DIGITAL MAPPING TECHNIQUES 2015

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Landslide Mapping on the Wasatch Plateau: Comparison of Methods Including High-Resolution LiDAR

By Richard Giraud and Greg McDonald, Utah Geological Survey and Karl Boyer, Manti-La Sal National Forest

Slide Captions

Slide 1 Landslide Mapping on the Wasatch Plateau

We are presenting our landslide inventory mapping work on the Wasatch Plateau in Central Utah. We are going to show the advantages and limitations of mapping with stereo aerial photographs, high resolution orthophotos, and LiDAR.

Slide 2 Project Background

We have been mapping landslides on the Wasatch Plateau since 2008. This is a joint project between the Utah Geological Survey and the Manti-La Sal National Forest. The area has a long history damaging landslides and the landslide inventory provides information to manage landslide problems. We map in Arcmap, produce a geodatabase of attributed landslides, and publish hard copy maps. The photo shows a fire-related debris flow following the 2012 Seeley fire.

Slide 3 Project Objectives

We map landslides at 1:24,000 scale and where LiDAR is available we map at 1:12,000 scale. The photo shows a fire-related debris flow in Huntington Canyon following the 2012 Seeley fire.

Slide 4 Mapping Areas Wasatch Plateau

This image shows the areas we have mapped. The red lines the areas we are mapping this year. To date we have mapped 623 square miles. The photos at right show the different sizes of landslides we map. The upper photo shows a large landslide that contributes sediment to a reservoir downstream. The lower photo shows a small landslide that impacts a forest road.

Slide 5 Twelvemile Canyon South Fork Landslides

This aerial photo sequence shows the scale, magnitude, and impacts of large landslides on the Wasatch Plateau. In the 1976 photo, landslides are evident but lack recent movement. In the 1984 photo, the 1983 Twelvemile landslide (2.5 miles long) reactivated and contributed large volumes of sediment to the South Fork of Twelvemile Canyon. In the 2000 photo, the 1998 North Fork Cooley Creek landslide (1.2 miles long) reactivated and contributed sediment to the South Fork.

Slide 6 Mapping Methods

We primarily use aerial stereo photos for mapping along with 7.5 minute topographic quadrangles, and NAIP imagery. We also use high resolution orthophotos (Bing and Google). We do field work to check our mapping. The photo shows a fire-related debris flow from the 2012 Seeley fire that deposited sediment in the Bridges campground in Huntington Canyon.

Slide 7 Stereo Aerial Photos

The use of stereo photos is critical because the vertical exaggeration amplifies the landslide morphological appearance and reveals subtle landslide features that show the landslide signature. High resolution orthophotos provide great detail but lack three dimensional viewing. Both black and white and color aerial photos from 1940s to 2000 are used for mapping.

Slide 8 Orthophotos

Orthophotos are used primarily for digitizing landslide boundary lines in Arcmap. The high resolution orthophotos allow for more accurate line work. The NAIP imagery is 1 and 2 meter resolution. The Google imagery is six inch resolution. The Google imagery has limitations at higher elevations due to snow cover.

Slide 9

Image showing LiDAR coverage in Utah

Slide 10

Map showing LiDAR coverage (in blue) in our mapping area.

Slide 11 LiDAR

High resolution LiDAR is the best tool in the box. We use LiDAR hillshades, slopeshades, and topographic contours for landslide identification and digitizing landslide boundary lines.

Slide 12 Field Mapping

Field mapping is critical to work out problem areas and to check mapped landslides. Field work is also necessary to understand the limitations mapping with aerial photos, orthophotos, and LiDAR. The upper photo shows the runout of the North Fork Cooley Creek landslide and the creek eroding into the landslide deposit. The lower photo shows a 1983 debris flow that deposited sediment in Pinchot campground. The debris-flow deposit overlies stream alluvium.

Slide 13 Sequence showing benefits of LiDAR, Topographic contour detail

The trees cover landslides making them difficult identify and map on stereo aerial photos. The topographic contours (40 feet) on the 7.5 minute quadrangle provide some suggestion that landslides may be present but not definitive evidence.

Slide 14 Sequence showing benefits of LiDAR, Topographic contour detail

The landslides are easily identified and mapped with detailed LiDAR topography contours (1 meter).

Slide 15 Mapping problematic landslides with LiDAR

Landslides can be identified on NAIP imagery but entire landslide boundaries are difficult to map. Some landslide boundaries are faint.

Slide 16 Mapping problematic landslides with LiDAR

The LiDAR hillshade provides better detail on the upper parts landslides but the landslide flanks and toes are difficult to identify and map. Even without tree cover, this shows the limitations of LiDAR and NAIP imagery. Three dimensional viewing of stereo aerial photos provide a better sense for location of landslide boundaries. Sharp steep landslide boundaries are easiest to map. Faint, transitional, and tree covered landslide boundaries are most difficult to map.

Slide 17 Mapping older and incipient landslides on vegetation covered slopes

The landslides cannot be identified on the NAIP and 7.5 minute topographic map.

Slide 18 Mapping older and incipient landslides on vegetation covered slopes

The LiDAR hillshade shows landslides that would be missed by traditional mapping on stereo aerial photos.

Slide 19 LiDAR returns from both a conifer tree canopy and ground surface

The shallow landslide is evident in the point cloud profile. Shallow landslides are difficult or impossible to map under conifer tree canopies using stereo aerial photos because the landslide does not create sufficient relief in the tree canopy to allow identification.

Slide 20 LiDAR returns from both a conifer tree canopy and ground surface

The shallow landslide clearly stands out in this hillshade image.

Slide 21 Landslides on East Mountain

East Mountain in the distance. We will now look at landslides on aspen and conifer covered slopes of East Mountain. From a distance faceted spurs and bedding are evident but landslides are not evident.

Slide 22 7.5 minute Quadrangle Topography

Landslides are not evident in the 40 foot contours. The apex of alluvial fans below short steep drainage basins are evident.

Slide 23 2009 NAIP Orthophoto

Landslides are not evident but the apex of alluvial fans are evident.

Slide 24 LiDAR DEM Slopeshade

Landslides and the apex of alluvial fans are now both evident.

Slide 25 Slopeshade and Landslides

Line work showing landslides and the alluvial fans on slopeshade.

Slide 26 2009 NAIP Orthophoto and mapped landslides

Line work showing landslides and the alluvial fans on orthophoto.

Slide 27 Small amount of landslide movement

Small amounts of landslide movement are difficult to detect. This photo illustrates the limitations of stereo aerial photos, high resolution orthophotos, and LiDAR in detecting and dating landslide movement. Field work is likely the best method to identify and confirm small amounts of landslide movement.

Slide 28 Small amount of landslide movement

The hummocky topography allow identification of a landslide but the small amounts of recent movement cannot be detected without field work.

Slide 29 Small amount of landslide movement

As with the previous image hummocky topography suggests a landslide but the recent movement cannot be detected without field work.

