NAVIGATING THE NEW ARCTIC

Understanding infrastructure risk due to permafrost thaw to inform decision-making in Point Lay, Alaska

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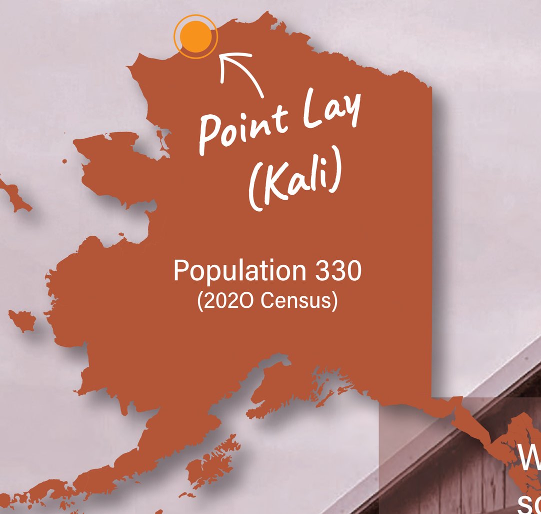
The Native Village of Point Lay (Kali) is located on extremely ice-rich permafrost (yedoma) and has been called "ground zero" for climate change in Northern Alaska. In March 2022, the tribal government of this unincorporated community formally declared a climate emergency. Ice-wedge degradation and thaw subsidence have created major threats to its housing, roads, fresh water supply and sanitation. The growing community is currently in its third location and seeking guidance from permafrost scientists and engineers on whether to consider relocating again. If it does not relocate, it must still identify the most thaw-stable ground to expand the townsite and the best building strategies to mitigate impacts of future subsidence.



Ground subsidence of up to 3 meters has destabilized homes, utility poles, and fire hydrants, and caused frequent breaks in underground water and sewer lines, resulting in multiple health and safety risks. Deep cracks in the terrain, sinkholes and surface water ponding create hazards for tundra travel and for children playing outdoors. These photos show the impacts of ice-wedge thermokarst on two homes. A 2022 survey by the Cold Climate Housing Research Center found about two-thirds of homes with damage due to thaw settlement and 70% affected by ponding.

ENGINEERING SOLUTIONS

While expensive, engineering solutions do exist, but it is important that they be implemented soon and perhaps focused first on sites showing the least advanced stages of ice wedge degradation.

- Inspect each structure to determine the extent and severity of cosmetic and structural damage. These data should be used to determine appropriate mitigation.
- Filling troughs and depressions with fine grained soil will help protect the underlying permafrost and establish drainage throughout the village.
- When constructing new structures, remove the upper portion of the ice wedges and replace the ice with fine grained thaw stable soils.
- Pile embedment should be at least 6 m when placed in thermokarst mounds and at least 9 m when placed in an ice wedge. If practical, avoid placing piles in wedge ice.
- For post and pad foundations, place a 1-to-1.5 m gravel pad beneath the structure in addition to removal of the upper 5 feet of wedge ice. The post/pad connection should allow the pad to remain in full contact with the soil as the soil subsides.
- If the new water/wastewater system is an aboveground system supported on piling, place the piling in thermokarst mounds and make the attachment fixtures adjustable and as flexible as practical.
- Implement an active maintenance program including snow management, drainage, and annual thermokarst monitoring.
- The role of infrastructure in accelerating thermokarst must be taken into account when planning new construction. We presume we would see similar degrees of thermal erosion and thermokarst develop over time if building on the same yedoma terrain with the same methods.

