Kuskokwim River Middle Mile Fiber Technical Feasibility Study
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Executive Summary

Prepared for:
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Rural Utility Service

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Rural Broadband in Alaska

Providing rural users with access to high-speed broadband connectivity is a priority for federal, state and local government organizations. Fiber-optic connectivity continues to be the gold standard for broadband access. Extending fiber-optic cables across long distances is expensive and logistically challenging and Alaska continues to have very remote areas with limited access to broadband. The Kuskokwim River serves as a transportation route and subsistence fishing resource for many communities along its shores. The communities of Aniak, Chuathbaluk and McGrath are home to over 900 residents, all of which currently have no reliable, high-speed terrestrial broadband connectivity. Placement of a fiber cable within the flowing waters of the river represents a potential opportunity to quickly and cost efficiently delivery broadband to communities situated along the river’s edge.

In December 2024 Ayers Telecom Consulting, LLC, in collaboration with Meridian Management Inc and ABR, Inc were awarded a United States Department of Agriculture Broadband Technical Assistance grant to study the feasibility of placing a fiber-optic cable in the flowing waters of the Kuskokwim River. The study was envisioned with the goal of exploring available means, methods and technologies to determine whether construction of a fiber-optic cable for use in the Kuskokwim River is operationally realistic. Construction and operation of fiber-optic cables within arctic rivers is an active topic of discussion within the Alaska telecommunications community and few concrete facts exist demonstrating its long-term feasibility. If feasible, operation of a river-based cable might improve the economic, logistical and administrative challenges associated with delivery of high-speed broadband to rural communities. The benefits of placing a cable within the river corridor must be weighed against unproven operational history and technical risks present in arctic river environments. Recent events on Alaska’s north slope have increased awareness and concern related to cable installation in ice-locked areas. Risk and concern exists relative to ice scouring, applicability of construction and logistics methods, repairability and achievable system availability. The funded study route spans a total of approximately 450 km and includes the communities of Aniak, Chuathbaluk and McGrath, Alaska.

The awarded project scope includes technical evaluation of transmission systems, facilities, cable systems, installation methods, instrumentation and system reliability. In addition to those technical elements, the project also evaluates the impacts on fish habitat and summarizes the permitting and environmental burden. The project is scheduled for completion in January of 2027.

Figure 1. Kuskokwim River fiber-optic cable feasibility study route and communities passed