Slide 30 Summary

Landslide Mapping on the Wasatch Plateau: Comparison of Methods Including High-Resolution LiDAR

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Manti-La Sal National Forest

Project Background

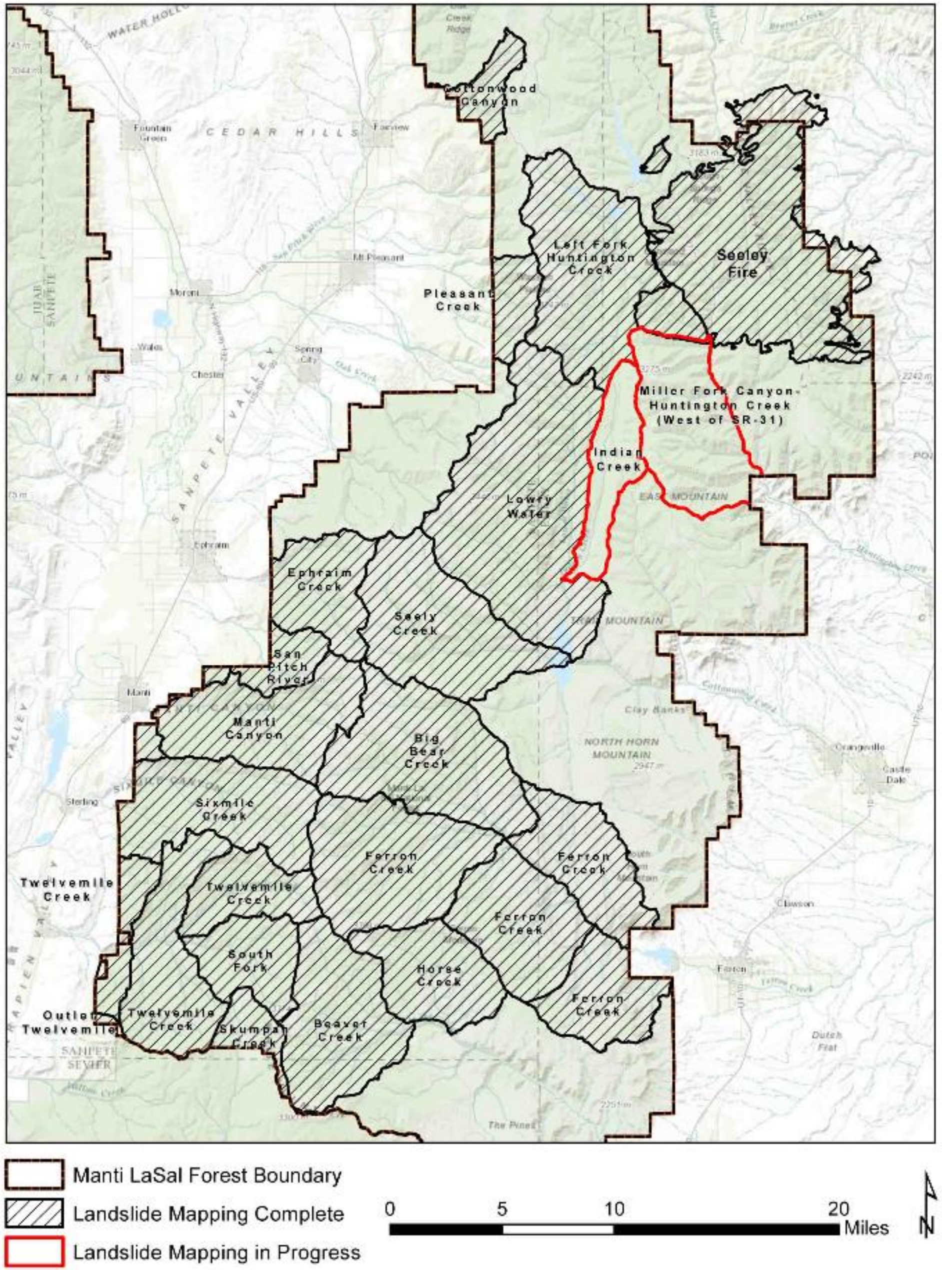
- USFS – Manti-La Sal National Forest
- History of damaging landslides/floods
  - Impacts to range, water quality, roads, infrastructure
- Landslide maps for integration into geodatabase

Project Objectives

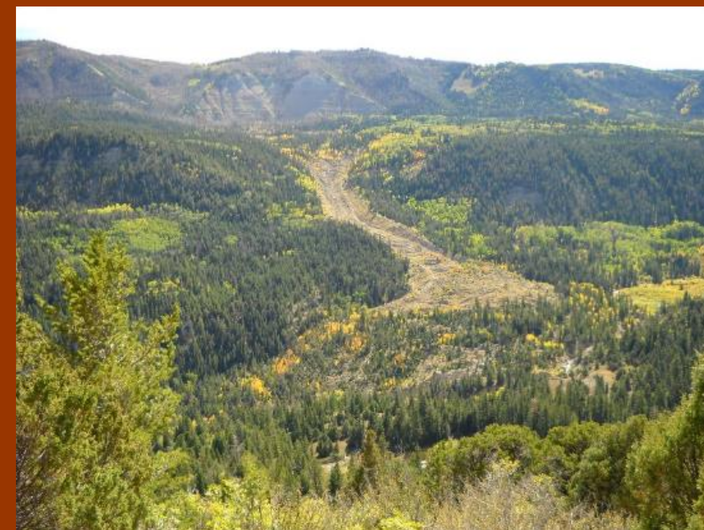
- Map landslides 1:24,000 scale
- LiDAR map landslides 1:12,000 scale
- Prepare landslide inventory
- Attribute landslides
  - Type, activity, confidence, physical parameters
- Create geodatabase

Wasatch Plateau Landslide Mapping Areas

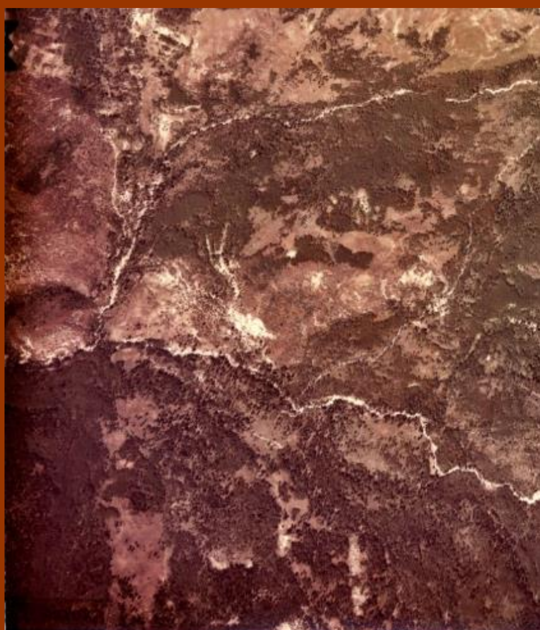
Status of mapping as of December 8, 2014
Agreement 10-CS-11041000-033, Modification #3 and Attachment D



