inherently less reliable and are not desirable. Equally, automated systems can be highly vulnerable when failure occurs, in part because it has not been necessary for the operator to get to know the system (Smith & Low, 1996).

3.6.2. Developing Modularity

Modularity is a design principle mentioned by nearly all of the operators and managers whom we interviewed. We observed multiple cases of operators unable to conduct O&M because components of their water and sanitation systems rely on disparate technologies that are not interchangeable. One community visited operates six lift stations, all of which use a different model pump. This lack of standardization both increases O&M costs and reduces capacity to respond to failures, especially when communities are logistically isolated due to winter weather and sea ice.

Future engineering design decisions that take a more holistic view of a region could rapidly increase modularity and increase regional capacity. When new systems are designed, it would be ideal that, in addition to such factors as cost, ease of acquisition and lead in time, decisions also take into consideration the kinds of infrastructure and equipment already deployed in nearby communities. The goal being to reduce a community's sensitivity to equipment failure, but also develop regional capacity for coordination and support.

To do this the ease with which the community can access parts, materials, equipment and technical help can be secured needs to be understood and must be considered in the planning and design of facilities (Smith & Low, 1996). Too, the availability of local skilled labor and resources will dictate the level and types of operation and maintenance that can be expected in a community or a region (Smith & Low, 1996). This in turn will dictate the type and design of equipment and facilities and the type of utility system that is appropriate.

3.7. Conclusion

Since the publication of research linking the availability of modern water and sanitation infrastructure with major health concerns (e.g. Hennessy et al., 2008), the State of Alaska, health practitioners and engineers have struggled to attend to these concerns with the provision of centralized systems. Most recently, the DEC has funded attempts to uncouple communities from centralized infrastructure through the Alaska Water and Sewer Challenge (Alaska DEC, 2015), and to spur worldwide research to develop innovative and cost-effective water and sewer systems for individual homes in remote Alaska communities. This project focuses on decentralized water and sanitation systems, and water recycling with the manifest goal to significantly reduce the capital and operating costs of in-home running water and sewer in rural Alaska homes.

Whether through centralized or in-home decentralised systems there are clearly many benefits to having modern water and sanitation infrastructure. However, the practice of either approach has been decidedly paternalistic with the 'du jour' solution determined by the State of Alaska.

Certainly, operating and maintaining a centralized water system in the Arctic has proven problematic, particularly in communities that continue to live a subsistence lifestyle with a limited cash economy (Marino et al., 2009). It may be therefore, that decentralised systems offer better and more affordable way to deliver drinking water and sewage disposal services to rural Alaska. However, local, culturally specific ideas about health and acceptable drinking water quality must be taken into account for this new approach to be successful (Marino et al., 2009). Moreover, there is an urgent need to monitor and understand changes in water security in the Arctic (Nilsson et al. 2013) and communities need to be a part of identifying appropriate indicators and approaches for doing so.

3.8. Figures

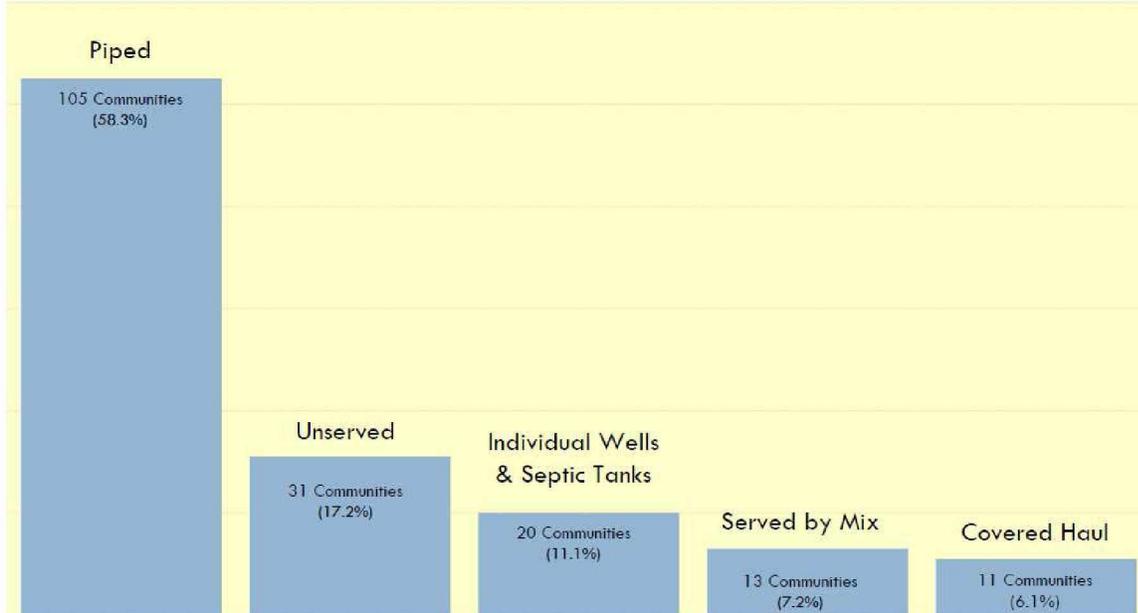


Figure 1: Graph showing the broad types of water and sewer systems that are operating in Alaska rural communities (Alaska DEC, 2015). 'Served by mix' describes communities that operate a variety of systems. 'Cover haul' systems are truck or trailer haul systems as described above.



