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Advancing water justice through a tribally-driven partnership: Designing sustainable rainwater harvesting systems in the Yukon–Kuskokwim delta of Alaska

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Community driven co-design models can help collaborators to respectfully engage in projects that provide much-needed resources and services to underserved communities. For example, partnerships between tribal, academic, and non-profit collaborators have the potential to generate positive outcomes for communities when individual efforts by those same groups may be less successful. However, cultural and spiritual differences between collaborators (particularly tribal and non-tribal) can lead to misunderstandings and negative project outcomes, despite good intentions and an honest effort by collaborators to achieve a common goal. Here, we provide a case study of a community-driven co-design project involving tribal, academic, and private collaborators to design and build a rainwater harvesting system with the Akiak Native Community (ANC), and their tribal council in Alaska, USA. A novel collaborative co-design process honoring the tribal sovereignty of the ANC is emphasized in this case study; a design model that is poorly represented in the literature with real-world examples. Logistics associated with designing and constructing the community-use rainwater harvesting system on Alaskan tribal lands is reviewed but the focus of this work is on the collaborative design process more so than the construction of the water harvesting system end product. More explicitly, the use of multiple approaches to promote collaborator involvement along with an emphasis on developing community driven project goals are highlighted as essential steps in our co-design process.

KEYWORDS

Akiak Native Community, Alaska, co-design research model, indigenous water justice, drinking water security, rainwater harvesting

1. Introduction

Access to clean and safe water is essential for all people yet modern governance systems, land-use practices, and climate change seriously threaten the availability of this critical resource at an unprecedented scale. In recent years, it has also become increasingly acknowledged that disparities in access to clean and safe water are contributing to negative health outcomes and environmental injustice challenges, particularly in tribal communities (Doyle et al., 2018; Deere et al., 2020). Unfortunately, the colonial structures and institutional systems that perpetuate these inequities in access to clean and safe drinking water are tremendously complex and interconnected, making it difficult for some tribal communities to control the quality of their own water resources. For example, within many parts of North America, water governance is highly fragmented across multiple layers of governmental departments and agencies (Dunn et al., 2017). The challenges are further complicated because the cultural and spiritual significance of water for many tribal communities does not dovetail with typical non-tribal water management practices or values. Generally, tribal nations and their citizens' relationship to water begins and ends with life, and their respect for water is linked to the health and wellbeing of all living beings. Despite a long history of respectful and sustainable water use, tribal perspectives on water resource issues have been—and regrettably remain—inexcusably undervalued within most natural resource management frameworks (Chief, 2018). Deep connections between tribal peoples and their environment, as well as a reliance on subsistence activities, tend to directly connect those communities to their rivers and streams in foundational ways, distinct from many non-tribal communities (Cozzetto et al., 2013). This is illustrated by the community's daily dependance on the river for subsistence, use of water for drinking, as an ice road used for transportation to and from the nearest town during the winter, and as a source of traditional knowledge. Such richness is rooted in centuries old knowledge systems that have sustained community members since time immemorial and continues to be foundational in contemporary spaces. Thus, current and future water security is an issue of utmost importance for many tribal communities.

Overall, American Indian and Alaskan Native (AIAN) communities experience a multitude of barriers when securing federal and state grants, which precipitates inequities across programs in tribal economic development, education, natural resources (e.g., water quality), community health, housing infrastructure (e.g., water and sanitation), and various additional programs. A 2004 United States Health and Human Services report about the challenges to AIAN's access to public health services, showed that the AIAN "population is under-represented as a proportion of total grant funding across all HHS agencies" (U. S. Department of Health and Human Services, 2006). While at the time, these populations were "∼1.5 percent of the U.S. population" (U. S. Department of Health and Human Services, 2006), they "receive[d] only 0.51 percent" (U. S. Department of Health and Human Services, 2006) of funding. Across several federal agencies, funding for health, education, house development, and agriculture programs remain disproportionately lower than other groups (U.S. Commission on Civil Rights, 2018). In addition to underfunded programs, the inconsistency of grant allocations to Tribal nations not only from year to year, but from one administration to the next, make it difficult for tribes to develop long-term programs (National Congress of American Indians, 2016; U.S. Commission on Civil Rights, 2018). Some of the barriers begin with inadequate access to information about funding opportunities all the way to limited internal capacity to management grants. Other constraints in successfully securing grants included short funding cycles, unrealistic requirements for matching funds or direct funds, and unrelentless competition for already small pools of funds. The inequities in funding resource allocations are exacerbated when information and data gaps persist from the lack of health data, making it difficult for tribal nations to effectively show their needs.

The Akiak Native Community (ANC) has a population of ∼442 people and is located on the west bank of the Kuskokwim River, on the Yukon–Kuskokwim Delta of Alaska. The Kuskokwim River flows past Akiak and other Alaska Native villages, including Nikoli, McGrath, Stony River, Sleetmute, Red Devil, Crooked Creek, Napamiut, Chauthbaluk, Aniak, Upper and Lower Kalskag, Tuluksak, Akiak, Akiachak, Kwethluk, Bethel, Napaskiak, Napakiak, Eek, Tuntuliak, Kongiganak, and Kwigillgnok. Historically, as the many fishing camps along the riverbanks attest, the Kuskokwim River has nourished the tribal communities as the primary source for water and habitat. The ANC has a unicameral governance system with key decisions being made by the Tribal Council. That council has responsibility for the tribe and negotiates with federal, state and local governments, and with the councils or governments of other tribes. While all issues related to the well-being of the community are addressed by the Tribal Council, issues related to water access and quality have been a growing concern for the ANC's governmental group. In step with the mission of the ANC, that group strives to promote community harmony with each other, their land and their environment by using and protecting its natural resources for fish and wildlife for food and clothing

The ANC community is remote, which means its subsistence way of life is not possible without clean water from the Kuskokwim River. The Kuskokwim is 702 miles (1,130 km) long and is the ninth largest river in the United States by average discharge volume (Kammerer, 1987). Subsistence fishing for salmon and whitefish has been a staple resource for many communities along the river within the watershed. Unfortunately, past mercury mining activities upstream of the ANC, as well as a recently initiated open pit gold mining project, may be negatively impacting the river. In addition to these mining activities, a new natural gas pipeline and power plant have been constructed upstream of the ANC. These developments in the watershed have led to concerns that the Kuskokwim River's water quality may be compromised, with particular fears related to heavy metal contamination that can accumulate within humans over time. To date, comprehensive water quality assessments to determine if upstream activities are in fact influencing downstream water quality have not yet occurred.