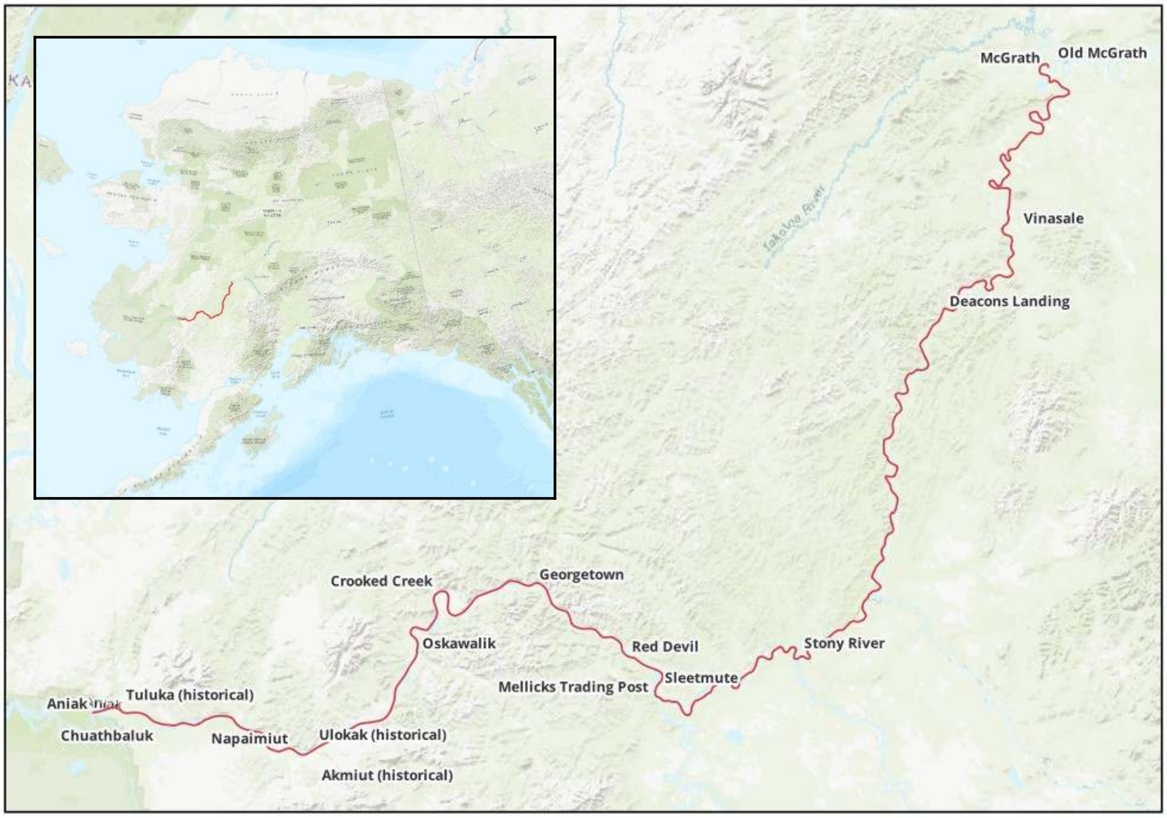


Figure 2. Kuskokwim River from the air

Kuskokwim River Feasibility Study

The study was developed with a two-part mission. The primary objective of the study is to produce objective recommendations which inform future decisions about whether a fiber-optic cable placed in the Kuskokwim River is feasible. Secondarily, the project provides reusable and extensible guidance related to the design and study of fiber placement in other arctic river systems. These objectives are captured through the development of a feasibility study package. In addition to the study deliverables, community outreach and engagement play a significant role in the project.

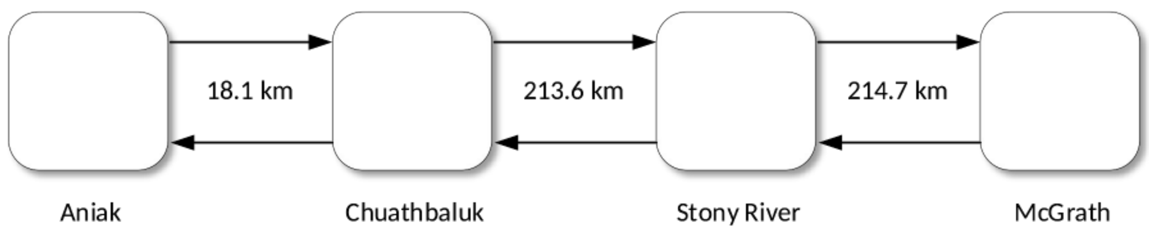
The installation of a fiber optic cable in the Kuskokwim River appears to be tentatively feasible for the portion of the river that lies south of the community of Stony River. Stony River lies approximately halfway between the two endpoint communities of Aniak and McGrath, Alaska. This tentative feasibility is contingent on the completion of follow-on experimental validation work to be performed prior to construction. The installation of a fiber optic cable between Aniak and Stony River should follow a phased, multi-year approach. The study team found a number of results that are important considerations for both this project and other arctic river projects.

- The installation of a fiber optic cable between Aniak and Stony River, Alaska should follow a phased, multi-year approach.
- Construction of a cable between Stony River and Mcgrath does not appear to be cost effective or technically viable.
- The Kuskokwim River is home to all five species of Pacific salmon along with other important fish and mammal species. Construction of a fiber system should account for and incorporate spawning seasons and habitat impacts into the schedule and plan.
- The fiber cable should be placed in the river thalweg and laid on the river bottom using a barge. Fiber construction using other methods such as water jet or plow is cost prohibitive and not feasible.
- Experimental validation of ice jam, ice scour, and cable armor effectiveness is recommended prior to any long-term cable installation. Permanent cable installation plans should incorporate experimental validation of the desktop study findings with the potential result that, following experimental data collection, construction could be determined to not be feasible.
- Instrumentation technology exists that has the potential to provide predictive failure awareness through fiber strand strain measurements.
- System availability simulations predict performance below the nominal 99.8% target level with performance approaching 98% at furthest communities passed (Red Devil, Sleetmute, Stony River).