Figure 2: The Bristol Bay region of South-West Alaska.

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Conclusions

This research began with a critique of the popularized concepts and frameworks of vulnerability and resilience, and through “community work” we also fed into the broader conversations around community adaptation. In either case, the aim was to understand and discuss how local people and communities cope with local problems, without invoking language associated with environmental determinism and victimization, or labelling communities as ‘vulnerable’ or ‘resilient’ (Haalboom & Natcher, 2012). Understanding challenges and concerns impacting communities at the local level, has provided opportunities to observe the human and social dimensions without reductionist or paternalistic overtones (Loring, Gerlach, & Penn, 2016). Likewise, the participatory and ethnographic approaches used to gather the observations discussed in this research have used water resources as a lens through which to evaluate engineering approaches and decisions, alongside the effects of social and environmental changes on Alaska’s rural communities

The human dimensions of water security with regards to developing effective, appropriate and sustainable engineering solutions are a central theme of this research, and one which engineers often do not consider fully. Only since the late 1990s have developers been obliged to hold public meetings and to gather local input for master planning processes (Nelson, personal communication, May 19, 2014; US Arctic Research Commission, 2015), and still today, the amount of community involvement depends largely on the project engineer or superintendent in charge, as well as on the level of engagement of the local community (Nelson, personal communication, May 19, 2014; US Arctic Research Commission, 2015). However, from this research the future challenges for water security in rural Alaska—as outlined below—are both place based and engineering focused. The attention will be on engineers to further recognise and evaluate the human dimensions of water security and rural communities both in the development and implementation of future infrastructure.

Rural Alaskans are keenly aware of climate change and are actively searching for innovative and effective solutions that complement rather than detract from community plans for development and prosperity (Cochran et al., 2013; Loring et al., 2016). Intuitively, we all understand that people are creative—that they experiment and innovate in different ways, and therefore we should expect that no two communities can or will mobilize resources in the same manner.

One of the most important findings in this research is the importance of the temporal aspect of environmental change in rural Alaska, with this perhaps overshadowing the spatial dimension that is so commonly emphasized in vulnerability research. The cumulative effects framework employed here draws attention to this temporal dimension; we propose that the seasonality aspect may also be important outside remote high latitudes as well, and other researchers have observed seasonal rhythms in rural livelihoods around the world (Ulijaszek & Strickland, 2009). We argue that a focus on community capacity and cumulative effects significantly improves researchers' and policy makers' toolkit for examining and addressing vulnerability to extreme weather and climate change.

There are myriad challenges facing Alaska's rural communities in the management of freshwater resources. There is no doubt that people in communities without water systems, or with failing systems, or where washed water health problems are being experienced, need a solution. Indeed, whether through centralized or in-home decentralised systems there are clearly many benefits to having modern water and sanitation infrastructure.

The word of caution that we identify here is that newly constructed water systems can compound existing insecurity. What we've argued for here is a discussion of water security in rural Alaska that moves beyond the typical focus on access and availability concerns to consider human dimensions as central to successful infrastructure development. The human dimensions of water security extends well beyond anthropogenic impacts on source water and hydrological regimes; like food security, social,

political, and economic factors feature centrally in whether people have reliable access to sufficient and safe water to enact their lives and livelihoods. In this way we have operationalised water security at a management level to provide local context and use, but also opportunities to include IWRM governance strategies.

As we have discussed, no one solution has been a success and without limitations (US Arctic Research Commission, 2015). Further solutions provided in the past decade have mirror those of the early developments in seeking to attend to water insecurity by providing 'modern', technology rich systems. Here and throughout, the argument has been for infrastructure development that accounts for community capacity and an understanding of human dimensions (Marino, White, Schweitzer, Chambers, & Wisniewski, 2009). While this is undoubtedly a multi-faceted challenge, at least one piece is concerned with managing the nexus of water quality standards, human health, and the practicalities of remote rural water system operation. While there are certainly other components that determine the configuration and design of water infrastructure, this research has observed that achieving regulatory standards contributes greatly to the complexity of the system and its operation. Further, this research has reported that the complexity of new systems is a determinant of their ability to meet community needs, operate within available community capacity, as well as the overall sustainability.

The water security framework we employ has directed our attention to key points of intervention, many of which have a distinct, place-based nature, for improving rural water security in Alaska, but all of which are arguably relevant to northern regions in rural Canada, and at a more general level, to water issues around the world. We argue further that that the best gains to water security in these regions can be had through improving local Utilities. While further investigation is needed, improving the Water Utility as a route to attending to water insecurity concerns may prove a more sustainable and empowering solution. Ultimately, local, culturally specific ideas about health and acceptable drinking

water quality must be taken into account for this new approach to be successful (Marino et al., 2009). Moreover, there is an urgent need to monitor and understand changes in water security in the Arctic (Nilsson et al., 2013), and communities need to be a part of identifying appropriate indicators and approaches for doing so.