Like other rural tribal communities, concerns about water security have led individuals to seek out an array of solutions to maintain access to clean drinking water. Within Akiak (∼80 homes in the village), as of this writing, there are about 10 homes that do not have running water. Many homes in the village have set up private water collection systems because access to water distribution systems such as wells or the water treatment plant are not universal. In addition to harvesting water from the Kuskokwim River, there is also a tradition of melting snow and ice for home use. People also buy bottled water from the community store as needed, but these reserves often run low during emergencies. Many elders within the ANC prefer the river water to the tap water because they perceive the tap water to have a bad taste and well water tends to have a strong iron taste and color. This perception is in relation to how water has been gathered and consumed prior to the establishment of the ANC's treatment plant. Water usage by the community also includes cultural uses, bathing, gardening and farming, food preparation, cooking, washing dishes, washing clothes, and saunas (i.e., locally called steams) owned by families but also used by community members. Water is further used at fish camps, workshops, and other outbuildings within the community.

While there is general consensus that thoughtful tribal community, academic, and non-profit collaborations can enhance the provision of much-needed human resources and services to communities (e.g., clean water), actual collaborative examples serving as evidence-based practice models currently are poorly represented within the peer-reviewed literature (Rogge and Rocha, 2004; Jones et al., 2007; Allen-Meares, 2008). This is problematic because as tribal communities increasingly work with non-tribal partners to address complex environmental and human health challenges, such models can help collaborators respectfully engage in a deliberate process to explore issues that are important to tribal communities. Collaborations that work to coalesce a broad range of expertise while centering Tribal sovereignty and self-determination are critical. All too often the power structures of multi-institutional collaborations tend to minimize the expertise within the community in favor or western colonial practices. Thus, efforts that work to acknowledge the vast knowledge, expertise and decision making powers that are held at the community and tribal governance levels can model best practices for these collaborations.

In this paper, we will describe the co-planning process that resulted in a rainwater harvesting system for the ANC. First, we describe how the core objectives of the project were identified and defined by the collaborating partners. Second, we identify and describe the steps involved in the co-design planning process employed by the ANC and collaborators. Third, we delve into the specific challenges and solutions addressed while planning the water harvesting system within the remote Alaskan community. Fourth, we conclude by describing the next steps for the ANC water cistern project and provide some reflections on the process outcomes to date. Our focus in this manuscript is on the collaborative design process but a complete rainwater harvesting system was successfully installed in the Summer of 2022. While we believe this co-design model can be widely applied to promote many different types of culturally appropriate research design projects, enough logistical information is presented here to aid other tribal and non-tribal partners interested in addressing their own communities' water security concerns with rainwater harvesting systems. A novel conceptual model is also presented, detailing the different steps involved in the co-design process (Figure 1).

2. Methodology

2.1. Project genesis

A unique aspect of this partnership was the requirement to acknowledge and honor the Tribal sovereignty of the ANC by centering their governmental status. The ANC is a federally recognized tribe, meaning they are recognized as a sovereign tribal government or nation under the United States Constitution (Bureau of Indian Affairs, 2022). Therefore, from the beginning of this project, the ANC asserted their authority to self-govern, and in this research partnership, their authority was incorporated into all decision-making steps. Furthermore, as non-Akiak Native Community partners were incorporated into the project, those collaborators needed to honor the community's Tribal sovereignty with an upfront understanding that upon completion of the project, the water system would ultimately be owned, managed, and sustained by the ANC.

Truly collaborative endeavors between individuals or organizations can result in partnerships that meet a common mission or facilitate collective planning beyond the capacity of any singular partner (Perrault et al., 2011). When collaborators bring together distinct resources and commit to building a partnership, genuine collaboration can be actualized, increasing the likelihood that the relationship and outcomes will be successful (Giffords and Calderon, 2015). Benson et al. (2000) assert that thoughtful collaborations can identify and solve a wide range of community challenges such as poverty, environmental degradation, hunger, or urban crises issues. Moreover, evidence-based models with positive collaborative outcomes have increasingly emphasized that all partners must benefit from the partnership, avoiding a one-sided or exploitative dynamic that can inadvertently manifest as collaborations progress (Bringle and Hatcher, 2002). Barriers associated with collaborating effectively have been well-documented (Cherry and Shefner, 2004; Ostrander and Chapin-Hogue, 2011) but we assert that tribal and non-tribal collaborations may pose some unique challenges. For example, when academics or non-profit organizations approach tribal communities with a pre-defined idea of a challenge or issue, the partnership could already be strained due to assumptions related to the communities' needs and values. By aligning methodological approaches with Indigenous planning, and by incorporating Indigenous knowledge systems, a greater level of trust and partnership among all parties will be promoted throughout the collaborative effort. Traditional Knowledge is the total understanding by Indigenous people of their relationship to the earth and the universe, and the knowledge inherent within that relationship. This knowledge includes the spiritual, physical, emotional, and mental aspects of a person and related components of the earth and universe to these aspects (Barnhardt, 2005; Hill, 2015). Therefore, taking time to build relationships before defining the aim of a collaborative effort is an essential first step in avoiding miscommunications and exploitative practices.

