Adaptation Challenges Experienced by Entities Serving Alaska Native Village Infrastructure Needs

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SYNOPSIS: This study determined how development actors' source of funding is associated with barriers to adaptation of infrastructure.

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Abstract:

Infrastructure adaptation is critical to Alaskan communities in the face of rapid climate change. Here, infrastructure adaptation refers to retrofitting existing systems and creating new infrastructure that can withstand the dynamic and extreme impacts of climate change. Despite the established urgency to pursue infrastructure adaptation in rural Alaska, these projects are often costly and inefficient due to a myriad of barriers, such as lack of essential knowledge or sufficient financial resources. The barriers experienced by development actors—i.e., external entities or stakeholders with decision-making power that operationalize adaptation projects—is largely unknown. To begin to understand these challenges and how to mitigate them, we observe barriers to adaptation experienced by developments actors are related to how these organizations are

funded. Enabling this study are open-ended responses from a survey that inquired on interagency coordination and barriers to adaptation, completed by regional development actors (n=37) in 2020 and 2021. Our results show that barriers to adaptation faced by development actors are not random and vary according how their funding is acquired. From this, we recommend the prioritization of Indigenous-led adaptation activity through (1) increased flexible federal funding available to local development actors and adaptation recipients (i.e., local communities) and (2) increased coordination between adaptation recipients and development actors during all stages of the adaptation process (e.g., planning, design, implementation, etc.).

1. INTRODUCTION

Climate change destabilizes critical infrastructure in rural Alaska, such as utilities (e.g. water, energy) and transportation networks (Huddleston et al. 2022; Taylor et al. 2022). Environmental changes such as permafrost subsidence, coastal land loss, and flooding, push the built system beyond its original design capacity, decreasing the level of service that it provides to communities. These decreases in levels of service often exacerbate existing infrastructure inequities, such as spatiotemporal disparities in access to in-home plumbing (National Research Council (U.S.) et al. 2010; Ouyang 2014; Center for Disease Control 2017; Brown et al. 2022; Taylor et al. 2022). For instance, a drinking water pipeline in Unalakleet, Alaska (AK) has a high-risk of collapse after excessive erosion removed the structure's protective soil barrier and exposed the pipeline to severe weather (Waldholz and Anchorage 2017). The loss of this village's sole water supply would contribute to the region's overall infrastructural decline and public health consequences (Gessner 2008; Mosites et al. 2020; Mattos et al. 2021). Similarly, extreme erosion in Napakiak, AK removed shoreline that served as a protective barrier from excessive wave damage to the local transportation network. After a storm in May 2018 destroyed the town's hovercraft landing, residents lost affordable access to critical supplies for one year (Kitka 2018). During this time, supplies were delivered by plane, which was considerably costlier. Many other communities struggle with similar infrastructure challenges arising from a changing climate. The Denali Commission found that 144 Alaska Native communities are facing major infrastructural concerns as a result of warming temperatures statewide (The Denali Commission 2019). Developers, planners, and residents in rural Alaska must pursue community-level adaptation, meaning retrofitting existing systems and creating new infrastructure to withstand the dynamic and extreme impacts of climate change, in order to avoid further decline of critical infrastructure services

(Bierbaum et al. 2013; Hall et al. 2019). Some examples of infrastructure adaptation are community relocation, weatherization of homes and businesses, and shoreline protection measures (Taylor et al. 2022), among others.

To be defined as successful infrastructure adaptation, such engineering must provide substantial benefits while being both socially and ecologically appropriate. An adaptation project that faces few barriers but does not effectively mitigate climate threats to infrastructure fails to protect community-level public health and safety. Conversely, a project that protects critical infrastructure services but disregards social needs is inappropriate, as well. For instance, in the 1970s, the federal government funded a centralized water system for Shishmaref, AK. However, community members continued to use and prefer traditional water sources, such as rainwater and surface water, over water from the piped system due to distrust of treatment chemicals and devotion to traditional ways of life (Marino et al. 2009). This resulting infrastructure project could be viewed as minimally beneficial for this location, which here we argue is maladaptation. Further, as Alaska Native populations often experience profounds legal, spiritual, and cultural connections to the physical land that they inhabit (Abate and Kronk 2013; Brady and Leichenko 2020), socially and ecologically appropriate adaptation in such villages are often synonymous. An adaptation suite that fails to account for these elements is unsuccessful adaptation, or maladaptation.