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Appendix:

“Community work” in a climate of adaptation: responding to change in rural Alaska¹

Abstract

We draw on our research experiences with municipal workers in Alaska, where the impacts of climate change are already extensive, to examine adaptation and related concepts, such as resilience and vulnerability, which have become widely used in science and policy formulation for addressing climate change despite also being subject to multiple critiques. We use local people’s experiences with environmental challenges to illustrate limitations of the climate change adaptation paradigm, and offer the additional concept of “community work” — which we describe as involving a mix of environmental management and capacity management — as a counterpart to the adaptive process at the community level. Whereas climate change adaptation insinuates active and purposive change, the reality we have repeatedly encountered is that people in these communities focus not on changing but on achieving stability: keeping aging and overtaxed infrastructure running while also working toward improving quality of life and services in their communities. We discuss how these findings are congruent with recent calls to better situate climate change adaptation policy in the context of community development, and argue that scientists and policymakers need to understand this context of community work to avoid the pitfalls that potentially accompany the adaptation paradigm.

¹ Loring, P.A., Gerlach, S. & Penn, H.J. *Hum Ecol* (2016) 44: 119. doi:10.1007/s10745-015-9800-y

1. Introduction

What we're doing out here, it's not adaptation. We're reacting, coping with the changes that we're seeing. It takes every resource we have to keep things running as they are and maybe make little improvements as we go. I'm not thinking about what I need to do differently in the future. I'm thinking about how to keep the animal control building funded so we don't have to put down all those dogs. I'm thinking about how to keep my employees from quitting when they're sick of having to fix broken sewer pumps and getting people's shit all over them in the process.

–Rural community manager

Climate change is just one of several environmental challenges affecting people worldwide (Parenti 2011; IPCC 2014), and many scientists and policymakers are working hard to support people and communities in coping with these challenges. Much of this work draws on concepts such as resilience, vulnerability, and adaptation (Moser 2009; IPCC 2014), science-based concepts that are regarded as useful for guiding the development and implementation of mitigating strategies (Walker and Salt 2006; Hinkel 2011). However, these concepts (adaptation in particular) have received multiple critiques with respect to their theoretical rigor, limits and inconsistencies in their definition and use, and their implications in practice for social and environmental justice (Hornborg 2009; Davidson 2010; Thornton and Manasfi 2010; Hinkel 2011; Haalboom and Natcher 2012; Bassett and Fogelman 2013; Loring 2013; Yanarella and Levine 2014).

Among these critiques is concern that approaches based on concepts of resilience and adaptation put too much emphasis on external factors and novel conditions, consequently misconstruing how communities change (Thornton and Manasfi 2010; Yanarella and Levine 2014). While the ability to absorb, be resilient, or otherwise respond effectively to unexpected change is essential to community

sustainability, the manner in which people live and pursue goals when they are not confronted with change matters as much, if not more to a community's trajectory of development. Since the effectiveness of social programs for development depends largely on the extent to which the underlying theories of change reflect the realities of community functioning (Stein and Valters 2012; Valters 2014), and given also that poorly conceived development programs invariably cause more problems than they solve (Kottak 1990; Scott 1998; Checker 2007), these critiques should be seriously addressed.

In this context, we describe here ongoing research in Bristol Bay region of Alaska (Fig. 1), an area already experiencing myriad challenges associated with environmental and climatic change (Brubaker *et al.* 2014). People in these communities report their goal is stability more often than it is change, and they work daily and tirelessly to keep aging and overtaxed infrastructure running while at the same time taking all opportunities to improve quality of life and services. We call this "community work," a term we select for its parallels to anthropological notions of housework and kin work. The relationship of community work with adaptation in a formal sense can be compared to the concept of niche construction — a parallel process to adaptation through which organisms create, modify, and manage their environments (Laland *et al.* 1996; Odling-Smee *et al.* 1996) -- because it captures individual agency and intentionality while also revealing change over time as the product of a push-and-pull between stability and change. We conclude with a discussion of community work's relevance to research and theory in human ecology and, in an applied context, to climate change policy and sustainable development.

2. Background: Adaptation and its Discontents

Over the decades, the concept of adaptation has been defined, debated, and re-defined to suit different academic disciplines and subjects of analysis, from the natural and biomedical to the social sciences (Darwin 1859; Mayr 1982; Bates 2004). As used in biology, adaptation generally has two related

meanings: as a description of traits or behaviors that persist through time because they have proven necessary or beneficial to an organism's fitness and survival (i.e., adaptations), and/or a description of the process by which those adaptations emerge (Mazess 1975). In the social sciences, the concept is similarly split; it is generally defined as the process by which people make behavioral adjustments that facilitate their reproductive success and therefore survival, but is also used encompass specific behaviors and cultural technologies. As with biological adaptations, behavioral and cultural adaptations are generally understood as somehow directed toward the environment. Netting (1993), for example, describes adaptations as specific strategies for coping with or managing environmental conditions. Bennett (1969), however, notes an important difference between adaptive *strategies*, which are devised by individuals to utilize resources and solve immediate problems, and adaptive *processes*, which produce 'patterned deviations' in society and culture over long periods of time (see also Thornton and Manasfi 2010). The former, Bennett clarifies, are not necessarily examples of or logically linked to the latter; and, as Bates (2004) and others have noted, the success or failure of adaptive strategies can only be observed retrospectively and over long timeframes.