While research emphasizing true codesign approaches between interdisciplinary collaborators is still an emerging field of study (Phillipson et al., 2009; Lowe et al., 2013), such methodologies are unequivocally needed for projects associated with water security and watershed conservation (Sivapalan et al., 2012; Rusca and Baldassarre, 2019). As noted by Krueger et al. (2016), when collaborators work on complex water related issues their differing philosophies, methodologies and vocabularies can create communication challenges and become excessively time consuming. Particularly at the project genesis stage of an emerging collaborative effort, Ansell and Van Blerk (2005), Rangecroft et al. (2021) and other groups (Wellcome Trust, 2014) have identified three guiding principles that can promote the establishment of

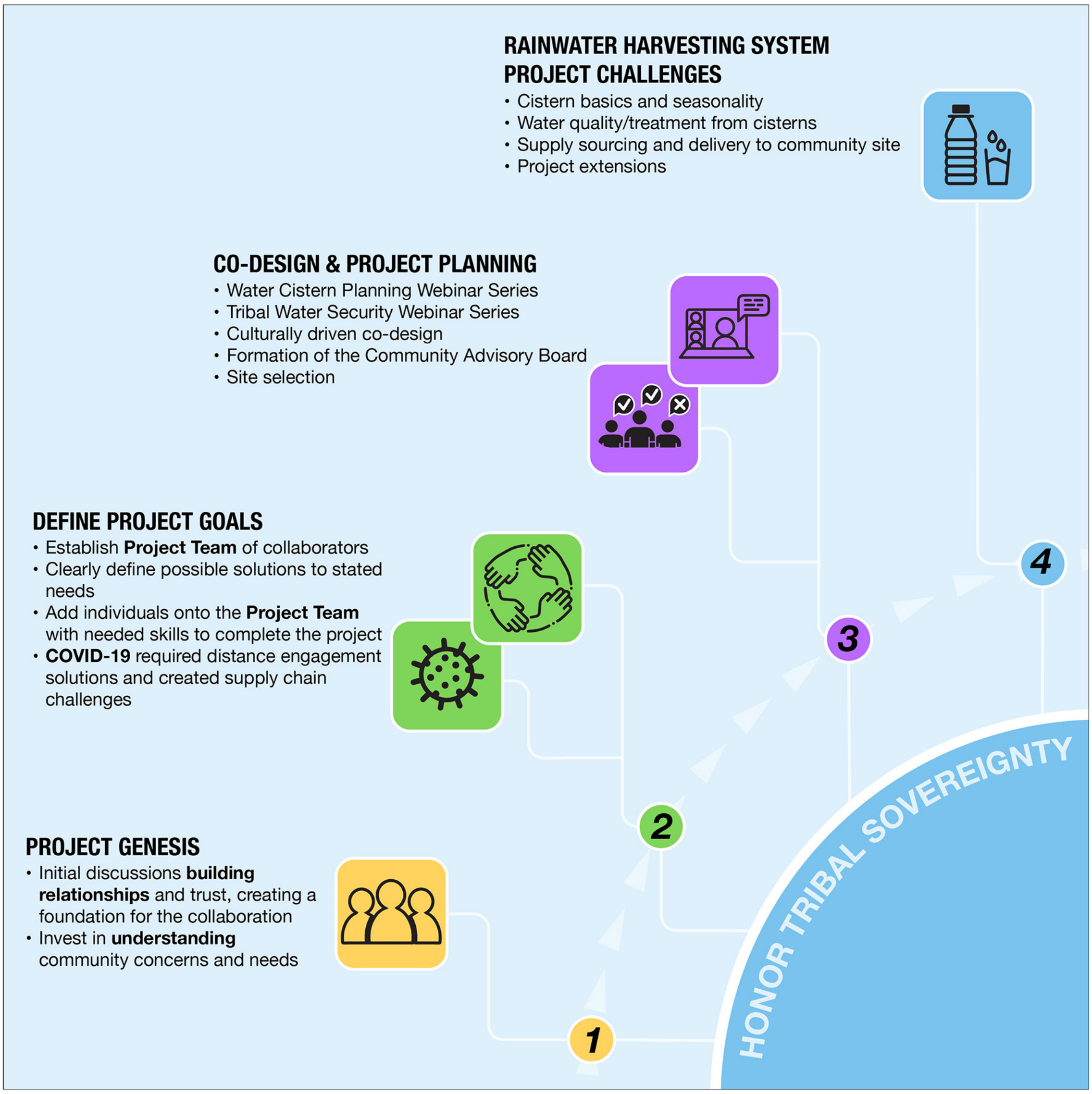

FIGURE 1
A conceptual model for our community co-design project. The steps in this model guided the co-design process for the Akiak Native Community water cistern system. This model emphasizes that early dialog and relationship building between partners is essential before specific design or project elements are determined. Conceptual model by Thomas Pool and figure by Jocine Velasco.

a good ethical partnership: respect for individuals; acting in people's best interests; and being fair. To engage in such ethical collaborations, we assert that those principles must be applied at the earliest possible stages of an emerging community partnership.

In our case, an existing community partnership between academic and tribal individuals was strengthened during an ANC meeting in February of 2020 when concerns were expressed about the Kuskokwim River water quality. Dr. Lefthand-Begay from the University of Washington had already been working with the ANC on a previous project, affording her the opportunity to speak candidly with community members about local issues and challenges important to them. Upstream mining of a closed arsenic mine was voiced as a potential threat to the Kuskokwim River water quality but larger concerns associated with water accessibility in the wake of climate change were also voiced. That dialog between Dr. Lefthand-Begay and ANC members about water security concerns solidified that issue as a focal point for collaborative efforts moving forward. This process of genuine and respectful discussion focused on the communities' human health and environmental concerns as the first step of the collaborative process.

As previously noted, we believe that when community partners are not involved early in defining the direction of a collaborative project with non-community partners, negative project outcomes and cultural misunderstandings are likely to occur. With this project, Chief Williams's partnership with Dr. Lefthand-Begay provided an essential foundation to genuinely begin defining the scope of the project. As a trusted and respected member of the ANC community, Chief Williams was able to clearly share the community's concerns associated with the Kuskokwim River's water quality and brought tremendous energy to the partnership with Dr. Lefthand-Begay. Importantly, gaining an appreciation of the needs and concerns of the community were discussed at this stage without an emphasis on specific solutions or project scope. We assert that these early conversations between collaborators effectively created a project partnership that was solidly in agreement with the cultural values and concerns of the ANC.