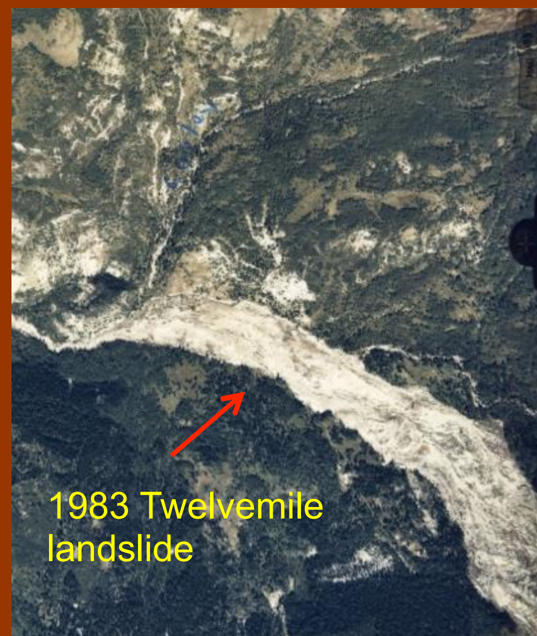
- **Total Map Area 623 mi^2**



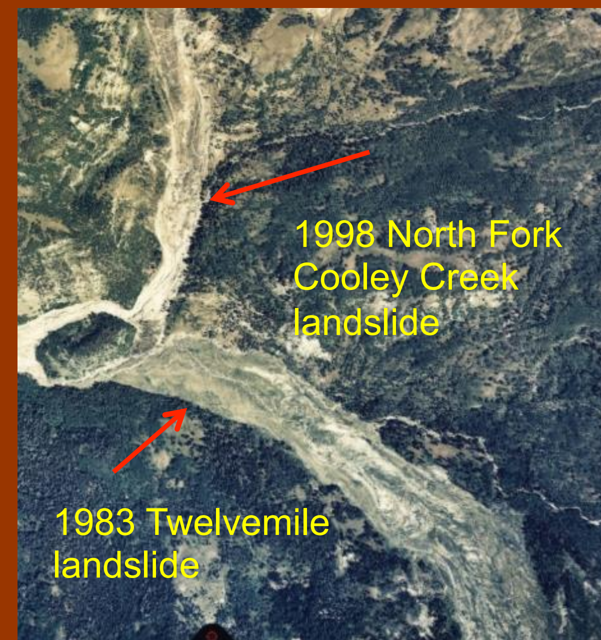
Twelvemile Canyon South Fork Landslides



1976



1984



2000

Mapping Methods

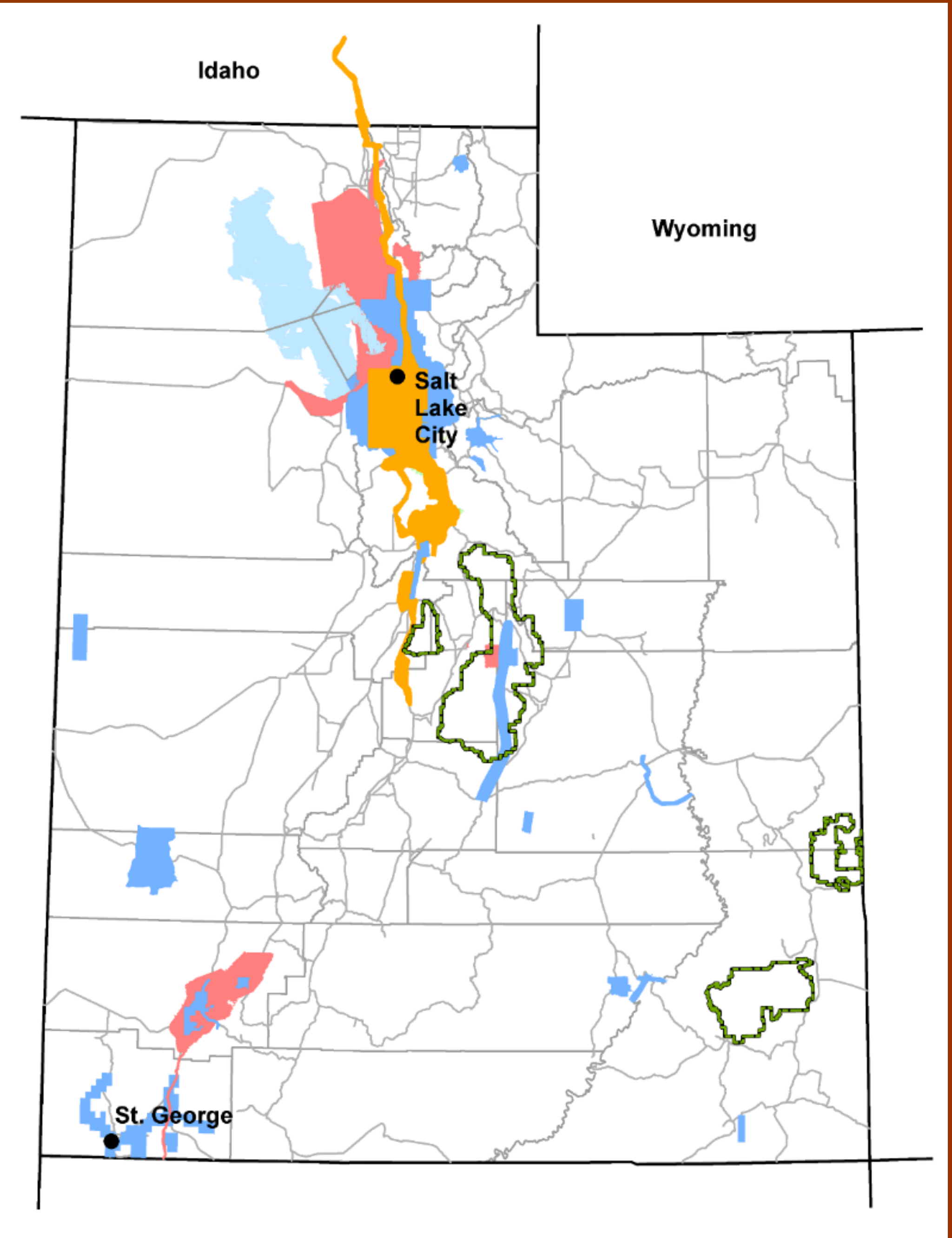
- Aerial stereo photos
- 7.5' topographic quadrangles
- NAIP, Bing, and Google orthophotos
- Fieldwork
  - Limited due to large map area/project timeframe

Stereo Aerial Photos

- Majority of mapping done on stereo pairs
- Several years of photos available
  - late 1930s/early 1940s through 2000
- Preferred years include 1940, 1964, 1991
  - Scale, resolution, quality, vegetation, development

Orthophotos – NAIP, Bing, and Google

- Available through AGRC server from 1990s through 2014
- NAIP every 3 years, Bing and Google uncertain?
- Good to high resolution imagery
- Used primarily for digitizing photo line work
- Along with aerial photos can constrain ages of historical movement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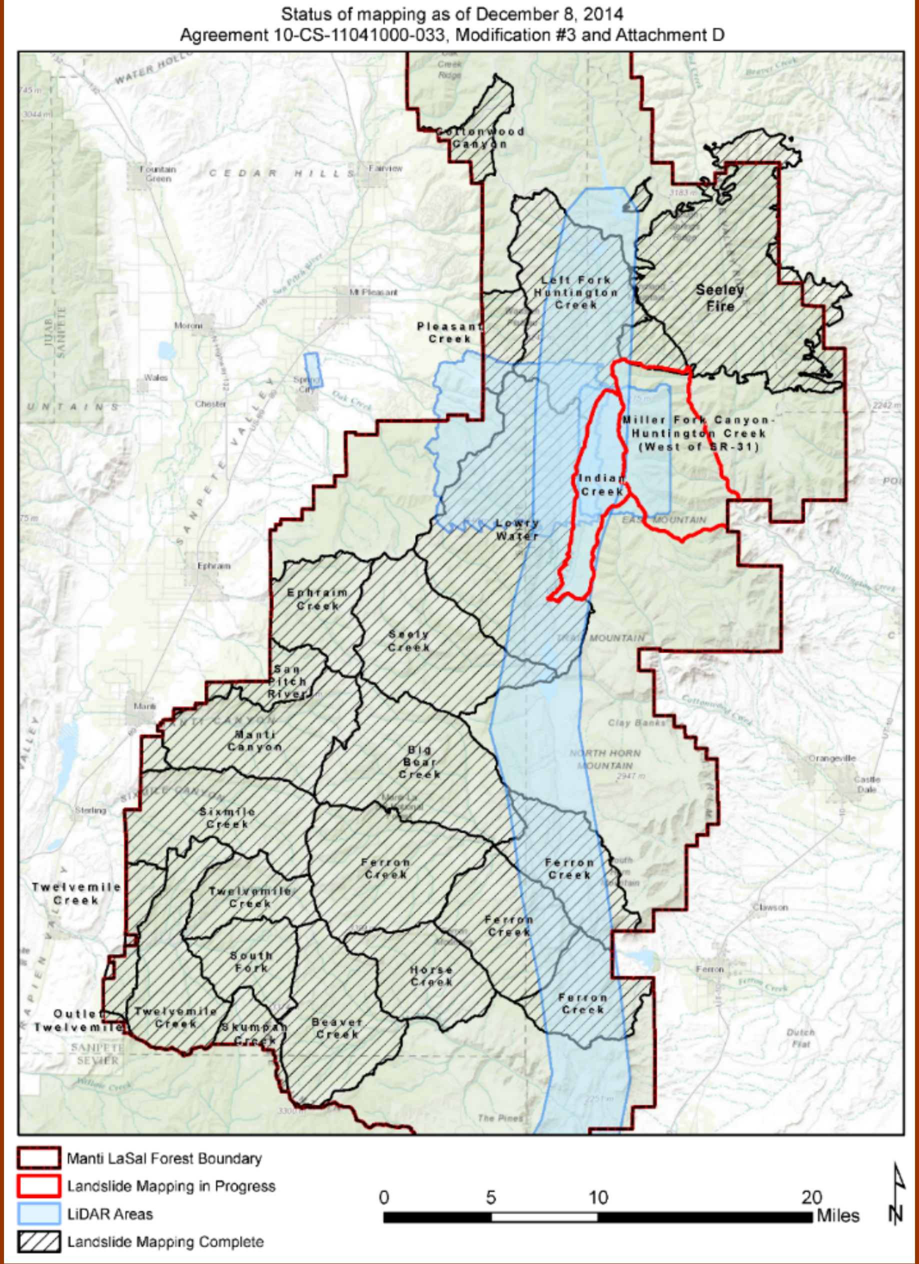
Wyoming
Salt Lake City
St. George