Use of the adaptation concept in science is widespread, but scholars in both the biological and social sciences have noted important limits (not always heeded) to the explanatory usefulness of the concept. In evolutionary biology, Mayr (1983) and Gould and Lewontin (1979) critique what they called the "adaptationist program," wherein scientists indiscriminately apply the concept of adaptation to any and all observable traits, potentially allowing for misinterpretation of the existence of a trait as evidence for its adaptive significance. Mayr (1983) argued similarly against conflating the current advantages conferred by adaptations with their original causes (i.e., the teleological fallacy). In his words, "considering the strictly *a posteriori* nature of an adaptation, its potential for the future is completely irrelevant" (p. 324).

A perennial critique of the adaptation concept in the social sciences stems from concerns regarding environmental determinism (Friedman 1974; Netting 1986). While the 'adaptiveness' of people's behaviors and technologies has regularly been the focus of anthropological research (Rappaport 1968; Bennett 1969; Robson 1978), some social scientists have been circumspect in using the concept because of the implication that people's behaviors and strategies are determined or given meaning by environmental constraints (Friedman 1974). Rather, they favor probabilistic and, more recently, co-evolutionary approaches to human-environment interactions, wherein a combination of human ingenuity, values, and collective goals determines how people modify their behaviors and their environments to meet their needs and aspirations (Netting 1993; Bennett 1996; Smith 2011).

In a sense, the critiques of applications of the concept of adaptation from the natural and social sciences both stem from the same problem: faulty inferences regarding causation. In the former, the concern focuses on teleological arguments and the attribution of adaptive significance to traits where there may be none; in the latter, an overemphasis on the role of environmental factors in determining the emergence of human behavioral and cultural strategies.

2.1. Climate Change Adaptation

Unlike biological and behavioral adaptations, understood as involving a long-term process of change, in climate change literature adaptation usually describes any actions taken to plan for, cope with, or respond to the impacts of climatic or environmental change, regardless of their outcomes in the short or long term (Nelson *et al.* 2009). (Tracing climate change adaptation in its progression from these origins to its current uses is beyond the scope of this paper, but see Adger 2006; Smit and Wandel 2006; Gallopín 2006.) Adaptation has clearly come to dominate climate change discourse (Thornton and Manasfi 2010), though with a broader and more informal meaning and with a different temporal focus. That is, whereas biological and behavioral adaptations are observed *a posteriori*, climate change

adaptation is an anticipatory concept geared toward planning and policy (Thornton and Manasfi 2010; e.g., Ford *et al.* 2010).

Thornton and Manasfi (2010) question whether this understanding of adaptation provides an accurate representation of how societies change and respond to change. They echo the deterministic critique of adaptation noted above, and argue that contemporary adaptation literature focuses too much on environmental and climatic change as a driver and too much on adaptation as a goal: "... [H]uman adaptation is not a single strategy but rather a set of diverse intersecting processes that may evolve autonomously or through planning in response to the panoply of climatic and non-climatic stressors" (p. 148). Climate change is no doubt an important component, but it should not necessarily be conflated with people's goals when responding to change directly or indirectly. Invoking an axiom from evolutionary biology known as Romer's Rule, they discuss how long-term behavioral and societal changes tend to be the result of conservative actions taken for the purposes of maintaining an existing way of life rather than creating a new one (Simpson 1967).

A second critique of the climate change adaptation paradigm focuses on social and environmental justice concerns, specifically the socially-constructed nature of climate change and people's vulnerability to it (Haalboom and Natcher 2012; Bassett and Fogelman 2013). Hornborg (2009), Loring (2013), Neocleous (2013), and Yanarella and Levine (2014) all argue that too much focus in science and policy formulation on adaptation can allow for a political acquiescence to problems such as climate change and to the unjust impacts on poor regions of unsustainable consumptive behaviors in the developed and developing world more generally. It is clear that many impacts of changing climate are already happening and cannot be ignored, but these authors are concerned that a political emphasis on climate change adaptation can (further) erode local capacity to address the fundamental economic and social inequalities that are the root causes of these problems (see also Parenti 2011).

Given these critiques, Thornton and Manasfi and others have also raised concerns that state-led initiatives for addressing climate change based on adaptation as it is currently conceived will fall into a common development planning trap: failure due to inadequate or inaccurate theoretical understanding of how lasting social change occurs (see also Nelson *et al.* 2009; Stein and Valters 2012). They argue that adaptation initiatives can focus too much on superficial assessments of local problems, resulting in 'tech fix' solutions that reflect the state's values for rural development but ultimately fail to address local needs, values, and aspirations (see also Kottak 1990; Scott 1998). Further, Thornton and Manasfi also raise a concern that top-down programs for climate change adaptation can overlook and even obscure the "ongoing processes of autonomous adaptation at the local level" (p. 133). It is these ongoing processes that we seek to better illuminate here.

3. Background and Methods

In the following sections we explore the local context in which people experience and respond to climate induced environmental change through our experiences working with people in remote rural communities of Bristol Bay, Alaska. Bristol Bay is a coastal region in the southwest portion of the state, which includes the watersheds of the Nushagak, Kvichak, and Naknek Rivers. Dillingham is the largest community in the region (population ~2,800), and it serves as a primary hub to the region's 34 other villages for provisioning (food, fuel, supplies), air travel, and healthcare services. Fisheries, in particular salmon fisheries, represent the major economic activity in Bristol Bay, to the order of 80% of local revenues. Numerous large canneries operate in the region during the summer, causing a spike in local populations from seasonal fishers and cannery workers. Most of the salmon caught is for commercial use, although a significant subsistence catch is taken by individuals who fish from boats or simply place set-nets along the shore of the river. As with much of rural Alaska federal transfer payments are important to local economies, and there is also a noteworthy tourism sector in the regional economy that includes adventure tours, hunting, and sport fishing.