2.2. Project goals

Initiated by the ANC leadership, early discussions led to brainstorming viable solutions to ensure water security for the tribe. The project team of collaborators at that time (Chief Mike Williams, Tribal Council members, and Lefthand-Begay), provided the momentum to move forward and define the scope of the project. This project team provided the foundation for collaborative dialog, fundraising, and consensus building within the ANC. In early discussions with core project team members, rainwater harvesting systems were identified as a viable option for the focus of the project. Many individuals within the community already utilize home cisterns for personal water use, and several families have spent countless generations collecting rainwater at their fish camps, but added capacity and access to rainwater with a large-scale cistern system was identified as a desired source of clean water that could benefit the whole community. This project direction was articulated primarily by ANC members, not project team collaborators from outside the community. More specifically, Dr. Lefthand-Begay provided valuable input as a water quality researcher but did not push rainwater harvesting as a water security solution for that community. ANC members like Chief Williams provided the vision for defining the water security challenge and the first steps toward a partial solution to the issue.

Notably, the scope of the project was not designed to completely address all water security concerns for the ANC. Unrealistic goals for community driven co-design projects can ultimately erode that community's confidence in collaborators when the project does not meet expectations or the project is left incomplete (Strier, 2014). Thus, a few large capacity cisterns with easy public access were identified as an achievable goal for the ANC project. Such a water harvesting system would support drinking water needs, household demands, and other community uses with the capacity to withstand the extreme weather conditions in Akiak, Alaska. Once the project team clearly defined that primary goal, additional folks including academics, a water harvesting expert, and green infrastructure specialists were asked to be part of the project team.

At this stage in the codesign process, considerable effort was made to avoid including extraneous tasks or discussion of topics that were not of interest to the ANC. For example, while some of the academics involved in the project have been involved in discussions defining topics such as water justice and water security, the group of collaborators at this point focused more on the logistics of how this project could benefit the community instead of creating shared definitions of terminology. For example, creating a water resource that was equally accessible to all community members occurred organically without a specific need to clearly define a shared understanding of water justice amongst collaborators. In this way, we minimized the time demand on all the collaborators for the project.

In the early stages of this project, the burgeoning COVID-19 pandemic profoundly transformed how collaborators could interact with each other, as well as the team's initial timeline. In fact, once the pandemic began, all members of the community were asked to quarantine themselves in their own homes. Thus, in-person meetings with collaborators were simply not possible to communicate project information. Given that this is a rural community, the development was even more significant because private home access to the internet was not common at the time. The community center and the school are the buildings with the most reliable access to the internet, but, because of community-wide closures, group meetings at those locations were not possible. The following design planning steps were modified to keep lines of communication open between collaborators while observing approved public health standards during the pandemic. However, we assert that our co-design case study demonstrates how resilient and adaptive this process can be when all parties remain invested in the success of the project.

2.3. Co-design project planning

After the project team determined that a cistern water harvesting system could address some of the ANC's water security concerns, the team began to follow an iterative research process as the project progressed. This involved regularly consulting with Akiak leadership and community members to gain broad and stepwise approval of the proposed work, which was done by holding frequent meetings with Chief Williams and presenting to the Tribal Council. During these presentations, major decisions were reviewed and discussed by tribal leadership, and with consensus from the Tribal Council the team was allowed to move forward in implementing such decisions. Indigenous Research Methodology principles were used during this process including respect, responsibility, reciprocity, and relationship building (Wilson, 2008). Our project team met weekly to discuss potential designs, recruit ANC members to help identify site locations, and envision how to bring an intergenerational community together to help build, maintain, and monitor the cisterns within their community. In addition to the weekly meetings, two overarching webinar series were scheduled by the team. The objectives for each webinar series were unique but they were both designed to share project ideas with the ANC community, providing them with information about the water project while simultaneously soliciting their input on how the project should proceed.

2.3.1. Water cistern planning webinar series

To engage as many ANC members as possible, our team scheduled a Water Cistern Planning Webinar Series featuring three webinars designed to exchange information and ideas between the core project team and the broader Akiak community. Chief Williams, the Tribal Council, and other community members publicized the event and distributed a flyer in the community. Webinar #1 was held on October 23, 2020. During the webinar, the overall project goal to develop a water harvesting system was reviewed by participants. Each phase of the project was proposed, and the community was invited to actively participate in the planning process. Furthermore, community members were invited to contribute their knowledge, skills, and abilities. To ensure the direction of the project was in-step with the ANC priorities, a plan of action was drafted by our team based on the comments by the community to be presented at later meetings for feedback and refinement.

Webinar #2 was initially suspended because COVID-19 pandemic restrictions made it impossible to meet in-person or online with ANC members. However, when the ANC's vaccination campaign began in January 2021, along with lower reported COVID-19 cases, it became possible for our team to resume. Webinar #2 focused on describing a range of cistern types for the ANC to consider and practical site locations were discussed. Next, the project team began generating a deeper understanding of how the community might use the cisterns to gather water by engaging participants in a set of open-ended questions. Such questions included these four:

- Where would be the best place for a community cistern?
- How do you imagine using this water?
- How might you transport this water from the cistern to your home?
- What kind of containers do you think you might use to carry water?
- How often would you use the water?

From those discussions, four target sites were identified that were selected because they were accessible to the community, had an adequately sized roof to capture water, located in an area that would be possible to maintain, and were near buildings frequently visited by the community (Figure 2). Once these sites were identified, the project team began conceptualizing a design to guide additional community discussions.

Webinar #3 focused primarily on a digital site assessment. Acknowledging the ongoing travel restrictions, what normally would have been an in-person site assessment was adapted to present a stepwise process for community members to carry out a site assessment. We asked ANC partners to provide measurements, describe the condition of existing structures (e.g., gutters and downspouts), and their ease of driving or walking up to collect water at the proposed cistern. During this webinar, a *Site Assessment Worksheet for the Akiak Native Community* was distributed, and community members were asked to take digital photos (using their own cell phones) of the sites and buildings. This allowed the project team and community to confirm the best locations to install a cistern.