PHOTO: JANA PEIRCE

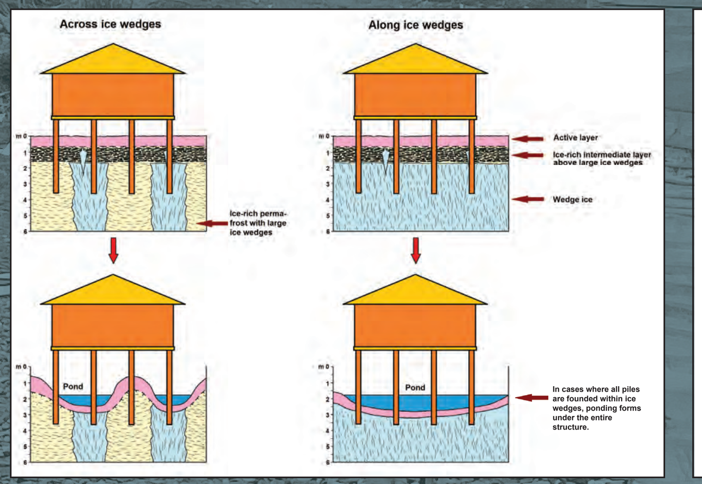
FINDINGS

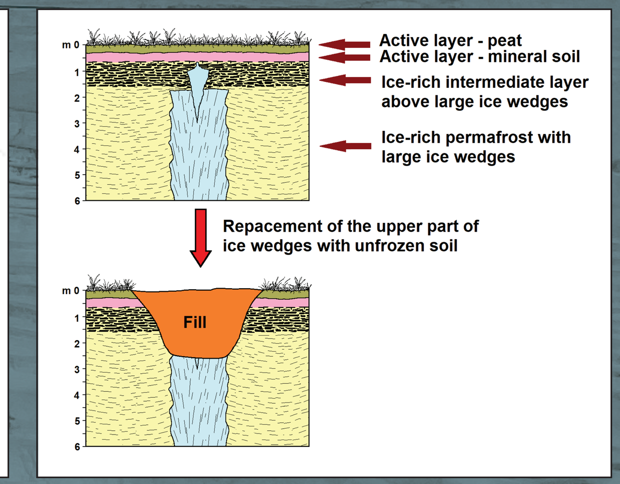
Permafrost cores were taken around the villages to determine the composition of frozen soils and measure the ground-ice content. The permafrost underlying most of the village was classified as yedoma: fine grained, ice rich permafrost penetrated by large syngenetic ice wedges, which in Point Lay extend to slightly below sea level. Wedge-ice content in yedoma may exceed 50% by volume. Based on measurements of excess ground-ice content, we presume that settlement of frozen soils upon thawing will reach nearly 40% of the initial thickness of the ice-rich permafrost, without taking wedge-ice volume into account.

The yedoma terrain appears uniform from north to south, making similar landscape changes in response to climate change and infrastructure likely if the area to the north of town were developed. Most ice wedges in this undeveloped area were encountered within 40 to 80 cm of the ground surface and reached a depth of 10 to 12 m, making them vulnerable to thermokarst and thermal erosion. Ice wedges in the drained thaw lake basins south and east of town are much smaller, with a vertical extent of approximately 3 m and ice content usually not exceeding 15-20%. These low lying areas are more prone to flooding.

PHOTO: BILLY CONNOR

Most piling beneath village housing was originally embedded 10 feet (~3 m). It appears that those piles embedded in ice wedges have as little as 1 m of embedment remaining due to ground subsidence.