As is the case for most of the residents of the high-latitude North, people in Bristol Bay are facing several climate change-related concerns. Warming and ocean acidification, for example, pose risks given the region's extensive reliance on fisheries (Mathis *et al.* 2014). Coastal erosion in communities on both the south and north shores of Bristol Bay is also a commonly identified problem with significant ramifications for community infrastructure. In some cases, coastal erosion is threatening water/wastewater infrastructure such as sewage mains, pumps, and lagoons, and in others, coastal inundation threatens freshwater supplies (Brubaker *et al.* 2014; Loring, P.A., Penn, H., Gerlach, S.C., Schnabel, W., 2015). The frequency and intensity of marine storms are also increasing, and bringing both heavy waves and water level surges that can worsen coastal erosion (Atkinson 2005; Atkinson *et al.* 2011). Further, changes in land cover are also occurring, including the expansion of shrubs in the tundra and a northward and westward drift of the arctic tree line (Beck *et al.* 2011). Projections for the region include warmer temperatures and higher precipitation (SNAP 2014), though in concert with these land cover changes it is unclear whether overall wetter or drier conditions will prevail. In the case of the latter, community water sources may be threatened as they already are in other parts of the state.

Our research in Bristol Bay involved a mixed set of ethnographic methods including informal interviews, direct observation, and participant observation performed from 2010 to 2014 in 11 communities that range in population from 100 to over 2400. Each community has diverse assets and needs with respect to civic government and infrastructure (e.g., water and wastewater systems) (Loring, P.A., Penn, H., Gerlach, S.C., Schnabel, W., 2015).² All participants in this research quoted here are (or were) employees of local municipalities or non-profit organizations, working in positions such as city planner, city manager, and water plant operator, and were recruited purposively with the aid of city

² Note that in our discussion below we will not refer to specific communities by name for reasons of privacy.

officials or similar representatives from regional tribal governments or consortia. The research is phenomenological, in that we recognize that the experiences of individuals, in this case municipal experts, can inform generalizable insights into the nature of climate change and climate change adaptation. Interviews were informal, guided only by general talking points about the challenges facing community infrastructure, management, and planning. Participant observation often took the form of community tours and afternoons spent shadowing or assisting participants as they attended to their daily responsibilities. Invariably, the first questions that we raise in these meetings relate to local needs, our goal being to adapt subsequent research activities accordingly (McGowan *et al.* 2014).

4. Discussion

Participants in this research identify a long list of issues that they are working to address every day, including environmental quality, food and water security, domestic abuse, alcoholism, and economic issues such as a lack of job opportunities and the price of food and fuel. This list is in line with other studies and reviews of environmental and socioeconomic challenges in the North (e.g., ACIA 2005; Ford *et al.* 2006; Gerlach *et al.* 2011). Given that the majority of our interviewees' expertise is in municipal operations and planning, our conversations not surprisingly emphasized issues of land use, water resources, and the operations and maintenance (O&M) of sanitation and solid waste infrastructure.

Among the specific issues described to us are (listed in no particular order):

- The need to relocate a failing sewage main from an eroding beach
- Municipal water and wastewater systems operating past end-of-life and/or over capacity due to community expansion and seasonal population influxes
- Insufficient budgets for community works and debates over the implementation of a new, region-wide "fishing tax" to pay for maintenance of the local port, roads, etc.
- Lack of data regarding regional hydrology for the purposes of siting new wells and planning community water systems
- Rural outmigration and its impact on employee retention in municipal jobs

- Employee training and certification
- Seasonal flooding of landfills and sewage lagoons and impacts on environmental health
- Toxic wastes disposal and recycling

This list provides a snapshot of the panoply of challenges facing rural communities in Bristol Bay and across the state. The list is not comprehensive, but in our experience it is representative of the wide range and diversity of issues that must invariably be fielded by one or perhaps two overburdened individuals (see also Lynch and Brunner 2007). While climate change has a hand in many of these issues, adaptation is rarely the goal that people have in mind when they are engaged in such tasks as repairing sewer pumps or working to start new waste backhauling programs. In fact, from the Yukon River communities where we have worked previously to the Bristol Bay region described here, we have heard it stated many times that “we don’t need scientists to tell us the climate is changing, but right now that is the least of our problems.”

Rather, we find that people are trying mainly to keep things running, and where and when possible, to make improvements for their communities. Further, obstacles created by the legacy of past decisions, usually made by outsiders implementing top-down rural development schemes, prove to be among the most ubiquitous challenges facing people in the region. In other words, people are regularly constrained from fully attending to goals such as community improvement because they are addressing more pressing issues that relate to maintaining the status quo. “I’m always standing on my back foot,” explained one city manager, “it’s not that we don’t have a plan, but that we don’t ever have time to work toward it. It takes most of my day and all of my employees’ time to keep that [water plant] running.”