Available LiDAR Data for the Manti-La Sal National Forest

- Utah Geological Survey, 2011 1 meter (50 mi^2)
- University of Texas (NSF), 2010 1 meter (25 mi^2)
- U.S. Bureau of Reclamation, 2014 0.75 meter (244 mi^2 total)
- LiDAR coverage 92 out of 623 mi^2

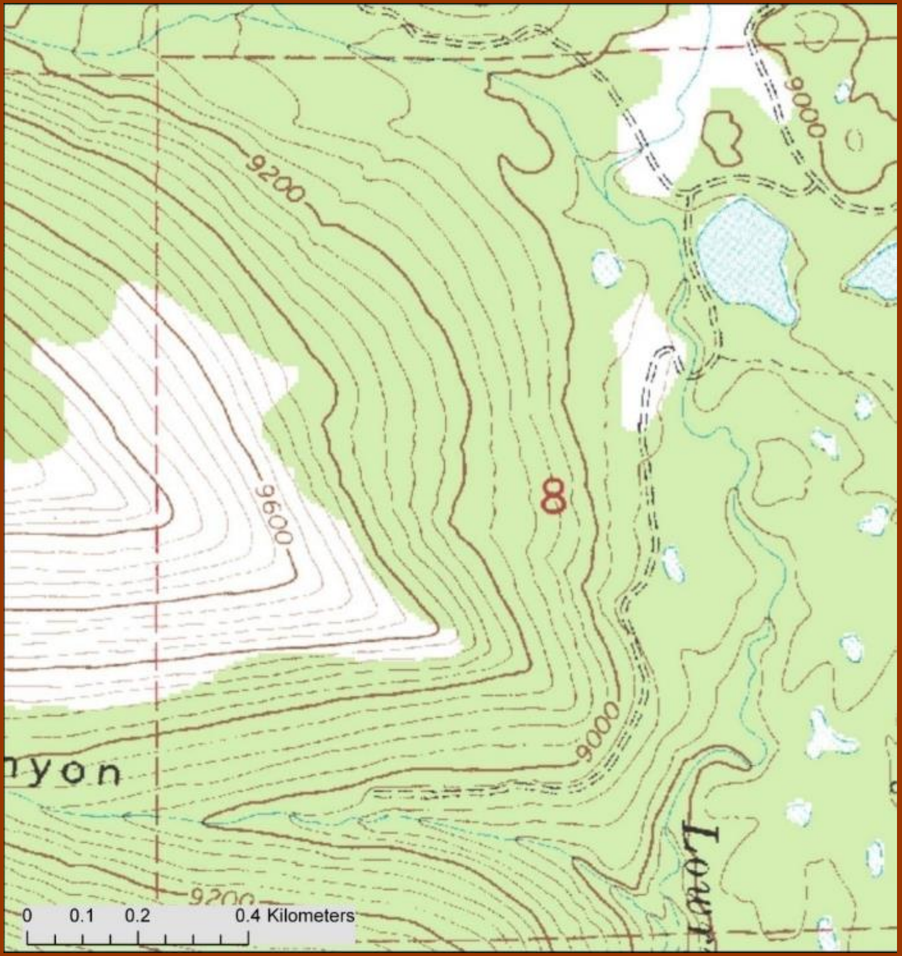
LiDAR

- Great resolution (~1 m)
- Penetrates most vegetation; notably conifer stands
- Several visualization options
  - Hillshade, Slopeshade
  - Contour
  - Slope
- Incipient and small “pop-out” slides
- Allowed for more-detailed map scale