Despite the established and urgent need for infrastructure adaptation in Alaska (The Denali Commission 2019), regional-level adaptation activity remains inefficient and under-resourced, with many obstacles that impede cost-effective and successful community-level adaptation (Taylor et al. 2022). Obstacles that prevent successful adaptation, referred to as *barriers to adaptation*, are conceptualized as the actors' subjective interpretations of the operating factors and conditions (i.e., physical, environmental, legal, social, practical/logistical, economical) that negatively impact the adaptation process and reduce the chances of success (Biesbroek et al. 2013). Alaska-specific research often focuses on costly technical barriers to adaptation experienced by operators and planners (Taylor et al. 2022), such as short construction seasons and the usage of building materials specialized for Arctic conditions (Larsen et al. 2008; Melvin et al. 2017; Sohns et al. 2021; Brown et al. 2022). However, technical barriers to adaptation alone are not sufficient to fully describe the barriers to adaptation that exist in rural Alaska (Taylor et al. 2022). In fact, the literature has described many non-technical barriers to adaptation that can extend infrastructure adaptation projects' timelines and costs, or even prevent adaptation from even occurring in the locations that

need it the most (Bierbaum et al. 2013; Azevedo de Almeida and Mostafavi 2016; Fitton et al. 2021; Taylor et al. 2022). These barriers often fall under four broad themes: (1) community involvement and capacity (Ristroph 2018), (2) financial (Pearce et al. 2012), (3) operational (Pearce et al. 2012), and (4) access to knowledge (Alessa et al. 2016; Ristroph 2018; Bronen et al. 2020) (Table 1). Some of these themes are exemplified through the infrastructural relocation of Newtok, AK, a lengthy and unfinished process that began in 1994 and is currently the only example of formal and federally sponsored relocation as a method of infrastructure adaptation in the U.S. (Ristroph 2021). This project faced several financial barriers to adaptation, including lack of clear funding channels, and many community capacity barriers to adaptation, such as local workforce limitations (Ristroph 2021). This timeline is insufficient for coastal villages currently at risk of irreversible infrastructure damage from erosion within as little as 10-15 years. With the imminent danger to communities, coupled with the fact that adaptation of infrastructure becomes more expensive and less effective with increasing climate change (Bierbaum et al. 2013), it is imperative that these projects overcome these obstacles.

In adaptation processes in rural Alaska, internal stakeholders (i.e., the village) work in tandem with external stakeholders, such as operators and planners with decision-making power, referred to here as development actors (Pisor et al. 2022). An example of a development actor is the Cold Climate Housing Research Center (CCHRC) (Hickel et al. 2018; Granger 2020), which builds housing and provides solutions towards energy efficiency for buildings located in circumpolar regions (Garber-Slaght and Craven 2012; Zufelt 2017). In the context of Alaska, non-technical barriers to adaptation are typically described from the perspective of residents through case studies, such as Newtok, AK (Ford et al. 2010; Marino 2012; Pearce et al. 2012) and first-hand accounts from Alaskan media (Goode 2016; Plummer 2018; Flavelle 2022). While fewer studies probe directly into barriers to adaptation experienced by development actors (Eisenack et al. 2014; Taylor et al. 2022), their internal perspective could reveal barriers that are difficult to perceive as the adaptation recipients (Nader 1972). Further, identification of barriers alone does not reveal barriers' origins or the conditions that allow barriers to emerge or persist (Eisenack et al. 2014). This knowledge is critical to effective interventions because if the conditions that foster barriers are known, those conditions may be altered in the planning phase, allowing infrastructure adaptation to become more cost- and time-efficient while still providing substantial and positive results (Moser and Ekstrom 2010; Eisenack et al. 2014). Since development actors make critical

decisions about what adaptation projects are selected and how the projects are operationalized statewide (Taylor et al. 2022), we argue these organizations' characteristics are contextual factors that can describe a regional synthesis of some conditions that foster barriers to adaptation (Meeker and Kettle 2017).