Submarine systems are adapted to river-based transmission

The telecommunications system design consists of the facilities, power systems, transmission equipment and instrumentation required to provide broadband connectivity within each served community. The design developed as part of this study utilizes modern, high-throughput transmission equipment along with a standard rural telecommunications shelter design to achieve the highest possible system availability. The design mirrors the architecture and technical solutions used in proven festoon-style submarine builds. The network design proposed was developed in conjunction with long-haul fiber-optic transmission equipment industry leader Ciena. The system design utilizes repeater equipment in Aniak, Chuathbaluk and Stony River in order to provide the required optical transmission system power budget. Each served community houses a standalone cable landing shelter facility with generator and battery backup. These shelters house the transmission equipment and local fiber distribution equipment for community broadband. The transmission system design provides an estimated maximum throughput of 400 Tbps using 48 fiber optic strands. The design does not make use of active wet-plant repeaters, all power amplification and signal regeneration occurs onshore. The topology utilizes a daisy-chain design due to the fiber strands all being collapsed within a single cable. The power system utilizes both battery and standby generator backup to ensure uninterrupted power delivery. LiFePO4 batteries are recommended in conjunction with the generator systems to provide uninterrupted power within communities.

Figure 3. Kuskokwim River transmission system required minimum repeater locations



Broadband infrastructure impact on fish habitat

The Kuskokwim River is a critical habitat for many species of fish and aquatic organisms in Alaska. This habitat, along with reliance of local communities on subsistence harvest of fish, increases the importance of fish habitat impact analysis. The project area is home to all five Pacific salmon species as well as Dolly Varden, sheefish, whitefish and marine mammals. The variety of aquatic life species present reinforces the importance of fully evaluating whether the construction and operation of a fiber-optic cable project has the potential to impact the animal habitat in the project area.

Historic mining activity, particularly around the community of Red Devil, in conjunction with increasing water temperatures has increased concern regarding sediment transport of previously frozen metal analytes. Dislodgement or unsettling of latent sediments could lead to sediment transport and contamination. This should be considered when planning shore landings and directional drilling activities as part of the project plan. Installation methods should avoid or minimize the use of plows and water jets to avoid injury to fish and aquatic organisms latent in the riverbed. In addition to the consideration of installation methods, the selection of installation timing is important to minimize fish habitat impact. Construction activities disturbing the water column or riverbed substrate during peak spawning and high flow seasons should examine the impact of those activities and provide mitigations if needed.

Deployment of cable instrumentation to monitor cable strain using BOTDR (Brilluion Optical Time Domain Reflectometry) methods could lead to the availability of distributed riverbed temperature profiles which may be of particular use to fisheries scientists, hydrologists and other researchers.

Including local voices through community outreach

Engaging with local community members and stakeholders is a fundamental element of successful broadband deployment projects in Alaska. The study includes a number of community outreach activities and deliverables that establish best practices for interaction with rural communities and tribal organizations.

Social media, utilizing personal community relationships, and contacting local governmental organizations were all used to identify key stakeholders for the project. The stakeholder process identified a clear pattern that resulted in successful engagement. Village councils and local governments in Aniak, Chuathbaluk and McGrath as well as the Kuskokwim Corporation, MTNT Ltd. (McGrath, Takotna, Nikolai, Telida), Calista and Doyon Limited were all identified as key stakeholders with a variety of interests. Interests include governance and representation, tribal advocacy, and environmental stewardship to economic development and educational growth within the communities.

A project website is available for review by the public. The website includes the project scope, deliverables, and expectations as well as serving as a long-term repository for study findings and content. The project website is located at **http://kuskokwimfiber.com**. Comments, questions and feedback can be sent to the project email address at **info@kuskokwimfiber.com**.

Waterway permitting differs from terrestrial fiber methods

The permitting and administrative approval requirements for placement of a river-laid cable installation within the Kuskokwim River in Alaska are extensive and span federal, state and local jurisdictions. Fiber cable placement in arctic river environments requires the engagement of a knowledgeable specialist with waterway permitting experience. Although similar in form to the permitting requirement for terrestrial cables, waterway cables have distinct and unique requirements that must be met to obtain administrative approval. Regulations include the standard National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA) permitting requirements but also include the Clean Water, Marine Mammals Protection, and Endangered Species Acts. Additional State of Alaska regulations invoke requirements from the Alaska Department of Fish and Game and Department of Natural Resources for approval.