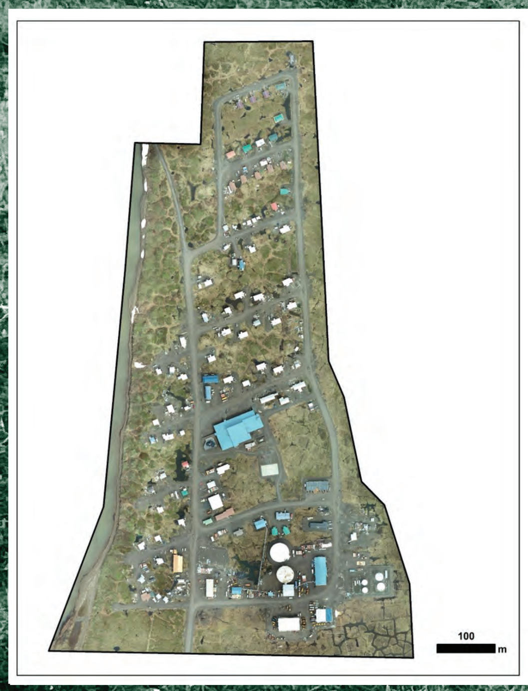


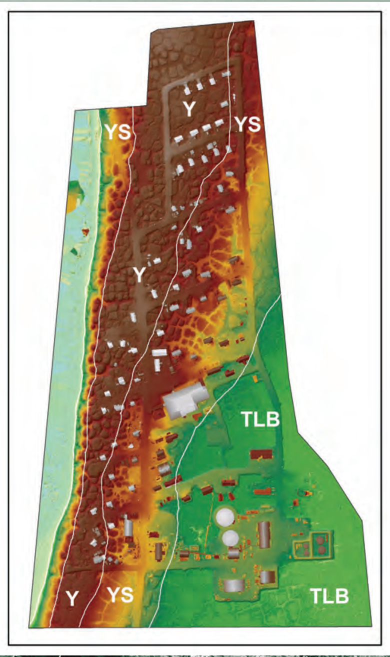
IMAGES: YURI SHUR AND MIKHAIL KANEVSKIY

Left: *The impact of ground subsidence on pile embedment in ice-rich permafrost depends on the placement of piling relative to ice wedges. We estimate ~30% of the residential piles in the village are founded in ice wedges.* **Right:** *For new construction, removing the upper portion of ice wedges and replacing with fine-grained thaw stable soils will protect ice wedges from degradation and reduce thermal erosion and ponding beneath the buildings.*

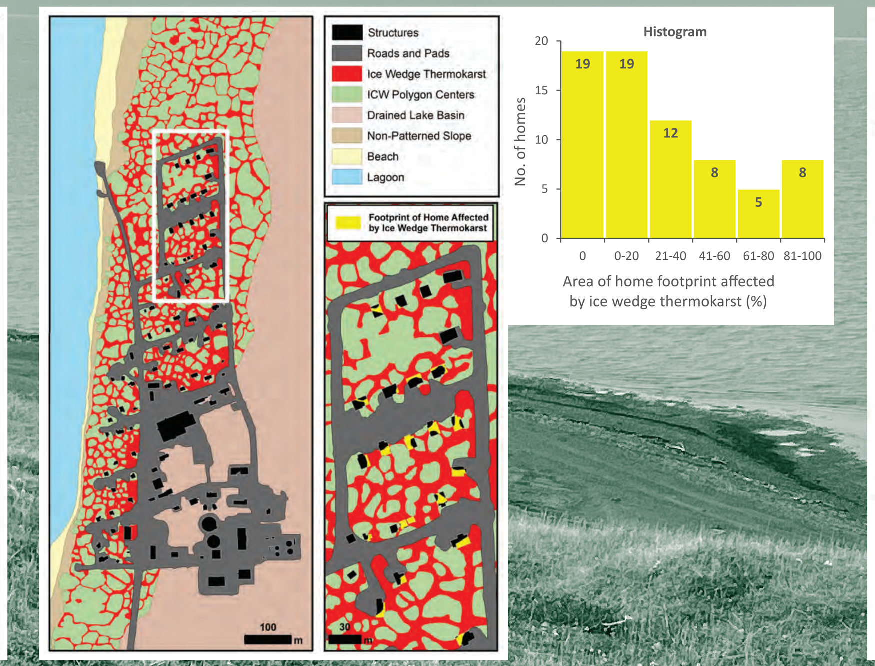
DATA PRODUCTS

High-resolution drone data and imagery yield research products with direct applications for community planning. Using a quadcopter drone, we flew a survey grid over Point Lay with data tied down to WGS84 UTM Zone 3N Ellipsoid Heights to develop these data products and analyses.

