Measuring the Impact of a Landslide on Transportation Infrastructure to Improve Mobility and Safety

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ABSTRACT

Not often are engineers given the opportunity to observe a landslide impacting a road in a controlled way and on a predictable schedule. Such an opportunity exists along the Dalton Highway in Alaska. Frozen Debris Lobes (FDLs) are slow-moving landslides in permafrost, with 43 located within the Dalton Highway corridor. These features are composed of a heterogeneous mixture of frozen silt, sand, gravel, and organic debris, with massive ice present in cracks that form from ongoing movement. The fastest FDLs move at average annual rates of over 15 m/yr. FDL-A, the largest of the studied FDLs and the closest to the Dalton Highway, currently moves 7.2 m/yr, and its rate is steadily increasing. We project that this landslide will reach the current Dalton Highway alignment by 2022, placing an estimated 46,800 tons of debris onto the roadway every year. In July 2018, we installed instrumentation between FDL-A's toe and the toe of the existing highway embankment to measure water pressure and temperature, in order to determine how FDLs modify the permafrost conditions in the subsurface ahead of them. We also used a back-pack mounted LiDAR system to measure the surface of FDL-A's toe, with the goal of determining volume change and capturing surface deformation as the FDL approaches the highway. Here we present preliminary results of the 2018 investigation and additional ways to document this landslide-embankment collision, which is needed to develop successful mitigation strategies.

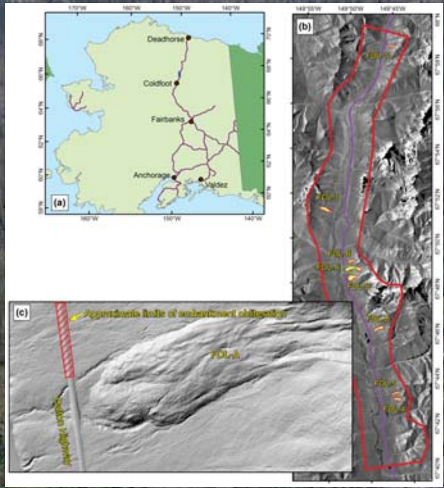

Figure 1. Location of the project area (a) relative to major communities along the Dalton Highway, northern Alaska. The blue rectangle in (a) indicates the location of map (b), which illustrates the area of interest (AOI). The AOI is indicated by the red polygon, the Dalton Highway is in purple, the Trans Alaska Pipeline System (TAPS) is in green, and the investigated FDLs are in yellow. The map in (c) is lower portion of FDL-A, indicating the location of the original Dalton Highway.

2018 LiDAR ACQUISITION

- Collected LiDAR point cloud using back-pack mounted system
- Produced digital elevation model (DEM) with 0.1-m resolution
- Allows change-detection analysis for critical infrastructure area

Figure 3. Acquiring 2018 LiDAR: (a) setting up base station; (b) collecting LiDAR data in back-pack mode.

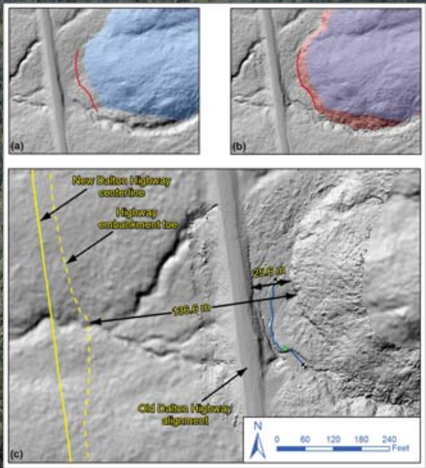

Figure 4. LiDAR data sets comparison and highway embankment configurations. The background image in (a) is 2015 LiDAR with 1-m resolution; the 2015 FDL-A toe position is defined as the shaded blue area, and 2018 DGPS toe measurements are shown in red. The background in (b) is a combination of the 2015 LiDAR and the 2018 LiDAR. The 2018 FDL-A extent is the shaded red area. Subfigure (c) details the July 2018 distances between FDL-A and the old and new Dalton Highway alignments.

2018 ONGOING MONITORING OF FDLS

- Most FDLs continue to demonstrate increasing rates of movement with time
- FDL-A is affecting the subsurface ahead of it, with pronounced movement to 2.5 m bgs, and even shearing into the weathered bedrock (occurring at 3 m bgs at TH12-9000)
- Based on 2017/18 readings, FDL-A is moving at 7.2 m/yr; based on its current distance and rate, it will reach the original Dalton Highway by 2022 and the realignment by 2038

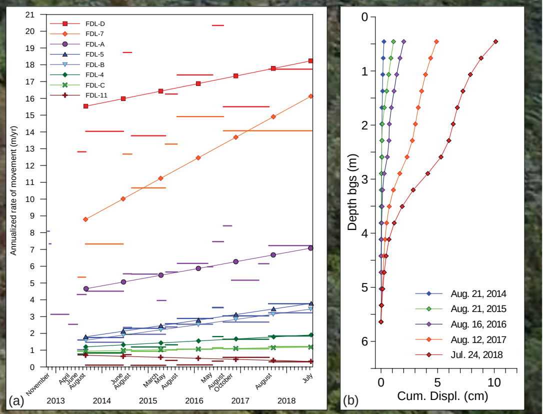

Figure 5. Ongoing monitoring results: (a) overall movement rates from eight studied FDLs; (b) inclinometer readings from TH12-9000.

2018 GEOMECHANICAL INSTRUMENTATION INSTALLATION

- Drilled two 3-m deep borings with 6.4-cm dia. auger and power head; intercepted water in each boring
- Installed vibrating wire piezometer and thermistor string in each boring
- Routed cabling to automated data acquisition system (ADAS); added air and surface temperature sensors
- Temperatures indicate frozen conditions at the bottom of TH18-02

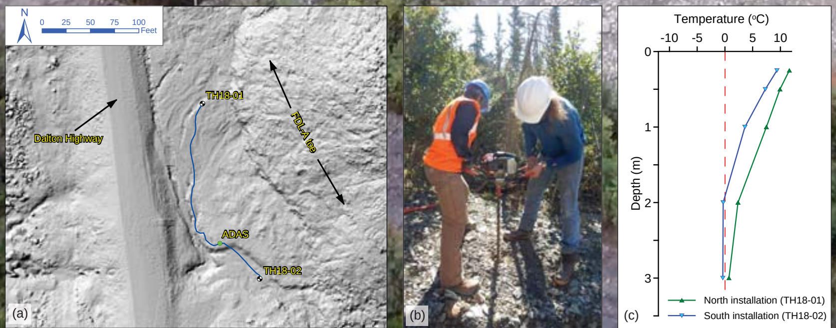

Figure 2. Overview of 2018 geomechanical instrument installation: (a) locations of borings and ADAS; (b) drilling with auger and power head; (c) preliminary temperature profile data from both borings. Background image in (a) is 2018 LiDAR DEM, collected as part of this project.

Background photograph of FDL-A taken in August 2016; it is closer now...

SUGGESTED FUTURE WORK

- Instrument the original Dalton Highway embankment to measure the effects of FDL-A's collision with this engineered structure.
- Conduct a geophysical survey concurrently with a targeted subsurface investigation to map the shear zone distribution, collect samples for soil strength measurements, and install instrumentation for additional water presssure, temperature, and displacement data.
- Build a numerical model to simulate FDL temperatures, hydrology, and movement.

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