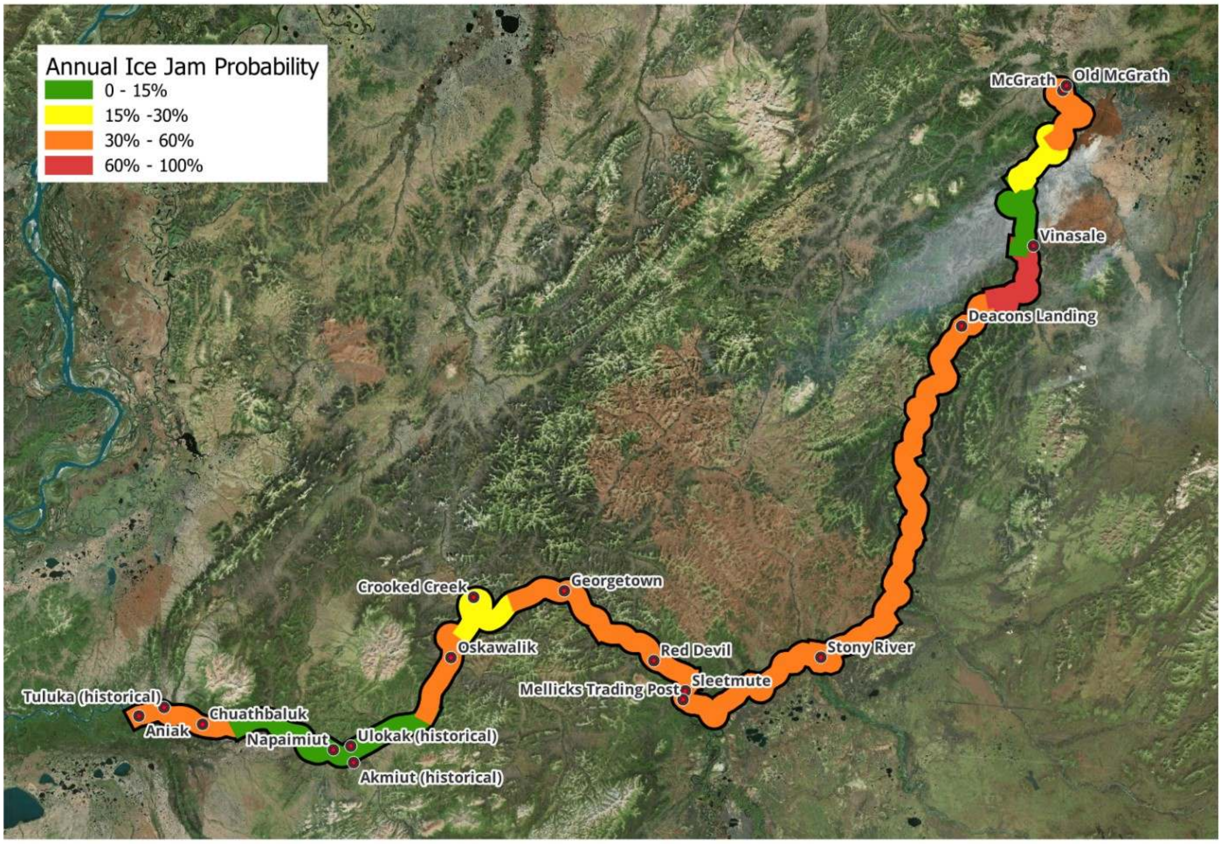
Seasonal ice jams in the Kuskokwim River are everywhere

The successful construction and operation of a fiber-optic cable in the Kuskokwim River relies on the identification and management of risk factors. The study team focused significant energy on the identification and definition of the factors that represented the biggest risks to operational success.