1.1 RESEARCH OBJECTIVE

Infrastructure adaptation projects are funded and operationalized by several development actors that complete various tasks (Pearce et al. 2012; Ford et al. 2015). Federal and state agencies typically focus on high-level adaptation tasks, such as funding, technical assistance, education, and policy, while local development actors that are funded by federal grants typically implement adaptation through activities such as design, construction, and maintenance (2021a). In completing these tasks, institutional inefficiencies (Table 1) can hinder successful and cost-effective infrastructure adaptation. For instance, successful adaptation planning requires a blend of Western knowledge (e.g., instrument-based sensing of erosion, temperature, etc.), Indigenous knowledge (e.g., cultural pactices, historical insight into climate change impact through storytelling), and local knowledge from adaptation recipients (e.g., up-to-date perceptions of adaptive capacity) (Kettle et al. 2014; Ristroph 2018; Birchall and Bonnett 2019; Bronen et al. 2020). However, since the tasks that are delegated to state and federal agencies do not require direct interaction with adaptation recipients (e.g., adaptation planning, risk assessment, environmental monitoring, etc.), these agencies often do not possess the financial and physical resources to foster a communication channel with such stakeholders. As a result, high-level decision-makers may have limited access to local input that comprises essential Alaska- and community-specific knowledge. Lack of financial resources within these agencies can also cause operational barriers, such as the hiring freeze at the Alaska Division of Geological & Geophysical Surveys that limited the human resource capacity needed to complete relocation planning for Kivalina, AK and Shaktoolik, AK (Immediate Action Workgroup 2009).

In this study, we explore how barriers to adaptation experienced by development actors vary according to how these organizations are funded, as this characteristic reflects the specific roles each development actor plays in the adaptation process. We do not argue that one type of development actor is more equipped to provide successful adaptation than others, or one type of development actor works in the better interest of adaptation recipients. For instance, while local

organizations supported by federal grants (e.g., tribal health consortiums) interact directly with adaptation recipients during the tasks delegated to them (i.e., construction, design, etc.), these development actors may experience similar barriers to adaptation to high-level agencies regarding community capacity and involvement. Rather, we attempt to trace regional patterns between the specific barriers and the type of development actors that experience them, showing the most common challenges within specific roles in the adaptation process. By doing so, results can suggest tangible methods to mitigate these obstacles and rectify pervasive oversights, such as alternative delegation of tasks and funding decisions (e.g., reallocation, deregulation, etc.). This study adds to the body of literature that adaptation providers can utilize to anticipate barriers at the institutional level, making adaptation activity more efficient at preventing additional infrastructure deterioration and inequities. Here, we pursue the following research objectives: (1) Identify the barriers to adaptation experienced by development actors that operate in rural Alaska; and (2) Understand how these barriers relate to the development actor's acquisition of funding.

2. METHODS

This study is based on a survey (n=37), distributed between the fall of 2020 and the spring of 2021, that assessed the barriers to adaptation faced by organizations that operationalize regional or statewide infrastructure adaptation services in rural Alaska. This approach provides a regional synthesis of barriers to adaptation across rural Alaska, rather than on a case-by-case basis. Since development actors operate throughout large portions of Alaska, a small network of development actors is sufficient to describe barriers to adaptation across the state, despite Alaska's considerable geographic size.

2.1 DATA COLLECTION & SURVEY DISTRIBUTION

A total of 41 key development actors were identified through three paths: (1) consultation with the Cold Climate Housing Research Center (CCHRC), (2) review of Alaska Housing Finance Corporation reports on housing in Alaska (Bristol Bay Housing 2020), and (3) semi-structured interviews with 25 stakeholders involved in infrastructure adaptation in rural Alaska (Taylor et al. 2022). To increase the reliability of the identified list, participants were asked to indicate other organizations they coordinated with on infrastructure projects that were not listed in the survey. There were five organizations identified by participants that were not in the list provided. Only

one of the additional organizations identified was added to the list of organizations in the survey. The other four organizations were excluded from the list as they were organizations that worked with only a single community, or the organizations did not have a strong tie to infrastructure.