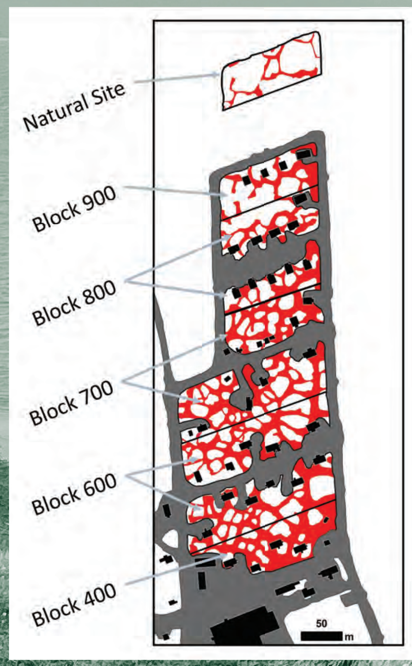


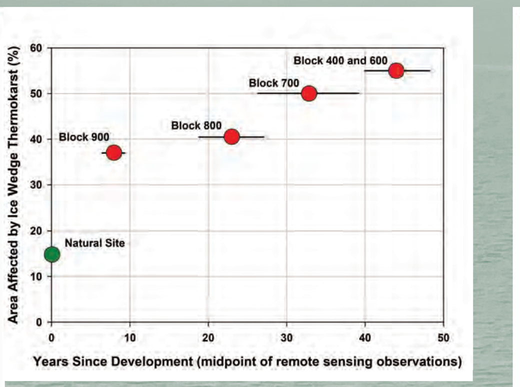


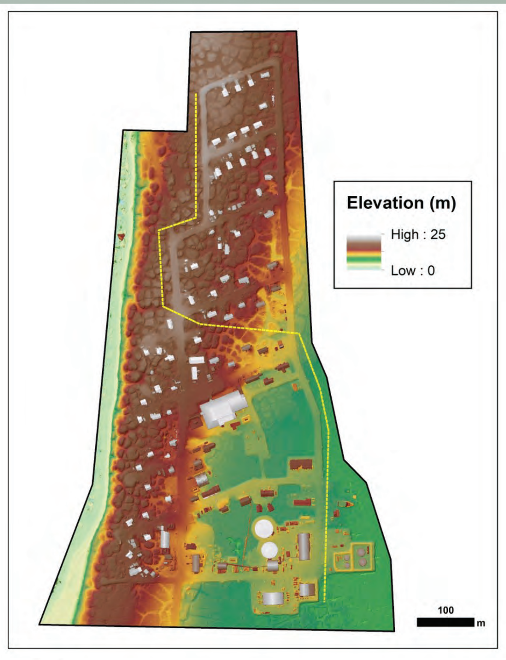
A digital terrain model derived from drone imagery reveals three main terrain units in the village: main yedoma surfaces (Y), yedoma slope (YS), and thaw lake basin (TLB).

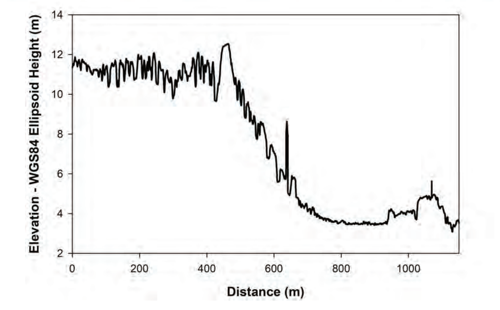


Generalized terrain units and infrastructure in Point Lay were mapped from an orthophoto mosaic and digital terrain model based on drone imagery. Estimates of the footprint of homes impacted by ice wedge thermokarst are shown in yellow in the inset map at lower right and in the histogram at top right.









Top: *It appears that thermokarst and thermal erosion have accelerated with the construction of infrastructure, which increases the mean annual surface temperature and active-layer thickness through a variety of processes. In the Point Lay townsite, thermokarst appears most developed under the oldest structures on the yedoma terrain (Block 400) and becomes less pronounced moving north.* **Right:** *Using drone-derived elevation maps, elevation profiles can be produced for any transect desired. Fill quantities can also be calculated for any transect.*

PHOTO AND IMAGES: BEN JONES

INTERVIEWS

We interviewed eight community members recommended by the Tribal Council and other community leaders. Each said they had observed significant changes to the landscape around Kali in recent years and described how these changes are impacting life, health and safety in the community. Residents commonly described the ground as falling or sinking, where it used to be flat, destabilizing buildings, exposing buried waste, and opening up cracks in the tundra that have required new and longer routes to traditional hunting areas. While there was no consensus on when these changes first became apparent, many observed that the speed of change has accelerated over the past few years. Frequent breaks in buried water and sewer lines resulting in underground leaks are thought to contribute to the more rapid thaw.

PHOTOS: JANA PEIRCE

Left: *Long-time resident Bill Tracey talks about the history of Kali and the accelerating ice-wedge thermokarst and surface ponding that are threatening infrastructure.* **Right:** *Fire chief Kuoiqsik Curtis points out areas of rapid thaw as well as exposed military waste on a map. He reports an increase in Search and Rescue calls because of the rougher terrain and the need for new trails that hunters do not know as well after old trails became unsafe.*

SHARING BACK

PHOTOS: JANA PEIRCE AND BEN JONES

Left: *During a June 2022 research trip, we hosted a community barbecue and open house at the end of our visit to share what we'd learned with tribal leaders and residents.* **Right:** *En route to and from Point Lay, we met with tribal and borough officials in Utqiaġvik to listen to their plans and priorities for adaptive solutions in Point Lay and to discuss data sharing with project managers and engineers designing a new aboveground water and sewer system for Point Lay.*

PHOTOS: BEN JONES

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