Input from the construction team provided valuable insight which influenced the selection of the recommended fiber cable path. That path, the deepest channel thalweg, balances the construction difficulty, cost and fish habitat constraints. The thalweg route, for the purposes of the desktop analysis, is determined through the examination of Marine Exchange vessel transit data between Aniak and McGrath, Alaska. These route tracks are manually centroid averaged to determine the most likely thalweg channel. The identified thalweg route is used to perform a self-burial assessment and develop an ice jam risk model. The route is analyzed using GIS methods along 25 km reaches. Available academic research suggests that ice jamming events on the river are primarily caused seasonally by the interrelated factors of island / sand bar presence and river constriction. A linear regression model is built and trained using historic ice jam data from the Cold Region Research and Engineering Lab (CRREL). This model generated an annual probability of ice jam prediction for each river reach. The probability of at least one ice jam within the river corridor in a given year is estimated to be approximately 99.98%. The expected (mean) number of jams that occur across all 18 reaches is 6.5 in a single year. For any given reach, the average probability of a jam is 36%. These statistical measures suggest that it is all but certain that a cable placed in the river will be subject to multiple ice jams annually.

Each ice jam that occurs within the river corridor creates a chance for a scouring event. These scouring events, if significant enough to defeat the cable armor, then result in cable breakage. This sequence of events is modeled in the reliability analysis to estimate the lifecycle availability and reliability of a cable system.

Figure 4. Kuskokwim River ice jam linear regression probability model results



Cable installation methods and logistics require careful planning

The goal of the study's construction team is to identify a cost effective, safe and balanced approach to deploy a fiber cable within the river corridor. The method of deployment chosen was selected by comparing the cost of constructing an in-river cable with traditional terrestrial overland construction and permitting methods. This relative comparison method allows the study to establish constructability against a well-known and understood benchmark. Terrestrial construction is considered the superior method of middle-mile fiber deployment but its expense, logistical and administrative challenges cause the river-based approach to be considered in many cases.

Generally accepted riverine installation methods are used in conjunction with submarine techniques adapted for longitudinal river installation. Construction emphasis is placed on reliability and environmental / habitat protection. Installation recommendations are established on a reach-by-reach basis and incorporate changing bathymetry, riverbank conditions, and community proximity. Installation is recommended using a controlled direct-lay with armored cable. Mechanical burial techniques such as water jet or plows are not feasible due to their cost and installation complexity. Increases in cost would drive the installation to match or exceed overland installation methods. Shore approach is designed using horizontal directional drilling

(HDD) equipment capable of a reach of 250 feet beyond the high-water mark on the shore side and reaching into the river thalweg on the river side.

Installation is recommended using a shallow-draft river barge similar to those frequently used for shipping and transport on the Kuskokwim River. Landing craft vessels are also recommended for efficiency and safety during installation. Bowhead Transport has a barge in current operation with the capability to accommodate the materials and equipment required for the project. This barge is 121 feet x 35 feet with 600 tons of capacity and routinely transits the river during open water months. The construction plan provides material staging at three locations; Aniak, Chuathbaluk and Stony River, which are coincident with the location of the transmission equipment and shelters.

Measuring cable strain to proactively detect failures

Successful telecommunications operations rely on proactive monitoring capabilities and rapid-deployment failure resolution methods. To this end, the study reviewed the applicability of BOTDR (Brilluion Optical Time Domain Reflectometry) equipment for installation between communities in order to facilitate the identification of physical cable strain before cable breakage occurs. The presence of observed cable strain is correlated to failure causing physical phenomena in the river such as ice, boulders, trees, etc. Experimental validation of strain measurement to cable failure correlation is part of future, yet unfunded study efforts. BOTDR equipment, through the measurement process, also collects temperature data. Although this data does not possess the precision to predict ice jam formation, it may be of use to fisheries and habitat scientists.

Reliability

System availability is often used as a figure of merit when evaluating the performance of telecommunications systems. Modern broadband connectivity is expected to be error-free and uninterrupted across all applications and user types. Large-scale deployments that involve significant capital investments and operational complexity frequently use predictive availability and reliability models to estimate performance. These models provide investors and operators with confidence that the system can meet operational expectations. To that end, an analysis was performed as part of this study to estimate the availability and reliability performance under the risk and operational constraints identified.

For the purposes of the analysis, a target lifecycle availability of 99.8% was established for the system. This target was used to establish unavailability allocations for transmission equipment, facilities and the cable itself. Using the ice jam model, seasonal ice formation and break-up periods and repairability assumptions a system model was created. This model produced mean time between failures ranging from 5-10 years and mean downtimes of 30-40 days. On an average basis, this achieved availabilities ranged from 99.3% to 98.5% depending on how far the community was upriver from Aniak.

A method for repairing the cable under river ice has been developed that requires experimental validation. This method is used in the repair model.