

Using Consumer UAVs and RTK GNSS for Low-Cost, High-Precision Mapping

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Goal:

**What quality of data can I squeeze
out of a \$1,000 consumer drone?**

- DJI Phantom UAV quadcopter
- iPad Mini tablet computer w/ArcGIS Collector
- Arrow RTK GNSS receiver
- Pix4D (Drone2Map) or Agisoft PhotoScan Pro image processing software.

UAS Regulatory Environment

1. Hobby use

1. Government use

1. Commercial use

- **The same UAS can be used by all three. It's mostly about intent, not about technology.**

Hobby/Recreational UAS Rules

AC 91-57a Circular(2015)

- Flown for hobby/rec use.
- Less than 55 lbs
- 400' AGL
- Coordinate with airport when within 5 miles.
- Give right-of-way to manned aircraft.



Public/Government UAS Rules

Decision Flowchart for Government Ops

-CoA issued for particular purpose in a particular area. Typical government CoA is issued in 60 business days.

-Agency to provide the FAA with a "declaration letter" from the city, county, or state attorney's office assuring the FAA that the proponent is recognized as a political subdivision of the government of the State under Title 49 USC

- Government ops by government for government.
- Includes public universities.
- Examples of government/public CoAs issued.

Commercial UAS Rules

- The only way to fly UAS commercially (using an off-the-shelf UAS) in the US is via a FAA 333 Exemption and Certificate of Waiver or Authorization (CoA).
- Current approval process is about six months.
- My 333 Exemption request was ~14 pages and took just under three months to be approved (April 3 – June 26, 2015) . It's valid for two years unless “sooner superseded, rescinded or canceled.”

The 333 Exemption carries the following requirements:

- PIC must be a FAA licensed pilot w/current FAA medical certificate.
- There must be a Visual Observer.
- PIC and VO must maintain visual line of sight (VLOS) while stationary and without aid (eg. binoculars).
- Daytime-only operations.

- Fly at least 500 ft vertically and 2,000 ft horizontally from clouds.
- Return-to-Home feature on UAS if comms lost.
- Give way to all manned aircraft.
- 500 ft from all non-participating people, vessels, vehicles, structures unless granted permission by said owner.
- Permission from property owner.

The CoA.

- A CoA is required in addition to 333 Exemption.
- The FAA has been issuing standard, nationwide CoAs along with 333 Exemptions. If you want to operate outside of the CoA limitations, a separate CoA must be applied for.
- The standard, nationwide CoA includes the following limitations:

- Visual Flight Rules (500 ft vertical, 2,000 ft hor)
- UAV weighing 55 lbs or less.
- At or below 400 ft AGL
- 5 nautical miles from airport with tower
- 3 nautical miles from airport with published instrument procedure, no tower.
- 2 nautical miles from airport with neither.
- 2 nautical miles from heliport.

- Manufacturer-supplied.
- Third-party. Dronedeploy, mapsmadeeasy, etc. Support for specific make/model UAS is important.
- Open source. <https://conservationdrones.org/>

-Video of sample mission.

https://www.mapsmadeeasy.com/drone_mapping

-Photo overlap. 60/70/80/90% overlap.

-Homogeneous surfaces (water, trees) confused the image processing software.

-Battery management.

- Standard photogrammetry toolset optimized for UAS.
- Pix4D (Drone2Map) and Agisoft PhotoScan Pro.
- Match images efficiently and accurately.
- Incorporate ground control.
- Produce DEMs/DSMs.
- Produce orthophotos, 3D models, volumes and elevation contours.

Workspace

- Workspace (1 chunk, 136 cameras)
- Chunk 1 (136 cameras, 4 markers, 17,628 points)
 - Cameras (135/136 aligned)
 - Markers (4)
 - Tie Points (17,628 points)
 - Dense Cloud (8,590,963 points, Medium quality)
 - 3D Model (1,693,824 faces)
 - Tiled Model (8 levels, 1.5 mm/pix)
 - Orthomosaic (4096x1941, 5.2 mm/pix)



Photos

A grid of 24 thumbnail images, each labeled with a filename from DJI_0001.JPG to DJI_0024.JPG. The thumbnails show various aerial views of the same area, including the baseball field and surrounding buildings.