2.3.2. Tribal water security webinar series

While the initial Water Cistern Planning Webinar Series focused on specific planning steps involved in the project for the ANC, a Tribal Water Security Webinar Series was designed to more broadly provide a forum for sharing and generating knowledge about various aspects of rainwater harvesting. These webinars were designed to bring awareness and give voice to Indigenous communities' concerns around water justice and the water-related issues currently in need of sustained attention and action, but the primary focus of this webinar series was to establish a space for community members to learn how to mitigate some of these issues. Meaningful community-level engagement ensured that the ANC and other Indigenous communities had the necessary knowledge to integrate rainwater harvesting practices into their individual and collective lives in ways that address their immediate needs and align with cultural practices.

The Tribal Water Security Webinar series is based on the ANC's information needs and practices. While there may be meaningful similarities between the ANC and other Indigenous communities, each community has their own intentions and realities which must be met, and these must be taken seriously when managing the logistics of planning a webinar based on its intended audience. When developing this webinar series, the logistics were informed by community informatics, a practice-based approach to the use of information and communication technologies to support communities with intentions of strengthening existing practices. As an approach, community informatics advocates for participatory design of technological interventions and the adoption of technologies that are based on the needs of their intended users.

The first step was to obtain the ANC's permission to plan a webinar series, as this ensured it had the community's support. To accomplish this, webinar series planners attended weekly project meetings and proposed ideas for the series to ANC community members, whose responses shaped how the webinar series was planned. Developing a clear understanding of internet accessibility in Akiak was equally important as a first step; knowing how community members would be able to access the webinar series was useful in later-step planning, as this helped us determine ways to ensure that the webinar series was as accessible as possible.

Digital spaces can be useful for Indigenous communities because they offer alternative approaches for communicating cultural practices and transferring cultural knowledge. That being said, however, these spaces can also cause concern for some Indigenous users, who worry that social media platforms and other digital spaces may be antithetical to their established cultural practices, particularly those relating to information sovereignty. As one attempts to mitigate cultural protocols in online spaces, it is crucial that researchers first obtain permission from the Indigenous community that they are working with during each step of the planning process. Thus, the online meeting site Zoom was used as the primary platform because its video conferencing option has become ubiquitous enough that it is safe to assume most webinar participants have some familiarity with it.

During the process of choosing speakers, the project team regularly consulted additional members of the ANC about topics that they wanted to be discussed in forthcoming webinars. This ongoing conversation provided valuable direction during the planning process, revealing a more detailed understanding of the types of knowledge that would be most relevant to the ANC. The audience's self-described needs were solicited, and individuals were identified to bring into the community who were well-equipped to meet the community's needs. This process of developing

FIGURE 2
Site location selection by Akiak Native Community (ANC). Candidate sites were identified by balancing the accessibility of locations with the logistical demands associated with harvesting large volumes of water. The top four locations that were presented to the ANC for debate included the **(A)** old water treatment plant, **(B)** back of the general store, **(C)** general store, and **(D)** school. Figure by Thomas Pool.

and maintaining a relationship with as many ANC members as possible throughout the entire process of planning the webinar series is aligned with Shawn Wilson's description of *relational accountability*, which holds that all participants maintain respectful, equitable relationships with each other and with the phenomenon that they are working to collectively understand together (Wilson, 2008). With respect to Tribal Water Security Webinar Series, this was achieved by creating the digital space for ideas to be exchanged and by following through on the logistics required to get the sessions in place.

2.3.3. Culturally driven co-design

Effort was made to adhere to culturally appropriate research methodologies as the project progressed, requiring a number of place-based considerations. For example, the team had to consider how the placement of the cistern would encourage or discourage use of the cistern after installation. Thus, the final placement of the system was based on where a majority of individuals were accustomed to gathering on a weekly, if not a daily basis, and if there were any existing physical, political, or cultural barriers that might limit individual access. In addition, seasonal changes were discussed to ensure the Akiak community's water harvesting structure prototypes could withstand outdoor site conditions in the Yukon Kuskokwim Delta of Alaska. Because our team understood that AIAN nations have different cultural practices and protocols surrounding water than many western derived philosophies, throughout the co-design process, the core project team promoted and supported the incorporation of Western and Native methods, materials, and construction of the water harvesting system. Moreover, it was necessary to consider how best to integrate different forms of knowledge and knowledge exchange with care, and to honor the time necessary for that process to take place. This was done by adhering to local decision-making processes, listening to local members, creating a space for members and participants to build relationships and following requirements and internal protocols established by the ANC Tribal Council (Barlo et al., 2021). For the ANC such protocols included several requirements. For instance, during the planning phase, the project team provided written summaries and reports, presented quarterly updates to the Tribal Council, and received approval from the Chief of the ANC and/or Tribal Council for each step taken. This ensured our team honored Tribal sovereignty and self-determination of the ANC and harmonized our approach with Indigenous research methodology approaches (Wilson, 2008; Barlo et al., 2021).

2.3.4. Formation of the community advisory board

A gap in our initial co-design planning process was the lack of frequent local participation and voice. Though key tribal leadership laid the groundwork and shaped each step, the project team often looked to community leaders to help with more specific tasks. Furthermore, the non-Akiak Native Community project team members did not want to create an overly cumbersome workload for tribal partners interested in helping with the project while simultaneously maintaining numerous other personal and professional obligations. Therefore, a Community Advisory Board (CAB) was formed to help guide the direction of this work. In addition, CAB members were asked to catalyze the project by fueling our collaborative work with their energy, ensuring the university team approached our work in a culturally appropriate manner, and by holding our team accountable to following cultural and community specific protocols. Invitations to be on the CAB were extended to community members that had previously expressed an interest in the project (i.e., attended a project meeting or had spoken with Chief Williams or Dr. Lefthand-Begay) but were not formally involved in the process until that time.

When members of the CAB joined, they were asked to attend our weekly digital team meetings, help lead key decisions, and carry out specific tasks such as distribute flyers locally, recruit other members, take measurements or photos, and help plan subsequent meetings. Because of the remote nature of the ANC, it was not always possible for the CAB members to participate in every meeting. The availability of CAB members, especially in the summer and fall months, was largely determined by their subsistence schedules, limited broadband, and cell phone access. CAB members were modestly compensated for their time. Given that CAB members took on those responsibilities willingly, this created a clear scope of work for ANC members that wanted to help with the project at that level in contrast to more periodic involvement. It is fair to say that without their guidance, the project would not have advanced beyond the first three months. Thus, the CAB was foundational to this work.