The city planner in one community explained, for example, that because it has a water treatment facility in operation, despite the fact that it is aging and already operating many years past its planned end-of-life, they are unlikely to receive financial support from the state of Alaska for new capital projects

because there are many other rural communities who lack any form of water infrastructure at all. This is a compelling example of how the relationship between a community's assets and ability to respond challenges as they arise is quite nuanced: a multi-million dollar water treatment facility, which might appear to be a source of capacity for the community, is in practice a liability that keeps people from working on other issues of community improvement.

In another community, the water manager is trying to create better employment opportunities for his neighbors, with the ability to respond to environmental challenges such as climate change a subsidiary goal:

I need skilled laborers to implement new projects or to fix things when they fail. The thing is, people want long-term jobs, so I need to find a way to keep them in the village, instead of going to work on the [North] Slope or somewhere else because it has a regular check. We are trying to organize a home plumbing and handyman service for people here, and maybe that work will be enough to keep them around.

The city planner and city manager of yet another community related concerns regarding the sustainability of fresh water supplies that also speaks to the matter of how climate change, while a component, is not a driver of local initiatives. The "downtown" area of the community uses water from two groundwater wells, but the remaining two-thirds of the population rely on private wells. The community is growing, and the city planner has concerns about where private wells and septic systems are being located, particularly because of a lack of regulations regarding siting and because there are no available data regarding the hydrogeology of groundwater in the region. The community does not have the resources to complete a groundwater model on their own, so there are also no plans for where new wells might be located if the public wells dry up or become contaminated. Climate change is a factor here to be sure; as noted earlier there is uncertainty about how hydrology in Alaska will change as a

result of warming, but that it will change is generally accepted. Currently, the city planner is trying to establish partnerships with researchers and agencies to improve their baseline data about local water resources.

In each of these examples, climatic and environmental changes play a role in local actions, but in none of these cases would it be accurate or even informative to describe the work these people are doing as climate change adaptation. It is noteworthy too that in the three communities discussed above, none have a formal climate change adaptation plan, and none report having the resources or pressing interest to develop one. The largest community in the region does maintain a 'comprehensive plan': the first was written in the 1960s and it has received updates every 2-5 years since the 1980s. The most recent update to the plan was completed in 2010, and climate change is never mentioned in the document, though weather and shoreline erosion are mentioned once. By comparison, sustainability is mentioned 22 times in the document, with respect to such diverse topics as fisheries, tourism, energy costs, and public facilities. As the city water manager explained,

I have a lot of things going on here, a lot of things on my to-do list. Climate change isn't on there. Now, I'm not denying it's happening. We see it here better than most people. We just don't want to be talking about climate change because we got a lot of other things to be working on. Let's talk about Pebble Mine. Let's talk about the Pollack fishery crashing the Yukon [River] Kings. These are problems we need to solve.

5. Community Work as Niche Construction

These cases illustrate how local people are constantly working to maintain the quality of people's homes, lives, and lived environments, attending to various O&M needs and addressing short-term challenges such as infrastructure failures, while also seeking to develop and implement plans for improving quality of life in their communities. Netting (1993) describes this day-to-day milieu simply as

environmental management, and the observation that is implicit in Netting's choice of terms is that the goal of this work is not systematic change but system maintenance and qualitative improvement of people's lived environment (Romer's Rule). As one city manager repeated several times,

Amenities, amenities, it is all about the amenities for people, making this city a nicer place to live. We want to build a new ball park over there, and a sidewalk along the main drag that runs to the cannery so all the workers don't have to walk out on the busy road. I don't always have time to think about that stuff though, but it's the best part of the job.

Another city planner explained:

Planning isn't the right word for what I do, what this job is. It's like steering a boat, sometimes in dense fog and while manually pumping the bilge and manning the mess. You've got to make sure everyone's fed and you want the food to be good, too. But you also don't want to sink, or capsize, or run aground. And I think it's like this everywhere, not just Alaska, bigger cities just have more people to do the job.

We use the term "community work" for what these people do in order to highlight the service aspect of the work, i.e., individuals working for the collective good, and also because like housework and kin work (Di Leonardo 1987; Schenone 2003), the importance of community work is currently overshadowed by more societally-privileged activities — by the man's work in the case of housework and kin work, and in this case, by climate change adaptation.

We define community work as a process wherein people take actions and enact strategies to improve quality of life for the community as a whole. Community work blends environmental management as described by Netting, with the management of community capacity in its various forms.

Consider as one informative example the case noted above of the city manager seeking to create part-time job opportunities in order to keep skilled individuals from leaving.

As noted, community work is analogous to the process of niche construction in evolutionary biology (Odling-Smee *et al.* 2003), a process through which organisms “define, partly create, and partly destroy their own niches” (Laland *et al.* 1996; Odling-Smee *et al.* 1996: 641;). Niche construction is a compelling metaphor here because it avoids the ‘causal arrow’ implied by adaptation (Lewontin 2001)—that environmental factors determine the traits of organisms. Instead, niche construction involves a more interactive interplay among people and the environment, addressing the concerns noted earlier about environmental determinism.

Niche construction has a complex relationship with adaptation, and the same is true for our proposed concept of community work (Fig. 1). When organisms modify their surroundings, they change the selective processes that will operate on future generations. Those changes may or may not prove adaptive in the future; they may create a habitat in which the organism can better thrive or they may create new constraints and challenges. Rural Alaska has many examples of poorly conceived infrastructure and natural resource policies that were well-intentioned when implemented but have locked people in to positions of food, water, and energy insecurity (Eichelberger 2011; Loring *et al.* 2013).