What's Possible with a Consumer UAS?

- Project YF. 30 acres.
- Goal: produce orthophoto and 4K video of a stream tributary.
- Challenges: limited batteries (2), vehicle didn't support charger, tried to do too much.
- Result: Success.

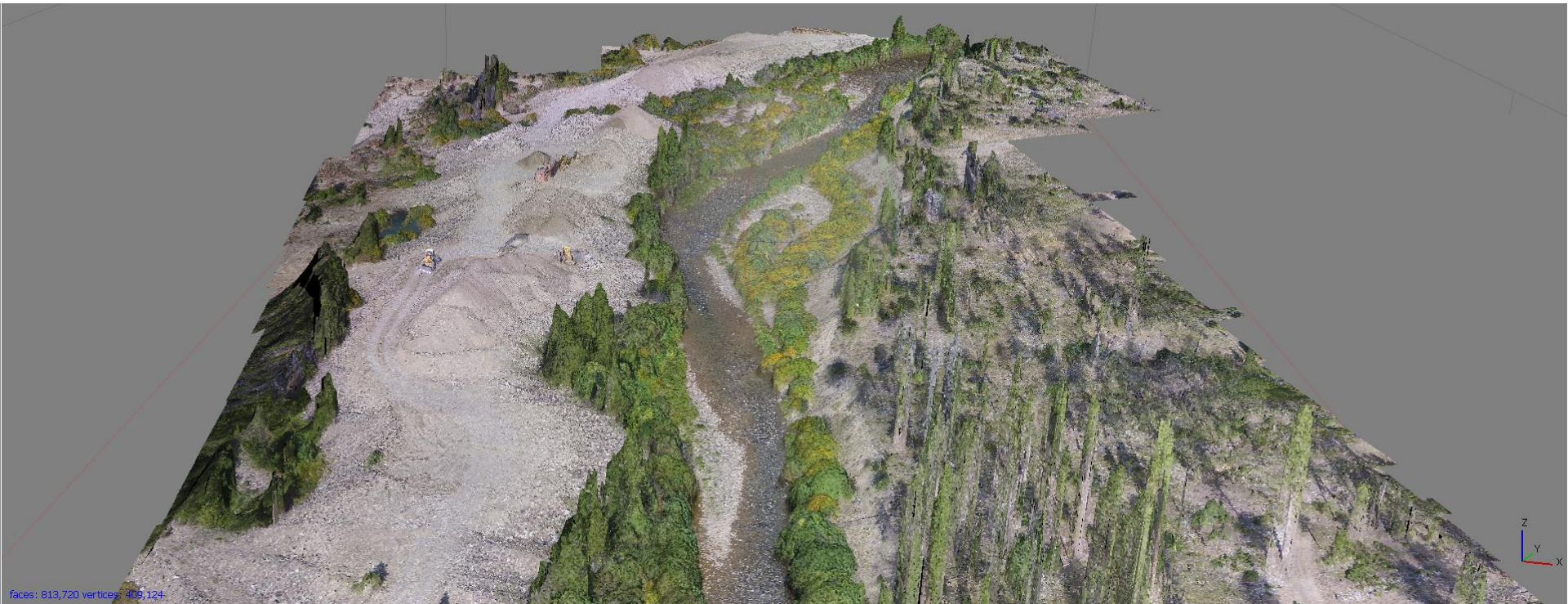