Once the development actors were identified, the survey was distributed online via Qualtrics (see Taylor et al. 2022 for more details on survey deployment). While the full survey comprises 22 questions, three were analyzed here pertaining specifically to barriers to adaptation. These questions/prompts were open-ended and captured challenges that the organizations experience during infrastructure adaptation, as follows:

- For housing services, what challenges does your organization experience when engaging with communities?
- Identify the top three factors that limit your organization's ability to integrate climate change adaptation into your housing services/projects.
- Describe housing projects you have worked on or services you have provided in rural Alaska that you consider to be unsuccessful or less successful and describe what specific characteristics make them unsuccessful or less successful.

Participants were provided with an informed consent document that described the purpose and funding of the research. Further, this research follows IRB protocol approved by Iowa State University IRB. Participants were given a $40 Amazon gift card in exchange for their participation. The response rate was 63% (n=26 organizations) and a total of 37 respondents.

2.2 QUALITATIVE CODING OF SURVEY RESPONSES

Open-ended responses in this survey underwent qualitative content analysis (Saldana 2013) via Dedoose (2021b) to identify emergent themes in barriers to adaptation, according to operators and managers. This analysis process started with an inductive coding process to identify the challenges experienced by operators and planners (Elo and Kyngäs 2008). These codes are defined in the coding dictionary (Table 1). Each respondent was assigned a descriptor based on their source of funding – Federal Agency, State Agency, Local Agency funded by Federal Grants, or Private Organization Funded by Shareholders and Donations – to describe the context in which the barriers to adaptation are occurring. This information was included in the survey and confirmed through literature. Coding was validated through intercoder reliability with two individuals other than the primary coder, reaching a Kappa value of 0.66, classified as "substantial" agreement (R.A. Singleton, B.C. Straits, M.M Straits 1993; De Vries et al. 2008; Saldana 2013).

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THEME	CODE	DEFINITION
Community Involvement & Community Capacity	Empowerment of Community Members to Make Decisions and Give Input	Encouragement of community members to take an active role in decision-making for infrastructure adaptation
	Lack of Understanding about Agencies	Role and limitations of agencies unknown to clients (community members)
	Lack of Community Engagement	Lack of community participation in meetings and input
	Sociocultural differences between local communities and external agencies	Language barriers and cultural differences between communities and external stakeholders that lead to maladaptation
	Local Workforce Capacity	Lack of community members to carry out adaptation plans, as well as high turnover in local leadership
	Lack of physical infrastructure within communities to complete tasks	Lack of required infrastructure, such as Insufficient bandwidth or lack of telephone infrastructure in remote communities, to effectively complete adaptation activity
Financial	Funding Inflexibility for Project Type	Lack of available funds due to strict allocation of financial resources and guidelines for how funding is utilized
	Lack of Access to Capital for Planning/Design and Construction	Lack of available financial resources for sufficient planning and construction
	Lack of Access to Capital for Community Engagement	Lack of available financial resources for sufficient involvement of the community
Operational Challenges	Administrative Capacity	Lack of sufficient personnel to complete tasks
	Excessive or Inflexible Regulations	Strict guidelines that hinder a development actor's ability to complete tasks, "red tape"
	Conflict Between Planning and Community Adaptation Needs	Discrepancy between the planned adaptation activity (or lack thereof) and what action is needed, in terms of scope and project goals
	Interagency Collaboration, Resource- and Data-Sharing Across Agencies	Lack of communication and collaboration between multiple agencies
	Logistical Challenges during Implementation	Difficult coordination of complex infrastructure adaptation projects – time,

		remoteness, weather-related challenges, inefficient communication
	Slow decision-making	Untimely decision-making
	Alignment of Priorities Across Agencies	Mismatch across agencies over which adaptation needs take precedence, if any
Knowledge	Alaska-Specific Expertise	Knowledge about Alaska-specific nuances, like Arctic construction and socio-cultural norms in ANVs.
	Lack of accessible climate projections	Lack of reliable data about climate change impact.