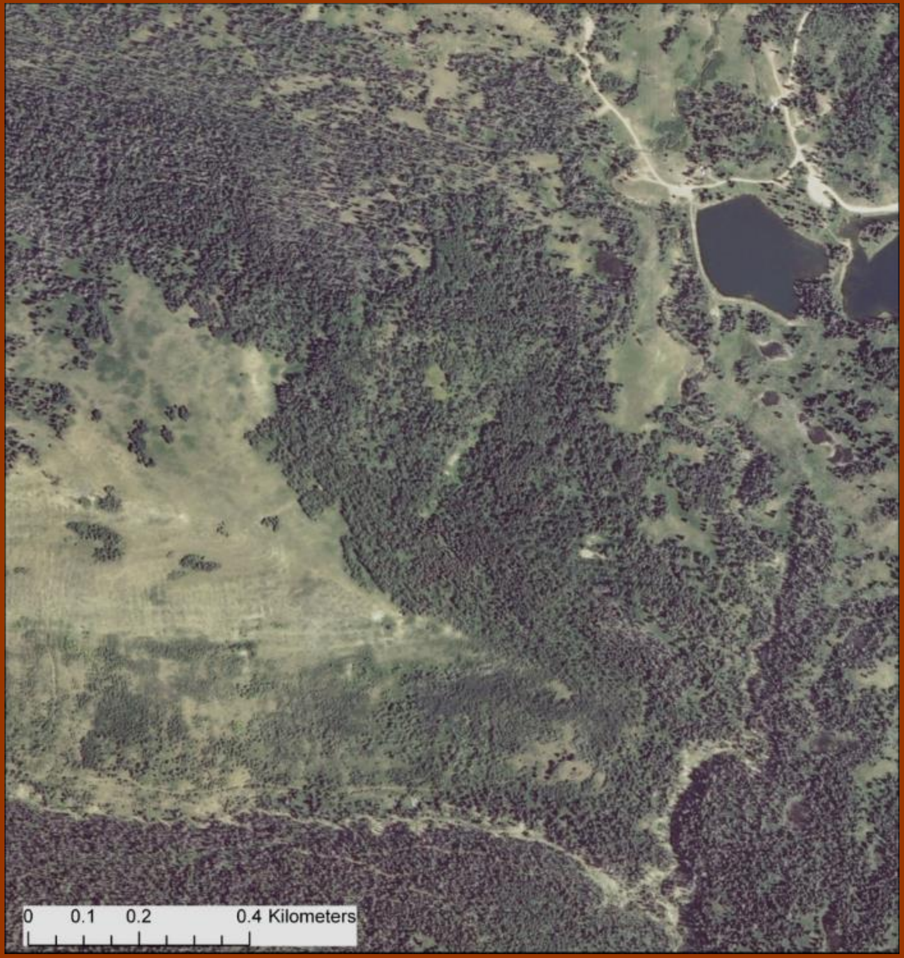
Field Mapping

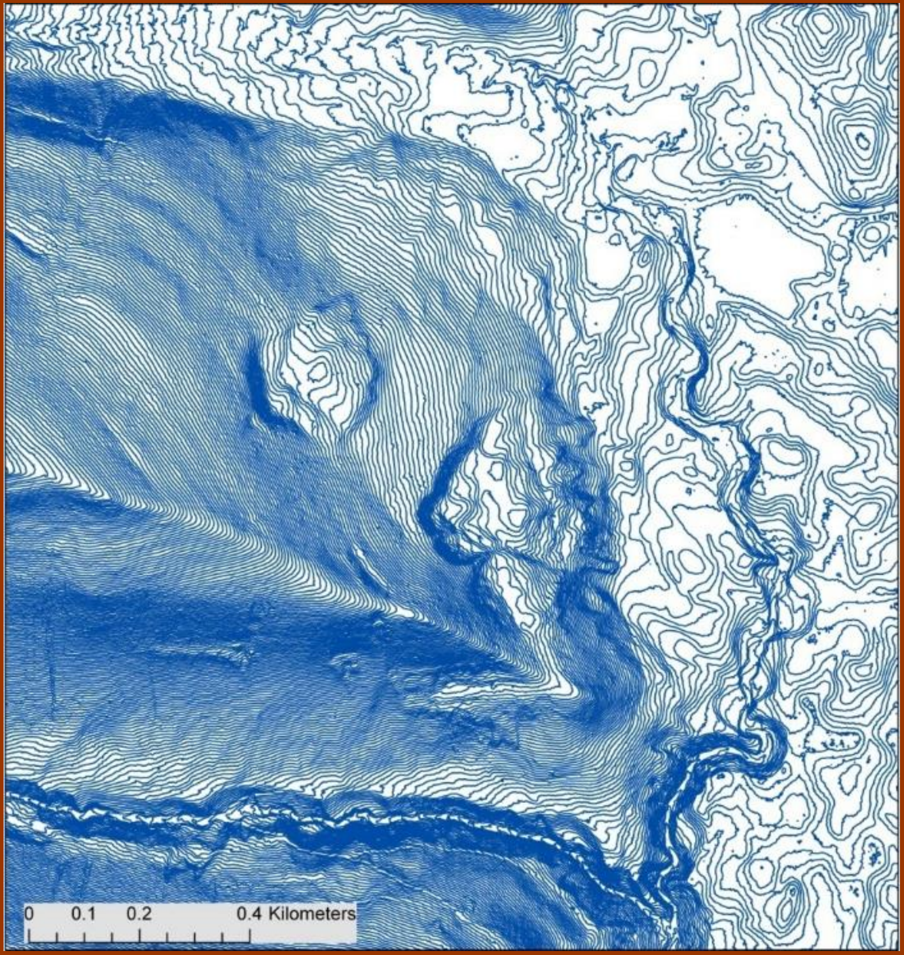
- Good for confirming questionable photo and LiDAR interpretations
- Detail mapping smaller slides/internal features
- Necessary for understanding character, scale, lithology, etc of landslides and their relationship to bedrock and other surficial deposits