Google Earth



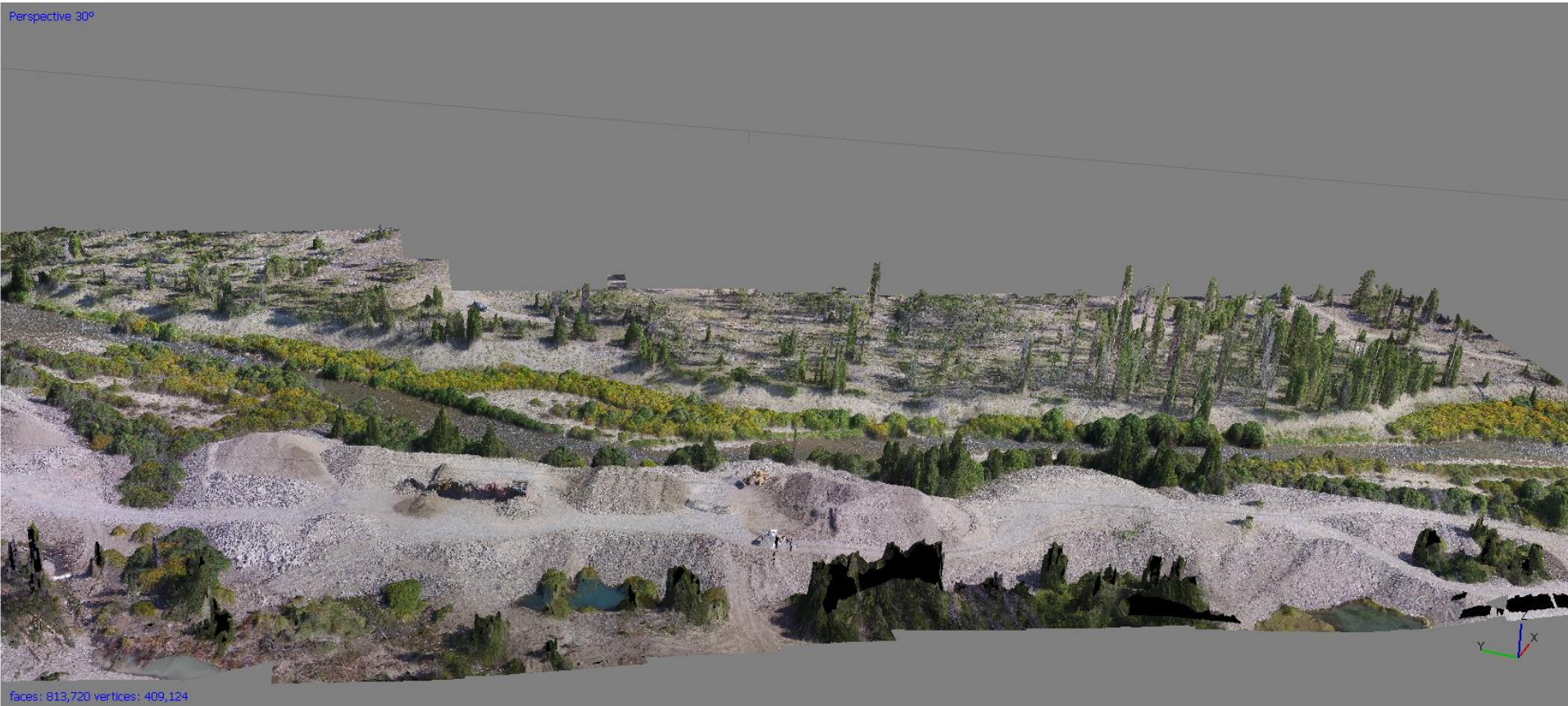
2cm/Pixel UAS



First Mission



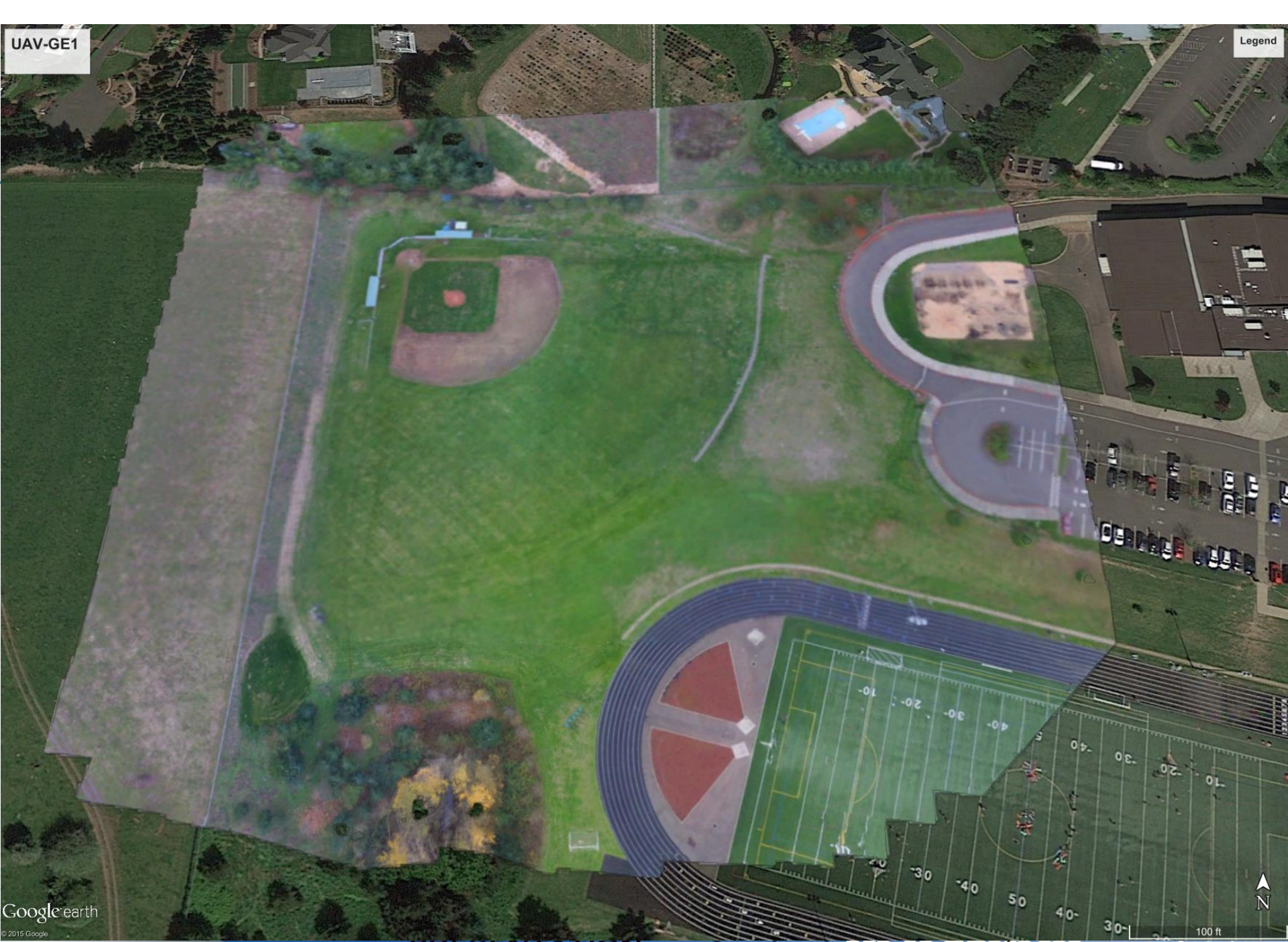