3. RESULTS & DISCUSSION

Table 2 contains code counts that show the relative prevalence of different barriers to adaptation amongst the development actors, according to how each acquires funding. Specifically, federal agencies cited the most barriers to adaptation per respondent (7.75), while privately funded development actors cited the least barriers per respondent (5.4). Further, federal development actors accounted for the largest proportion of operational challenges, even though only 20% of the total respondents were from this type of agency. More broadly, the lack of community engagement is the most predominant barrier across all development actors, account for 13% of all references to barriers to adaptation. All development actors frequently cited that adaptation projects are "less successful when they do not have a high level of community input and participation." This statement makes sense, as community members can help to make important decisions (e.g., new site for community relocation, when to pivot from protection-in-place to relocation, etc.) and can provide essential local and Indigenous knowledge, such as how create adaptation plans that are feasible for Alaskan communities and how local vulnerability and exposure to climate change changes with sociocultural factors, rather than physical changes alone (Bronen et al. 2020). However, several respondents claim that adaptation recipients are apathic, and developments actors struggle with "convinc[ing]…customers that it's a worthwhile investment" (2021a). Due to the long history of disenfranchisement, erasure of Indigenous culture through mandatory westernization, and ineffective adaptation projects (Ferguson-Bohnee 2020; Bronen et al. 2020; Sohns et al. 2021), mistrust of external agencies and subsequent disinterest in adaptation activity is not surprising. For instance, during the infrastructure relocation planning process of the Isle de Jean-Charles in Louisiana, such challenges impeded state planners' goal of using community input to identify a new location for the town (2016). Due to the necessity of community engagement in

adaptation activity, this finding describes a deeply destructive feedback loop that must be interrupted for improve adaptation activity.

The lack of access to capital for planning and implementation is the second predominant barrier to adaptation across all development actors, accounting 10% of all references to barriers to adaptation. This finding is not surprising, as previous literature has established that there is a multi-billion dollar gap between available adaptation funding and comprehensive adaptation need in the United States (McNeeley 2012; Pearce et al. 2012; Azevedo de Almeida and Mostafavi 2016; Ristroph 2018, 2021). However, local development actors supported by federal grants cited financial and knowledge barriers to adaptation at a higher rate than other types of development actors, claiming that "lack of funding" and "learning as we [go]" are some of the top factors that limits the organization's ability to adaptation infrastructure (2021a). However, high level agencies (i.e., federal and state agencies) are typically responsible for financial decisions, gathering climate and conducting exposure assessments, and technical support for adaptation processes – meaning that local development actors funded by federal grants experience these barriers to adaptation very profoundly but have limited agency to mitigate them (Moser and Ekstrom 2010). Further, literature has found that high-level agencies' inflexible funding environments and inaccurate perceptions of community-level adaptation needs result in inadequate financial resources for grant recipients, as well as inaccurate perceptions of a community's hazard risk, resilience to climate impact, and adaptation priorities (Huntington et al. 2019; Blair and Kofinas 2020). On the other hand, local authorities' perceptions of these traits tend to be more accurate, despite their limited ability to operationalize this knowledge.

Table 2: Count of barriers to adaptation by type of development actor. The most frequent challenge within each type of development actor is typed in italics.