Topographic contour detail



Topographic contour detail

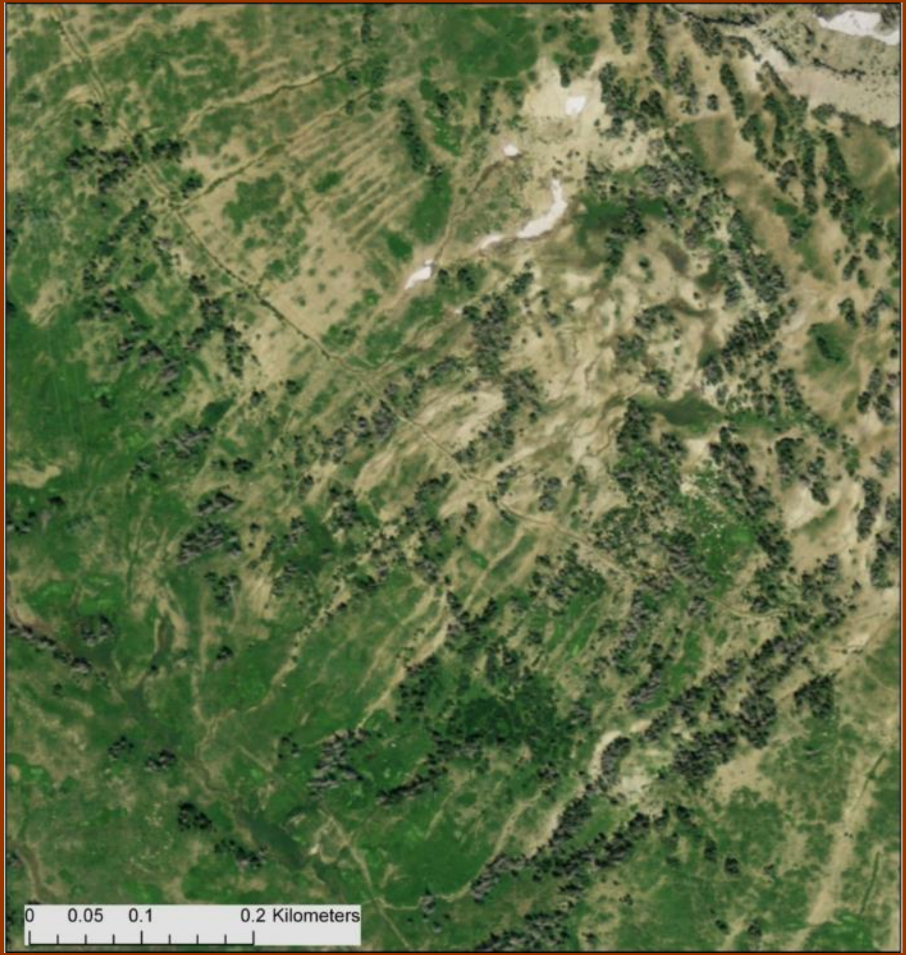


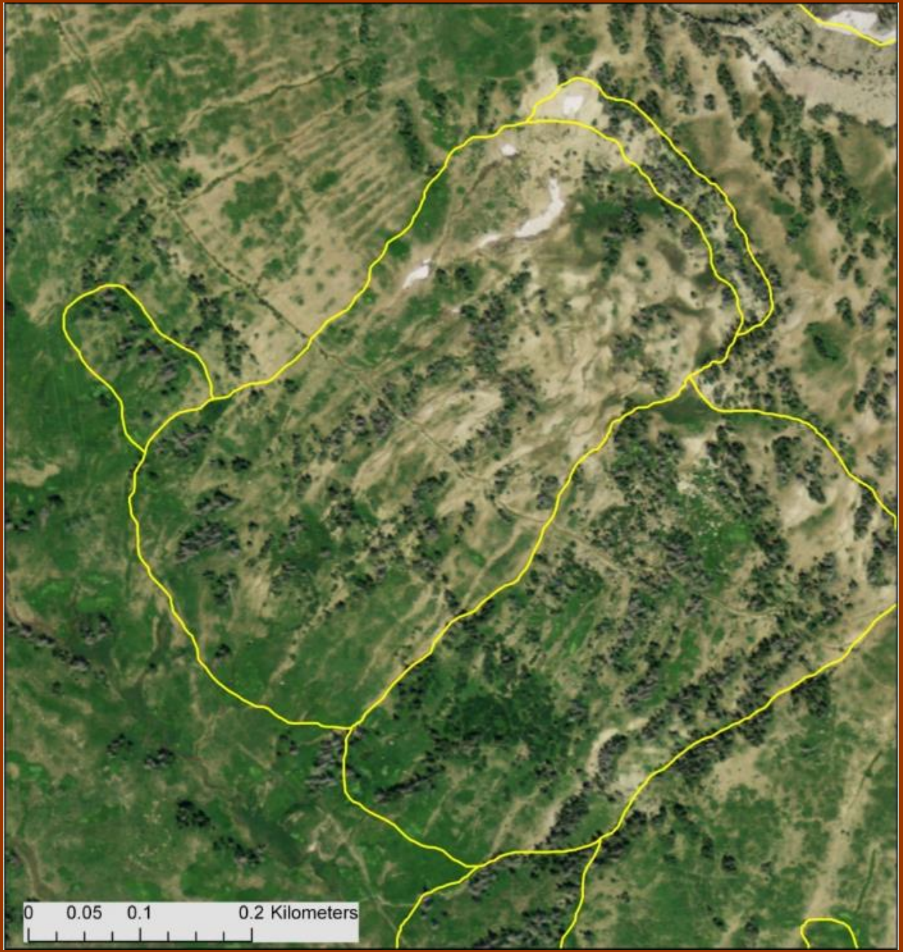


Problematic landslides

well-defined heads

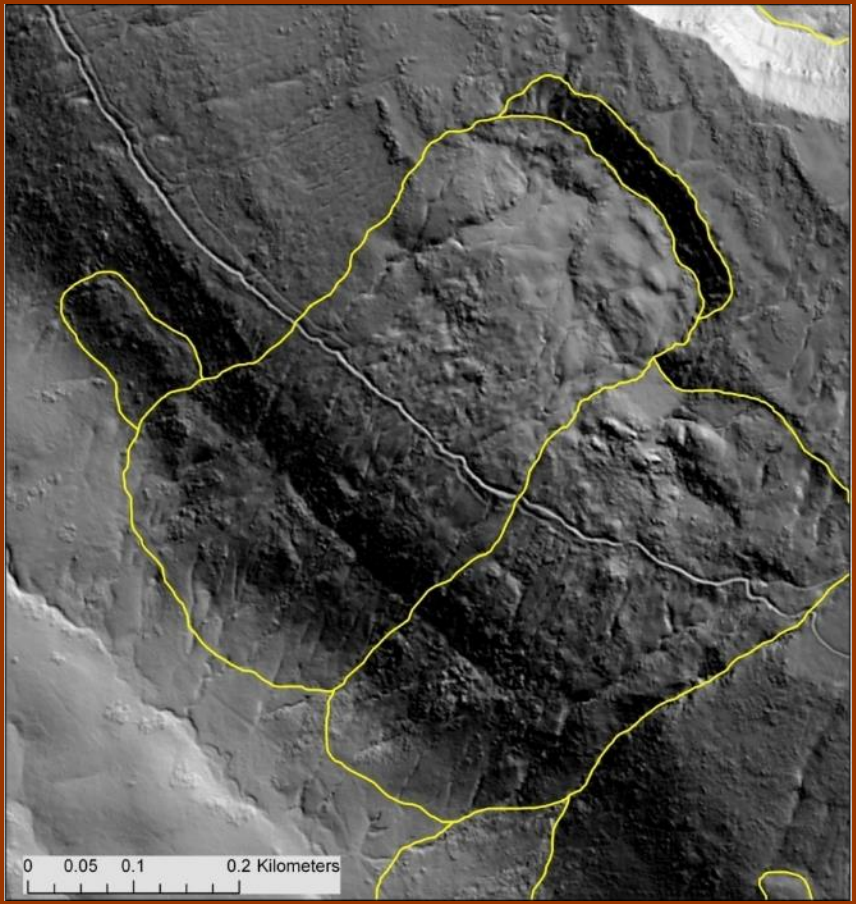
"ghosty" mid/lower portions



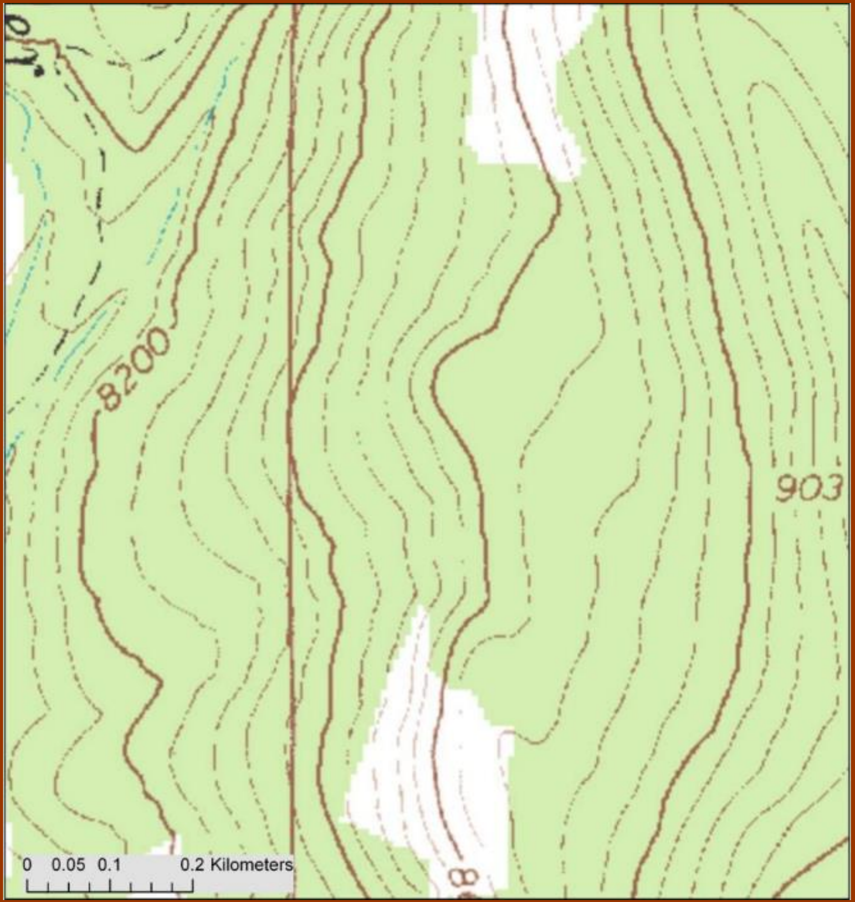


LiDAR did not change general interpretation

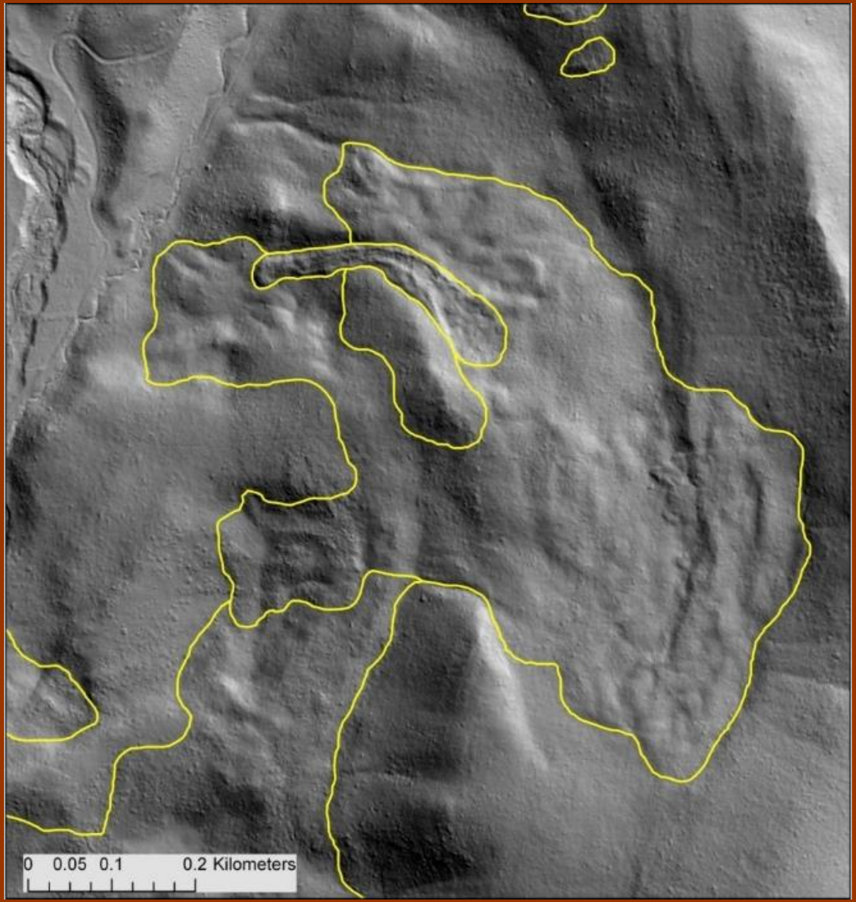
May be useful for refining boundaries, subdividing inset slides