As within any collaborative project, power dynamics between participants can emerge potentially stifling full participation or engagement by all parties involved in the work (Resurreccion et al., 2004; Cook, 2013). While formation of the CAB was practically necessary for the success of the ANC project, it served the dual purpose of also formally recognizing the wonderful efforts of many community members that were already involved with the project. Efforts were still made to invite all community members into the water project discussions, but formally empowering members of the CAB reinforced that their perspectives and ideas were valued by the whole project team.

2.3.5. Site selection

Site selection for the water harvesting system was an iterative process requiring input from the ANC members and project team members with cistern construction experience. Issues that needed to be addressed when considering sites ranged from hydro-social dynamics related to community access to technical attributes related to water harvesting area building traits. This was an extremely important decision in the project co-design process because it (1) would determine how accessible the system was to the community and (2) help define who would be responsible for maintenance of it into the future.

Community input was largely solicited during the Water Cistern Planning Webinar Series but additional conversations with community members also assisted with the site selection process. Following the Water Cistern Planning Series webinar #2, the project team identified four potential building sites they believed might be able to harvest enough water for the system (Figure 2). All sites had some form of public access and a large enough roof area to harvest a reasonable amount of water. Initially, satellite imagery was used to determine the approximate roof size in order to select a site, then more accurate measurements were taken on the ground by community members. Narrowing down the selection process to those sites also helped to clearly define the maximum harvesting capacity for the system itself (i.e., how much total water can be in the system at any one time available for community use). Getting broad consensus from the community on the positives and negatives associated with those options was a critical step in the process. Furthermore, having a short list of potential sites was also extremely helpful in grounding the discussion. Ultimately, the cistern site was selected by the project team, including the advisory board, once they had solicited that community feedback.

2.4. Rainwater harvesting system logistics

The logistical components of this work were an important part of the co-design process because many of these decisions were made either by community members, or in collaboration with the larger team. And while the primary goal of the project was to partner with the ANC to develop a water security solution by constructing a community owned water harvesting system, a secondary project goal for many of the project team members was to learn from the co-design design process; with the hope that neighboring tribes with water security concerns could engage in a similar design-build. Thus, the project team chronicled some of the specific issues and challenges that arose during the design process. Multiple aspects of cistern planning and construction are reviewed, highlighting that local community partners, water quality specialists, and rainwater harvesting designers were all needed to bring the water system to fruition for the ANC. While lessons learned in previous sections of this work can be broadly applied to other co-design tribal and nontribal partnership efforts, we include the following water harvesting system logistics to provide other communities with critical content that will help them streamline their design-build process if they choose to replicate the ANC project.

2.4.1. Rainwater harvesting cistern basics

All water harvesting systems consist of three main sections: a catchment area, a conveyance network, and a storage area (Figure 3). The catchment area is where water (rain, snow, or ice) first touches the water harvesting system. The conveyance network is where the water moves from where it is collected to where it will be stored. The storage area includes the container of collected water and the surrounding site where the container is placed. Additionally, for drinking water systems, a water filtration or purification system can be added to the system to deactivate viruses, bacteria, protozoa, and other microorganisms. Otherwise, the water must be boiled before use for drinking water or household uses such as brushing teeth etc.

Given that many ANC families have intergenerationally collected or harvested water for drinking and other uses, this project was designed to support the ANC's goal to reconnect with intergenerational ways of gathering water to supplement their drinking water supplied by existing centralized piped water systems. So when considering ways to build on their existing practices, the team drew on some key resources that focus on a Western method of water harvesting in cold climates such as the

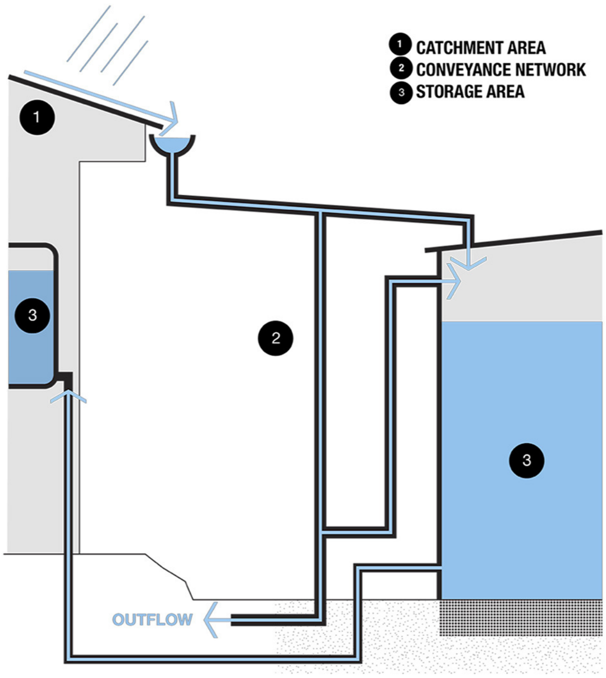

FIGURE 3
Diagram of an above-ground water harvesting system showing its three main sections. Regardless of site-specific variation in water system plumbing, these three basic elements are typically part of any roof-based harvesting system. Figure by Jocine Velasco.

document, *Water Cistern Construction for Small Houses: Alaska Building Series* (Cooperative Extension Services, 2008). Another resource was the handbook, *Alberta Guidelines for Residential Rainwater Harvesting Systems* (Despins, 2010). Although as a team, our co-design process was informed by these examples of rainwater cistern literature, we worked with community members to center and implement their knowledge alongside this literature. Our approach to honor an array of knowledge systems, and center ANC water knowledge, was only possible by creating the space and time to hear the input, reflections and criticisms offered to the team by the project's CAB, Tribal Council and other key leaders in the community.