	Type of Development Actor				
	Federal Agency	State	Local Organization Funded by Federal Grants	Private organization, funded by donations or shareholders	Total by Barrier to Adaptation
Frequency of Descriptor	8	11	13	5	
Total Challenges by Type of Development Actor	62	46	79	27	214
BARRIERS TO ADAPTATION					
Community Involvement & Community Capacity	**18**	**24**	**24**	**8**	**74**
Empowerment of community members to make decisions and give input	1	5	1	1	8
Lack of understanding about agencies	1	1	4	0	6

Lack of community engagement	5	*7*	9	1	22
Sociocultural differences between local communities and external agencies	4	1	3	0	8
Local workforce capacity	2	5	4	4	15
Lack of physical infrastructure within communities to complete tasks	5	5	3	2	15
Financial	**10**	**6**	**23**	**8**	**47**
Funding inflexibility for project type	2	5	7	1	15
Lack of access to capital for planning and implementation	6	1	*16*	*5*	28
Lack of access to capital for community engagement	2	0	0	2	4
Operational Challenges	**27**	**11**	**20**	**7**	**65**
Administrative capacity	1	0	2	1	4
Excessive or inflexible regulations	6	1	2	1	10
Conflict between planning and adaptation/community needs	2	4	7	1	14
Interagency collaboration, resource- and data-sharing across agencies	5	0	1	1	7
Logistical challenges during implementation	5	3	5	2	15
Slow decision-making	1	0	0	0	1
Alignment of priorities across agencies	*7*	3	3	1	14
Knowledge	**7**	**5**	**12**	**4**	**28**
Alaska- and community-specific expertise	*7*	1	7	3	18
Lack of accessible climate projections	0	4	5	1	10

4. PRACTICAL IMPLICATIONS

Regional barriers to adaptation must be surmounted so that adaptation activity can become more time- and cost-effective at preventing further infrastructure degradation and subsequent health and safety risks. These results indicate that financial and community engagement barriers are the greatest challenges to development actors that operate in rural Alaska. This finding, along with patterns between the source of a development actor's funding and the barriers to adaptation that they experience, reveals possible leverage points to mitigate these barriers and improve the capacity for adaptation through targeted financial investments and inclusion of local communities in the adaptation process.

Currently, local development actors do not take lead roles in funding and planning decisions, limiting their ability address their greatest challenges, and lack of community engagement is a significant obstacle across adaptation processes. Based on these results, we suggest pursuing Indigenous-led adaptation activity through two methods: (1) increasing the amount of flexible funding available to adaptation recipients and local development actors that are

supported by federal grants, and (2) increased coordination between adaptation recipients and all development actors throughout planning and implementation stages. While increased funding necessary for comprehensive adaptation across the U.S. (Davenport and Flavelle 2021), research suggests that in regions with decades of infrastructural neglect, such as Alaska Native villages, adaptation funding must be increased in both amount and flexibility (Henson et al. 2020; Cohen and Marx 2021). As localized decision-makers tend to have accurate perceptions of climate change's impact on a community and how to best tend to those impacts according to available resources (Kettle et al. 2014; Blair and Kofinas 2020), funding is used more productively when tribal nations and local communities can spend according to their own priorities and needs. This approach minimizes the risk of maladaptation due to high-level decision-making in funding and planning that may not reflect the needs of adaptation recipients. For instance, federal funding is often siloed by infrastructure type, meaning that infrastructure sectors (e.g., roads, housing, utilities) are funded through different avenues. As a result, communities are forced to adapt infrastructure piecemeal, promoting unsustainable adaptation activity since climate change impacts many components of critical infrastructure simultaneously (Taylor et al. 2022). By increasing flexible funding available to local development actors and adaptation recipients, adaptation activity can avoid such situations, becoming more cost-effective and impactful.

Further, coordination between adaptation recipients, local entities, and high-level agencies (Knapp et al. 2017; Brock et al. 2021) cultivates essential trust and community engagement throughout the adaptation process (Bronen et al. 2020). For instance, the Department of the Interior hosted consultations with tribal leaders in planning how to best protect subsistence lifestyles in the Arctic (U.S. Department of the Interior 2022). Similarly, in August 2022, the Alaska Native Tribal Health Consortium partnered with the National Oceanic and Atmospheric Administration (NOAA) to accomplish several objectives, including the creation of the Alaska Tribal Climate Change Advisory Group that aims to ensure that Tribal climate change efforts are led by Alaska Natives (National Oceanic and Atmospheric Administration 2022). Consultations and partnerships such as these examples may help to avoid detrimental oversight by out-of-state contractors and external agencies, particularly in the planning stages. This coordination could also promote the use of Indigenous knowledge throughout adaptation tasks. For instance, climate impact and exposure assessments are typically conducted by high-level development actors, such as federal and state agencies. However, these assessments often are unrobust and cannot be applied to localized