As a theoretical framework for understanding how societies change, niche construction has already had some uptake in archaeology and in studies of human-environment co-evolution (e.g., Laland and O’Brien 2010; Rowley-Conwy and Layton 2011; Smith 2011; O’Brien and Laland 2012; Codding *et al.* 2014). As Laland and O’Brien (2010) note, “[niche construction] encourages us to think beyond climate, instability, and external environment ... and incorporate human activities as active variables” (p. 315). This is our goal for the concept of community work. People no doubt must often respond directly to

environmental change and surprise, but they are also innovators and ecosystem engineers. The lesson that emerges from our fieldwork is that when people experiment and respond to change they tend to do so with conservative goals in mind, and within an inherited social and ecological niche that exhibits the built, social, and environmental legacies that can create vulnerabilities as well as constraints and opportunities (Laska and Morrow 2006; Eichelberger 2011).

The community work perspective, thus, turns focus to this interplay of historical legacies and people's short- and long-term strategies and how these develop into the long-term outcomes that we recognize as adaptation or maladaptation (Laland and O'Brien 2010). Likewise, it brings attention to the fact that human-driven processes of stability and change happen at multiple organizational levels.

5.1. Planning for Change

The community work / niche construction perspective thus supports provocative hypotheses about how short-term environmental management strategies and long-term adaptation processes are related:

- What are the tensions or synergies among specific strategies for achieving community stability and longer term adaptations?
- Can too many reactive responses to drivers such as rapid climate change entrench communities into maladaptive positions?
- What are the tensions or synergies among individual- and community-level strategies for stability and change?
- How diverse are people's responses to change and how does this response diversity impact community-wide outcomes?

We know, for example, that in some cases people make decisions that enhance their short-term security but create greater problems over the long term (Barnett and O'Neill 2010); the transition to living in fixed communities in rural Alaska has provided people with a number of modern amenities but it has also reduced their flexibility and mobility, resulting in issues of food and water security that are worsening as climate changes (Eichelberger 2011; Loring *et al.* 2011). With a better understanding of

why people choose or are locked into making decisions that have long-term consequences, such maladaptive tradeoffs might be better avoided through policies that focus on keeping people's options open.

An understanding of this dynamic is therefore essential for outside agencies and policymakers seeking ways to help communities plan effectively for change. In part, this is because it mandates a different methodological approach for assessment and planning than typifies the climate change adaptation literature. Currently, quantitative indicator frameworks scoped around the concepts of vulnerability and adaptability are popular for forecasting societal impacts of climate change (e.g., Allison *et al.* 2009; Cinner *et al.* 2009; Mathis *et al.* 2014; Himes-Cornell and Kasperski 2015). These frameworks usually focus on some specific climate change-induced challenge, for example a decline in fisheries, and then model vulnerability and adaptability using mainly secondary sociological data and 'expert' opinions of what resources are most important for responding to that challenge. Because these indices are not always developed through a participatory process (Reed *et al.* 2006; Ray-Gadamus 2013) they often encode reductionist and in some cases paternalistic notions of people's abilities and what they need to respond—financial assets, for example, are regularly emphasized as important for responding to change, and average years of formal education per capita is often used as an indicator of a community's "capacity to learn" (Alessa *et al.* 2008; Cinner *et al.* 2009:7).

Yet, we know that different groups of people will solve environmental problems in diverse ways despite similar constraints and resources (Barth 1956; Leslie and McCabe 2013); what one community may solve with financial resources, another may solve through collective social action, and so forth. Likewise, people's vulnerabilities are also often an important source of strength when pressed (Brown 2012; McGreavy 2015); by conflating vulnerability with deficit and negative risk, however, these indices

and the policies they inform may altogether miss the mark of identifying what kinds of support communities need the most.

This is not to say that such indicator frameworks are not useful, but that they are limited methodologically. It remains to be established in a rigorous way whether ability to respond to change can be meaningfully assessed with quantitative or categorical data. Also, to our knowledge very few of these indicator sets, which are effectively deterministic models of human behavior, have been tested for goodness-of-fit (Blount *et al.* 2015 is an important exception). Thus, putting too much stock in these indices would be dangerously close to committing what Friedman (1974) called “mechanical” or “vulgar” materialism³ (p. 456) wherein people’s behaviors and social forms are misunderstood as being mere epiphenomena of their resources and environments.

Participatory and ethnographic approaches and the perspectives offered by political ecology are therefore essential if policymakers want to understand community work and how people respond to climate change from within that context. Policymakers, in general, seek quantitative and standardized ways to measure, compare, and prioritize community needs (Scott 1998), which is likely why the indicator frameworks discussed above are so ubiquitous; yet, people simply do not experience the impacts of climate change in standardized or comparable ways— they respond to environmental changes within a complex sociopolitical and socioecological milieu that is shaped both by historical legacies and their visions for the future. Whether people are enabled to plan and experiment or are locked into a position of coping with crisis after crisis are fundamentally questions of power and

³ Note that Friedman’s critique was unfairly levelled at early ecological anthropologists (e.g., Harris, Rappaport), some of whose research was mischaracterized and misunderstood (Rappaport 1977); nevertheless, the critique is relevant if these indices are taken as ultimate mechanistic formulations of human behavior.

authority as much as they are of the resources people have at their disposal (Loring *et al.* 2011). The goal, then, should be to find ways to pair these quantitative models with qualitative frameworks that can account for such issues as agency, power, and path-dependence. We have had some success with a such framework, based on ecosystem services and path dependence theory (Loring *et al.* 2008, 2011), the goal of which is to look at so-called “response space” and “response pathways” (Tompkins and Adger 2005), and diagnose policy-related limits and bottlenecks to community experimentation and innovation in the face of change.