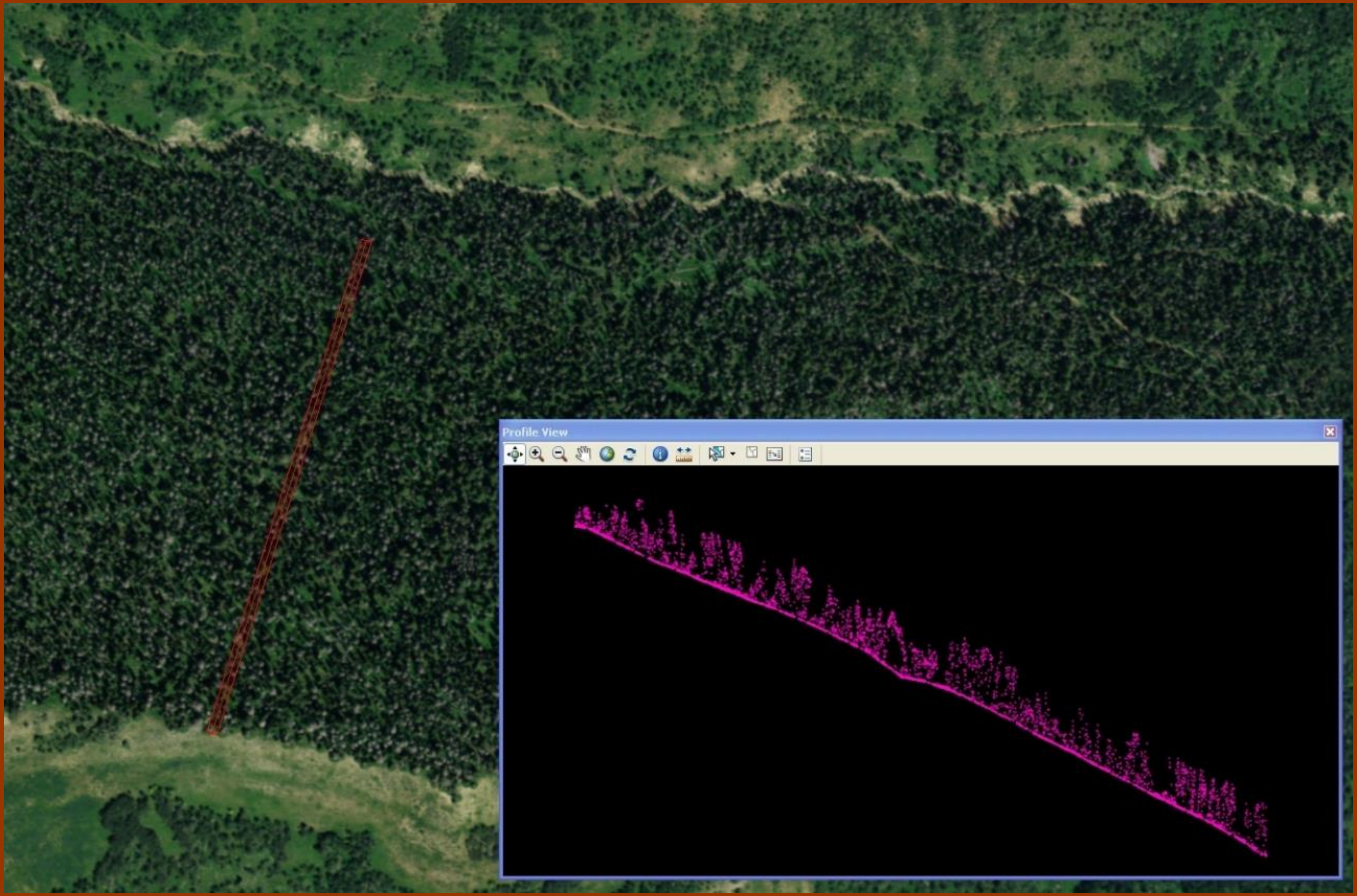
Vegetated slopes
Older and/or incipient landsliding