When our team tapped into this literature and began to share these Western processes with the community, the uneven access the ANC has to such literature at the community level was notable. Though the community has a robust workforce including plumbers, electricians, carpenters, teachers, administer leaders, etc., anyone interested in seeking literature about sustainable water infrastructures, including cistern planning, building and implementation, would find access challenging, despite the community's prioritization to secure consistent, safe drinking water throughout the year. The local library is housed in the elementary school, which serves the intellectual growth of K-12 students, not ANC as a whole. Therefore, community members who wish to access such literature would have to find other avenues to access such literature and would have to absorb the cost of buying such resources. Lastly, the suggestions from these documents needed to be adapted to fit the needs, strengths, capacities, and realities of ANC members. With that being said, high-quality, non-leaching materials were preferred whenever possible for their environmental and public health benefits and their longevity. Such adaptations were necessary to meet the local conditions of the ANC. To help meet the information gap described here, hard copies of this literature were printed out and given to the ANC for troubleshooting water harvesting systems issues. Such logistical challenges must be considered for neighboring communities who might want to take on similar research and work.

For this project, ANC members were hired to install a gutter system along as much of the roof's edge as possible in order to maximize the catchment area's water harvesting potential. The rooftops were the primary catchment area for rainwater and melting snow collection. To decrease plant materials that decompose and settle in the collected water, the project team avoided roof surfaces under trees or overhanging vegetation. One member of the community, who was recruited by advisory board members, brought expertise in plumbing and carpentry, and took on the responsibility of hiring others to support this step. The installation of the gutter system was the first engagement our team had with local paid experts, and if not for these internal experts, the installation process would have been much slower, if not impossible. Thus, the CAB and local experts were key in getting these major steps completed.

Due to the remote location of the ANC and COVID-19 travel restrictions, our academic team had to establish clear communication with the community experts and community team members. Such communication took place through the webinars described above, weekly team meetings, and occasional follow up phone conversations. In these conversations, photos and sketches were used to communicate across groups. For instance, our team described how the gutter system and conveyance network would be assembled. Specifically, attached to one end of the gutter system, the conveyance network consists of a downspout that connects a pipe system serving multiple functions. That system manages direct water into a filtration system, direct water into the storage area, and drain excess overflow when the storage tank is full. We also provided basic steps to the water harvesting system construction, including:

1. Calculate estimated collected water quantity for a given roof. Single family homes, as well as large community buildings such as the school or the ANC building, can be utilized to have additional water collection potential.
2. Acquire the storage tank(s). A tank can be many things including a clean, used 55-gallon barrel (food-grade), a leak-proof shipping container, or a tank cast from concrete. Install a spigot and overflow valves on the storage tank.
3. Optionally, clean the rooftop and install wires to prevent birds from landing on the roof. Bird droppings are common water harvesting pollutants.
4. Purchase supplies and construct the conveyance network. The gutter system should either be covered with a screen or should connect to a commercial filtration device.
5. Level and construct the storage tank area. Secure the storage tank and redirect water downhill and/or away from the building's foundation in case of overflow and leaks.

6. Decide, purchase, and construct a sediment and contaminant filtration system depending on water use.
7. Optionally, construct and connect to an additional storage tank inside the building for ease of use.
8. Inspect for leaks and disconnected parts and replace damaged equipment. Decommission a water harvesting system by draining it completely when not in use to prevent stagnant water and ice that can damage parts.

2.4.2. Cistern seasonality

One main consideration for a rainwater harvesting system in Alaska includes determining if the collection tank will be used exclusively in the spring, summer, fall or year-round. As our team moved the project along, this became a central question from ANC leaders and members. This clearly determines the cost, frequency of maintenance, usability and scalability of the prototypes chosen. Insulation and temperature-regulating supplies will be necessary for year-round water harvesting systems in Akiak. Year-round cisterns are further divided into two types: above-ground temperature controlled and below-ground cisterns. Additionally, prolonged freezing temperatures can damage exposed pipes, valves, and filters if such parts are not properly insulated. The size and shape of cisterns are to be determined based on those variables as well as the cost and the desired water quantity being collected. Because some buildings are heated with wood stoves in Akiak, soot is reported by ANC tribal members to be an issue for taste and overall quality associated with existing water harvesting systems in the community. However, existing rainwater harvesting systems in the ANC vary in quality and complexity, including some makeshift systems that consist of a plastic bag over a cylindrical container without a lid. Such a system is vulnerable to settling compounds from local burns. In this project, the type of filtration system added into the cistern plumbing will determine the quality of water collected and its use by the ANC. Furthermore, the cistern will consist of a cover to keep out settling soot.

Rainwater harvesting in remote Alaska presents very specific challenges that need to be addressed. Using local knowledge, experience, and expertise we developed a 2-part plan to be implemented in phases. The small spigot and connection assemblies on the bottoms of the tanks are extremely vulnerable to prolonged freezing temperatures. These fittings have been equipped with insulative foam to protect during the colder season. Additionally, for this phase as the freezing begins, and at the first cistern maintenance session, all water will be drained out of these fittings to help mitigate damage. During this first winter, the community will be supplied with backup fittings in case damage is to occur during the beginning stages, to be used in the subsequent spring. Furthermore, the pump and filtration and purification devices are mounted inside an insulated pump house to protect them from freezing.

The capacity of these cisterns and roof collection area makes it possible to extend the season of this system into the winter. Using local expertise and experience in phase 2, a simple insulated structure could be built around the cisterns. In addition to the insulation, the new structure could be passively heated by waste heat from adjacent buildings. This would allow for available rainwater into the winter. This first phase of construction can thus be implemented with the intention of modifying cisterns at a later date to be year-round sources of water. The cistern itself has the potential to be insulated by either enclosing the planned roof structure or with an insulative wrap. At this time the cistern will undergo a winterizing process including disconnecting susceptible fittings and ensuring the cistern water has been used before deep freeze sets in. Not all installations need to be planned for year-round use, yet this process allows communities to upgrade from a seasonal use system if they so choose, following the initial construction of the cistern.