6. Conclusion

Ultimately, scientists and policymakers who work in the area of climate change seek to provide a science-based framework for decision-making and development, and adaptation and its related concepts have proven effective as a shared language. Many researchers have highlighted the various caveats and pitfalls of this vocabulary however. As one way to address these issues, we offer community work as a concept that, when paired with adaptation, more accurately represents of how people and societies experience and respond to change than the concept of adaptation alone. Community work avoids the implications of environmental determinism and victimization that presently muddle the discussion and contribute little to our understanding of how local people and communities cope with local problems, which is often from the bottom up and too often with limited human and financial capital. With a more robust theoretical understanding of human behavior that incorporates people’s values and intentions for both stability and change, venues for supporting communities that do not fall into the developer’s trap or issues of social justice noted above become possible. It has been argued that the best first step for addressing climate change impacts on communities is to fix existing problems that have ready solutions, such as food and water security and failing infrastructure (Gerlach *et al.* 2011). The perspective argued here requires only that policymakers reorient their attention toward these community goals, helping people to solve existing and future problems on their own terms and

regardless of whether these initiatives map in clear-cut ways to state prescribed and sanctioned modes of development.

7. Figures



Figure 1: Map of Bristol Bay Communities.

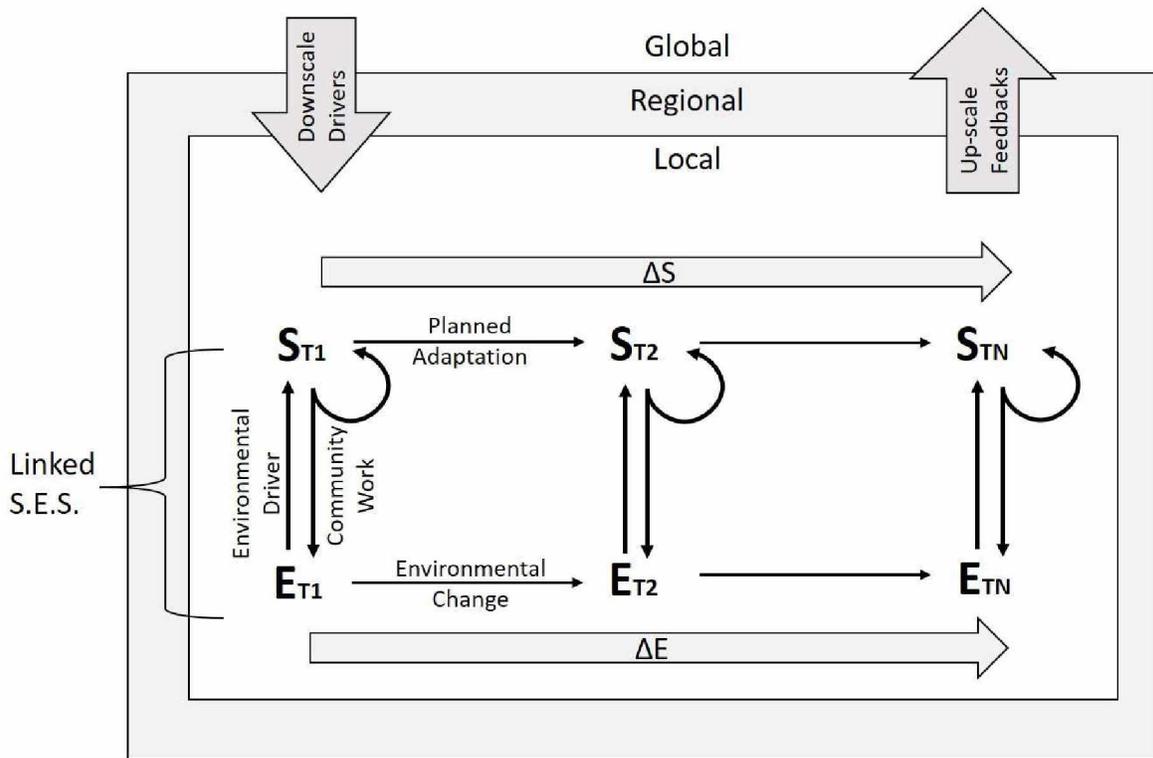


Figure 2: Schematic of the relationships among community work and adaptation (adapted from Day et al. 2003). Environmental changes (ΔE) and social changes (ΔS) manifest over time as a result of these two interactive processes. Each point in time exhibits sociocultural and ecological legacies of past strategies and activities; over time, incremental changes made as a part of community work can lead to environmental and social changes that, in hindsight, are understood as adaptive or maladaptive. Planned adaptation measures may also be necessary in response to external drivers, though the outcomes of these too will only be seen after the fact and over time. SES stands for social-ecological system.

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