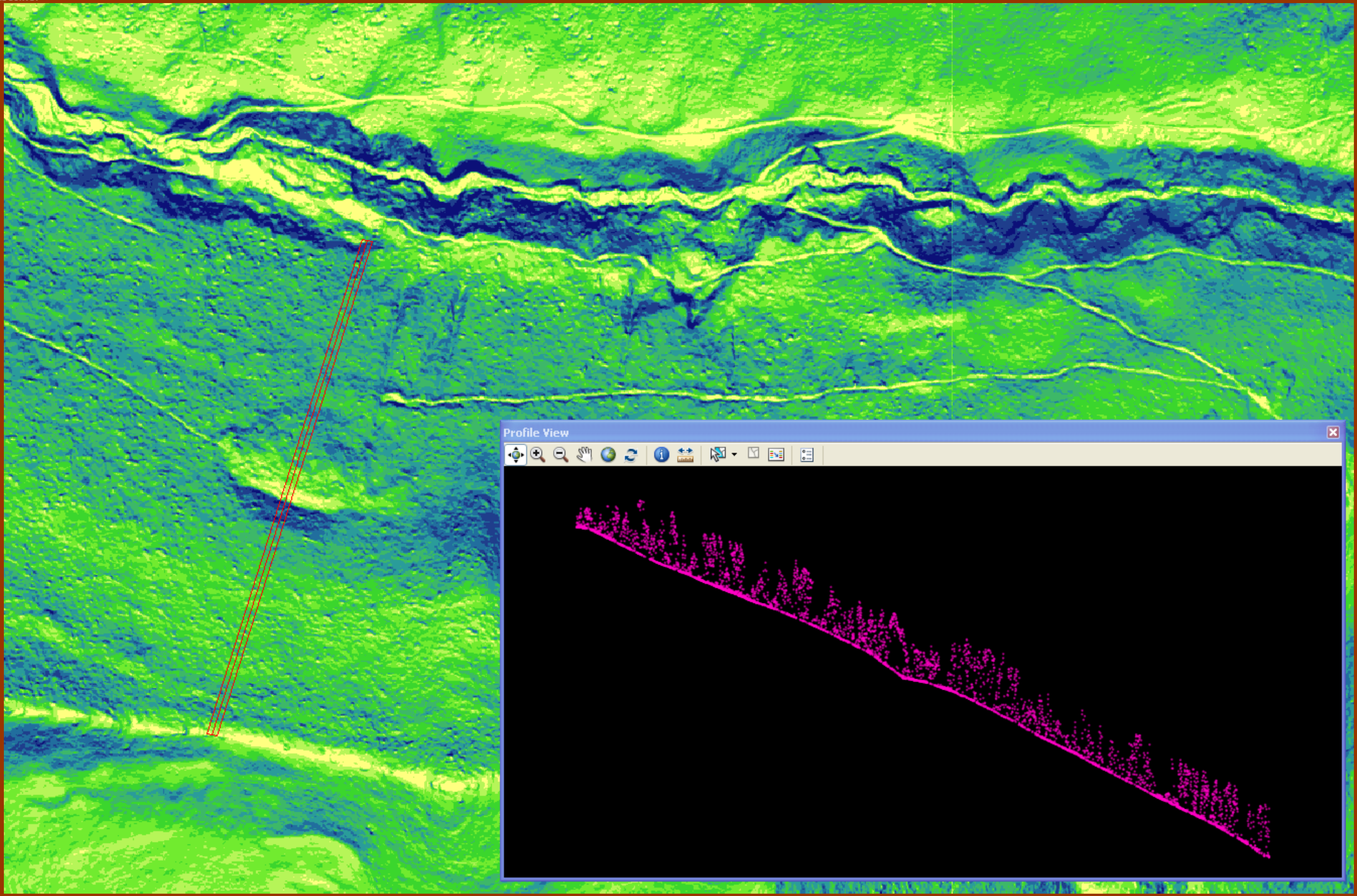



0 0.05 0.1 0.2 Kilometers

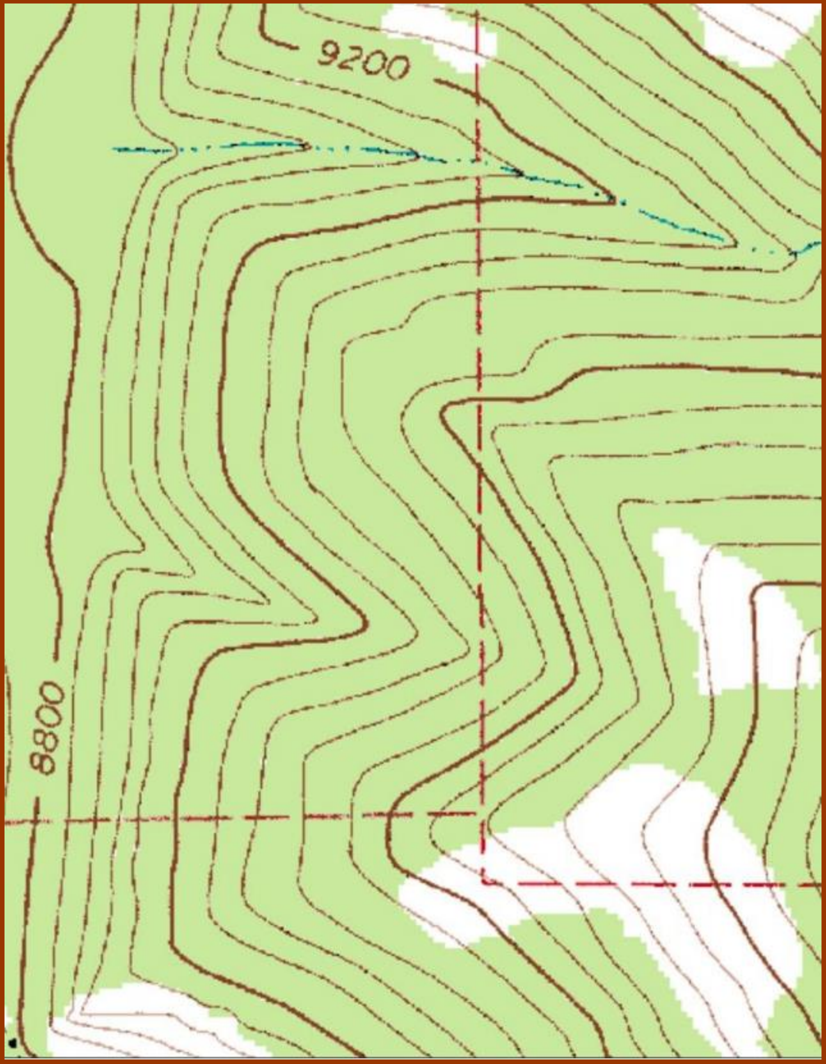

0 0.05 0.1 0.2 Kilometers

Conifer forest slopes




Profile View

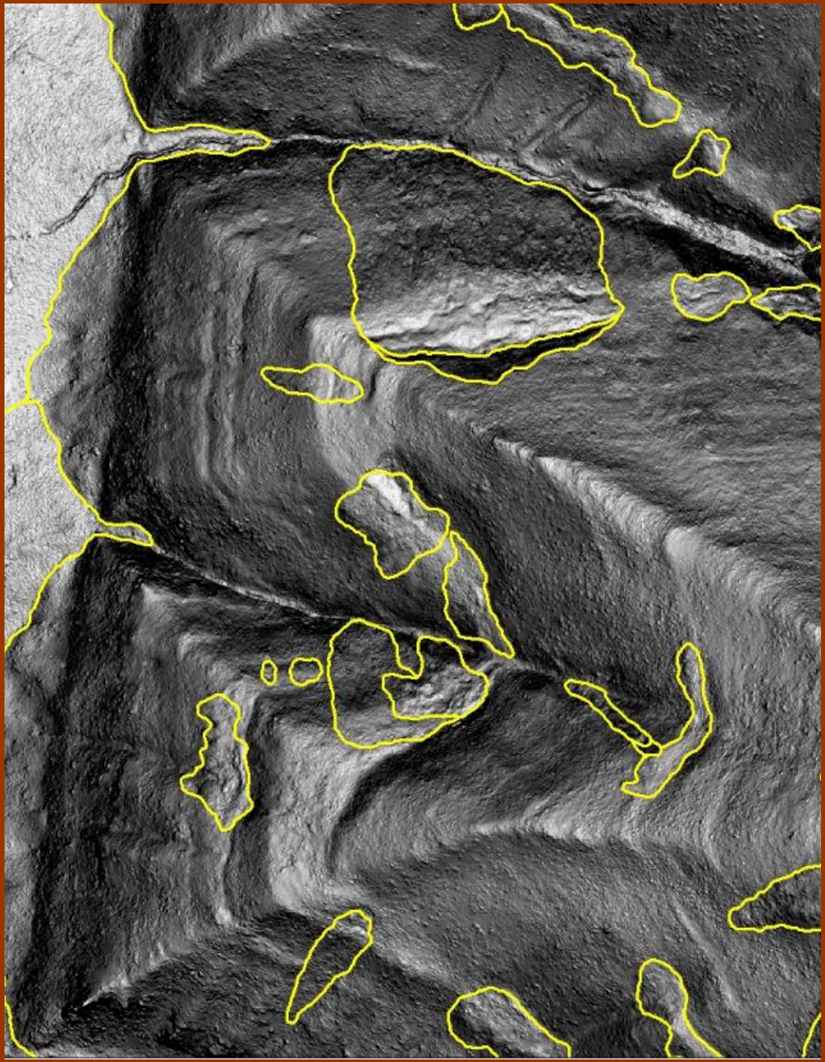
7.5' Quadrangle Topography



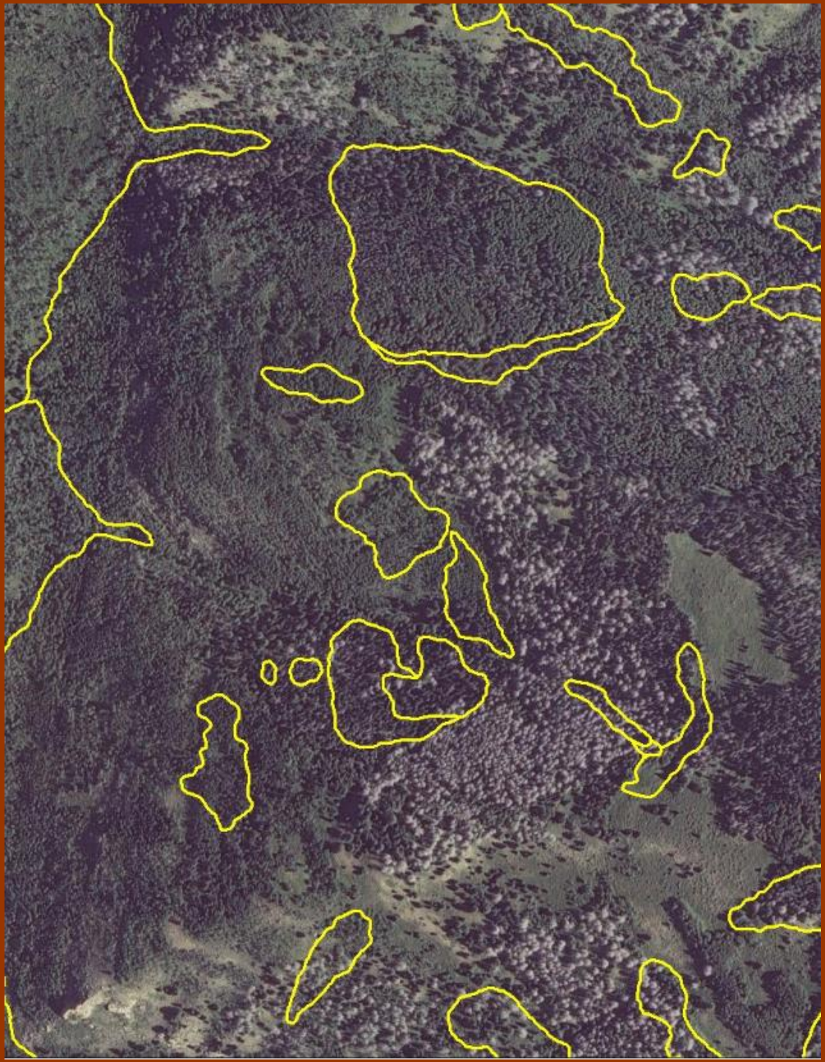
2009 NAIP Orthophoto

LIDAR DEM Slopeshade

Slopeshade and Landslides



2009 NAIP Orthophoto



Summary

- LiDAR
  - Very beneficial
  - Much improved accuracy
  - Break out small landslides slides within larger landslides
  - Limitations but the best supporting tool out there
- High Resolution Orthophotos
  - Map small landslides not possible stereo aerial photos
  - Limitations with snow cover and dates
  - Good for comparing
- Stereo Aerial Photos
  - The best overall tool because of stereo viewing
  - Scale limitations for small landslides
  - Tree cover limitations
  - Good for historical movement