2.4.3. Water quality/treatment from cistern

Most roofs in Alaska, including in the ANC, are ideal to harvest water from as they are all metal. This prevents bacteria from becoming trapped in porous spaces and contaminating the water. For the ANC system, because the portability and safety of the system was a high priority among advisory board members, the system was designed with a three-step filtration and purification process. In order from downspout to point of use, the main components of this process included: (1) WISY Sediment filter – This component is meant to be installed just after the downspout, but before the cistern. The purpose served by this filter is a centrifugal pre-filtration process that separates larger sediment and particles that are washed down from the roof and gutters. With larger solids removed at this level, raw rainwater can then move through the system and be stored nearly sediment free in the cistern. (2) VIQUA Sediment and Carbon Block Lead Reduction – This component is meant to be installed after the cistern (opposite from the WISY Sediment Filter), and closer to the point-of-use spout, but before the UV Purification filter described next. These prefilters remove additional sediment, grit, sand, rust, dirt, chlorine, lead and other organics that might affect taste, odor, and color. (3) VIQUA UV Filter—The last component is meant to be installed after the sediment filters in step two and before the point-of-use spout. This UV filtration process is designed to remove granular particles that were too small to remove in previous steps. This step is coupled with UV disinfection that deactivates the DNA and RNA replication pathways in pathogens such as viruses, bacteria and protozoa found in fecally contaminated water. This step deems most pathogens unable to replicate and unable to cause illness in humans. Another option for the future systems, depending on performance of the original filtration system, is a first flush diverter which aids in separating the first rain to rinse the roof in case it contains harmful bacteria from bird droppings during a dry spell.

The rainwater harvested will have many uses other than potable water including washing, food production, flushing etc. Once completely installed, this rainwater capture and disinfection system will have been installed in such a way that allows for future additions of a UV filter and pump assembly. In addition to the pre-filters, the ANC system will have a Berkey water filter for emergency use only. This is a post collection treatment method tested to have at least a 99.99% success rate in removing bacteria and viruses.

2.4.4. Supply sourcing and delivery to the site

The sourcing and installation of a rainwater cistern for most households located in the contiguous US is relatively feasible. However, with the remote nature of this village, and the limited transportation and barge options, one of the most time-consuming and resource demanding aspects of this project was the sourcing of materials and shipping to the remote village of Akiak. Due to temporary closures of several businesses associated with COVID-19, materials were tough to procure. Furthermore, as the ANC is accessible in summer by only river or by plane, the delay in barge schedules, and delivery of all items had to be planned carefully. The cisterns, pipe, fittings, straps and Versagrid for the base construction were purchased in the Northwestern part of the US and delivered to Akiak by a barge service near the Port of Seattle. Those materials were shipped *via* multiple boats and waterways to Akiak. The remaining base material included locally sourced sand from the community supply. The task of sourcing parts for this remote location illustrates the challenges that make achieving water equity difficult. Therefore, we emphasize here the need for more focused care for those planning to purchase and deliver products from the lower 48.

With the difficulty of shipping items to Akiak, several items were sourced closer to site location, shipped by mail, or carried in person by a team member from Washington. For instance, the spigot assembly and other small plumbing parts as well as a few hand tools were mailed to Akiak by team members. The remaining smaller items such as hand tools, solvents, and miscellaneous goods were also mailed to Akiak. Some tools and shovels were borrowed from the local community. Gutters were sourced from a nearby store in Bethel called Swansons True Value. Though this was a challenging project to locate materials for with ease, the iterative design provided the flexibility needed as we began sourcing. Allowing for a flexible design and timeline was crucial to the project's success.

2.4.5. Project extensions

We have outlined the collaborative process leading up to the construction of the water cistern system. Upon completion of the system within the ANC, we will continue the collaboration *via* a few project extensions. First, a Rainwater Harvesting Guidebook will be written with information on designing and building similar water harvesting systems in other tribal communities. Water security has been a growing concern across communities and this guidebook will highlight some of the logistical challenges and solutions we encountered during the design and build process. Second, we will develop a curriculum in partnership with ANC school teachers that will dovetail with the cistern project. For example, activities describing the water cycle, water quality tests comparing surface water and cistern water, and storytelling activities involving rainwater harvesting have been discussed. Lastly, we will ask for community perspectives on the project *via* surveys to assess the effectiveness of the water harvesting system and general user feedback. We want to determine if the water cistern system is meeting the needs and expectations of the community, giving the team an opportunity to modify the system as needed to better serve the ANC.

3. Conclusions

The primary aim of this co-design project was to improve the ANC's access to clean, safe, and affordable water with the planning of a cistern installation. Our approach considered the importance of building lasting community-university relationships while promoting and honoring local tribal leadership and decision making. It is the hope of our entire team to strengthen this iterative protocol so that it may be applied to adjacent tribal communities who are also striving for water justice. Though a rainwater cistern placed in Alaska may only be able to offer a seasonal solution to water scarcity, it strengthens water security in a culturally sound practice. Our team will thus continue to build our network to seek innovative solutions to this seasonal challenge.

We have outlined the collaborative process leading up to the construction of the water cistern system. Upon completion of the system within the ANC, we will continue the community collaboration. First, a Rainwater Harvesting Guidebook will be written with information on designing and building similar water harvesting systems in other tribal communities. Water security has been a growing concern across communities and this guidebook will highlight some of the logistical challenges and solutions we encountered during the design and building processes. Second, we will develop a curriculum in partnership with ANC school teachers that will dovetail with the cistern project. Activities describing the water cycle, water quality tests comparing surface water and cistern water, and storytelling activities involving rainwater harvesting have been discussed and encouraged by the CAB. Lastly, we will ask for community perspectives on the project *via* surveys to assess the effectiveness of the water harvesting system and general user feedback. We want to determine whether the water cistern system is meeting the needs and expectations of the community, giving the team an opportunity to modify the system as needed to better serve the ANC.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

CL-B and MW originated the concept and coordinated the community-based aspects of the research. TP, JV, CM, PL, and CL-B all contributed to the text and provided input to the structure of this work. TP and JV prepared the figures. CL-B supervised the project and contributed significantly to the text. MW provided final

approval and review of this manuscript on behalf of the ANC Tribal Council. All authors contributed to the article and approved the submitted version.

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Conflict of interest

PL was employed by the company American Rainwater Catchment Systems Association.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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