decision-making (U.S. Army Corps of Engineers, Alaska Division 2009; Immediate Action Workgroup 2009; The Denali Commission 2019). However, Indigenous communities typically have intimate knowledge of the local ecological systems within a cultural context, creating a human sensor network that traditional sensors cannot replicate. The collective memory of Arctic residents, acquired by generations of storytelling, contains data on historical environmental variability that ranges beyond the relatively sparse data acquired by Western science in the past few decades (Alessa et al. 2016; Williams et al. 2018). Research has shown that community-based observation networks are organized to methodically collect observers' memories of environmental change and effectively relay essential information to non-local development actors (Johnson et al. 2015). This information can supplement instrument-derived datasets from outside organizations, such as the Arctic Observing Network and the Sustaining Arctic Observing Network (Alessa et al. 2016), to create a comprehensive dataset that is a robust portrayal of environmental change in the Arctic (Ford et al. 2010; Johnson et al. 2015; Alessa et al. 2016; Wilson et al. 2018). By employing community-based monitoring networks along with the tactics discussed in this section, adaptation activity can become more cost-effective and more deeply engaged with adaptation recipients throughout all stages of decision-making.

4.1 LIMITATIONS

While this study reveals interesting trends, as with all studies, limitations are present. First, it is important to note that this survey measures perception of barriers to adaptation. Perception is subjective, shaped by experiences and worldviews of the respondents. However, since all data, even instrument-based observations, is susceptible to bias, this is not to mean that survey data is less valid than other kinds of data. Further, this survey focused on development actors related to housing infrastructure. It is possible that development actors that interact with other types of infrastructure (e.g., water, telecommunications, transportation, etc.) may cite different patterns between barriers to adaptation and funding. These limitations provide the opportunity for future research to develop literature's understanding of the interactions between infrastructure adaptation and the characteristics of development actors. For example, a future study could diversify the types of development actors included in their surveys.

In addition, although there is a relatively small participation number in this study, rural Alaska is remote with small communities, allowing development actors to work regionally across

Alaska. As such, important trends can still be revealed on a regional basis. Similar studies have used similar sample sizes (Spearing and Faust 2020; Blair and Kofinas 2020). Although some participants are Alaska Native and live in this region, community members were not explicitly included, and this research does not claim to represent the perspective of these communities. Analysis of development actors' perspectives provides a robust understanding of the barriers to adaptation of infrastructure of those serving Alaska Natives, externally to the village. Stakeholders from tribal organizations were included in the scope of development actors, including nonprofit tribal consortiums and tribal housing authorities.

5. CONCLUSION

Infrastructure adaptation is essential for rural Alaskans in the face of intensifying climate change. While regional adaptation activity exists in a limited capacity, several barriers to effective and efficient adaptation consequentially result in increased project timelines and costs. Although such obstacles are often analyzed at the community level, less is known about institutional barriers to adaptation. By analyzing challenges faced by development actors, this study found that barriers experienced by a development actor and who that development actor is—e.g., how the development actor acquires funding—are not independent. For example, one key finding is that federal agencies tended to experience more barriers to adaptation than other development actors, such as local organizations funded by federal grants. By understanding such relationships, we can suggest productive mitigation strategies. In sum, we have the following key recommendations. Adaptation funding at the federal level is currently insufficient for the needs in rural Alaska, and federal dollars are typically spent inefficiently when local groups cannot prioritize action items for their specific communities. Accordingly, we recommend the prioritization of Indigenous-led adaptation activity through the (1) increased amount of flexible funding available to adaptation recipients and local development actors funded by grants, and (2) increased coordination between all external agencies and adaptation recipients through consultations and community-based monitoring networks.

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