First Mission

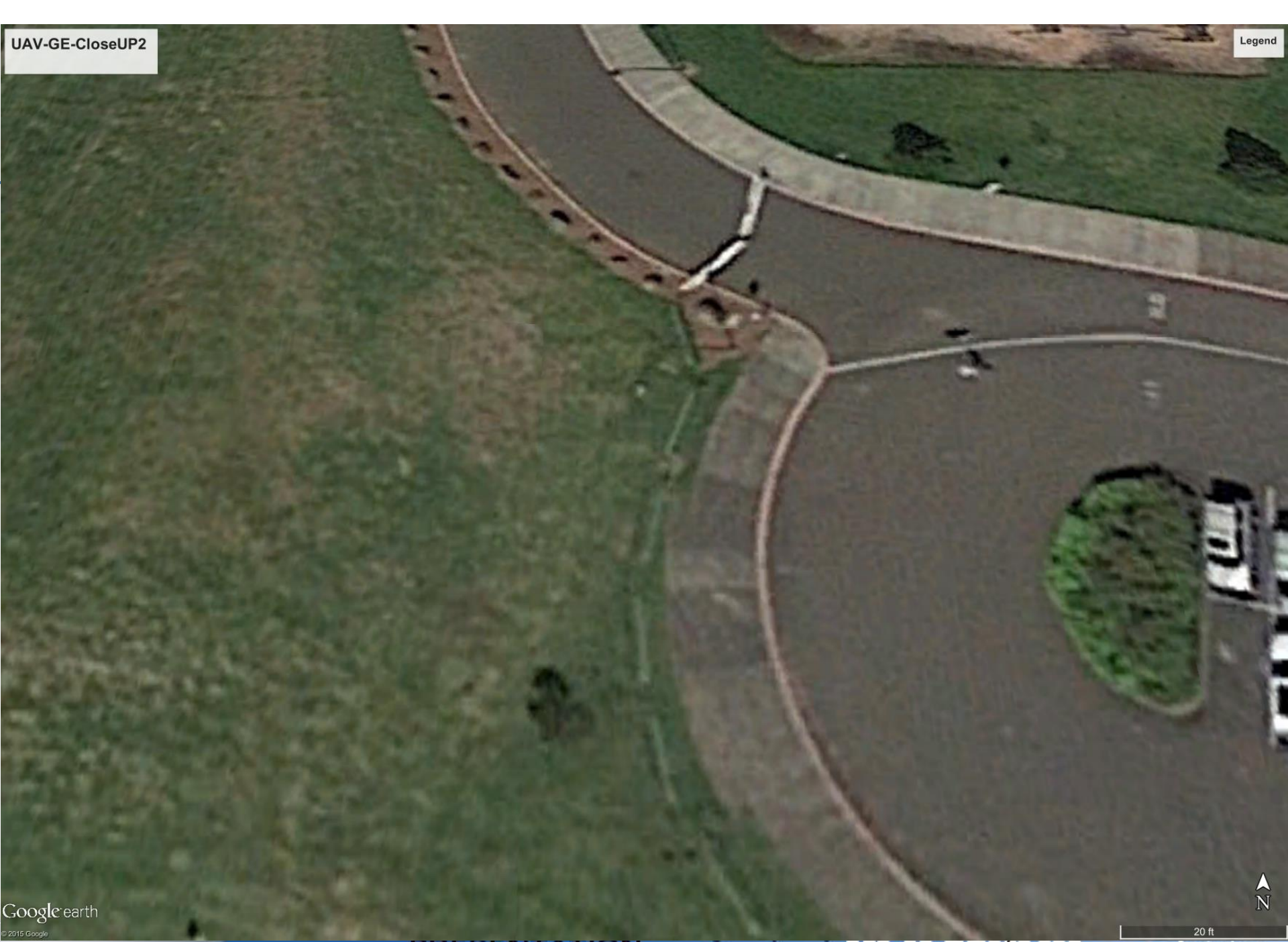


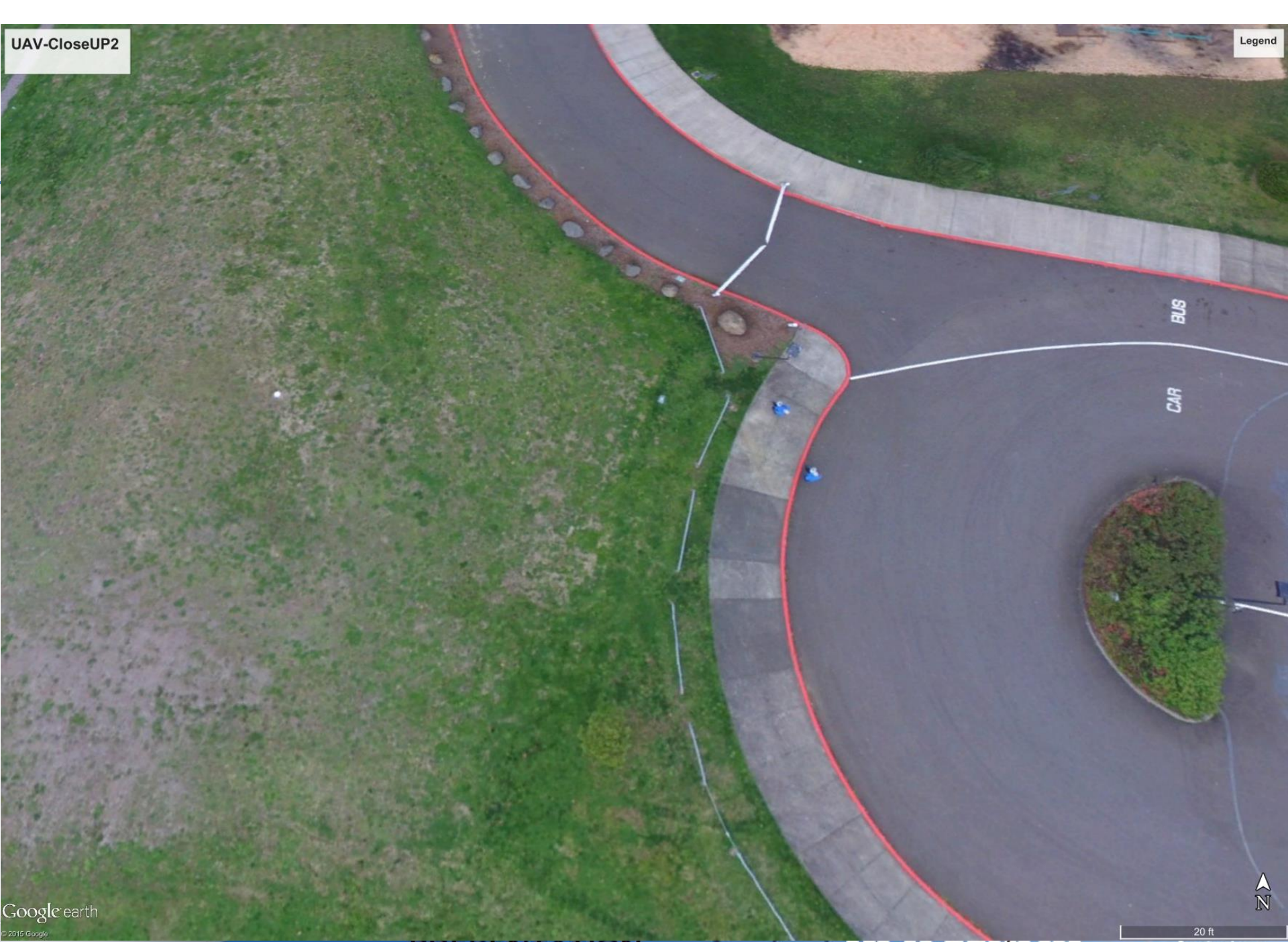
- Project RR. 5 acres.
- Goal: produce orthophoto and elevation contours. Integrate with Google Earth.
- Challenges: Weather, people.
- Result: Success.

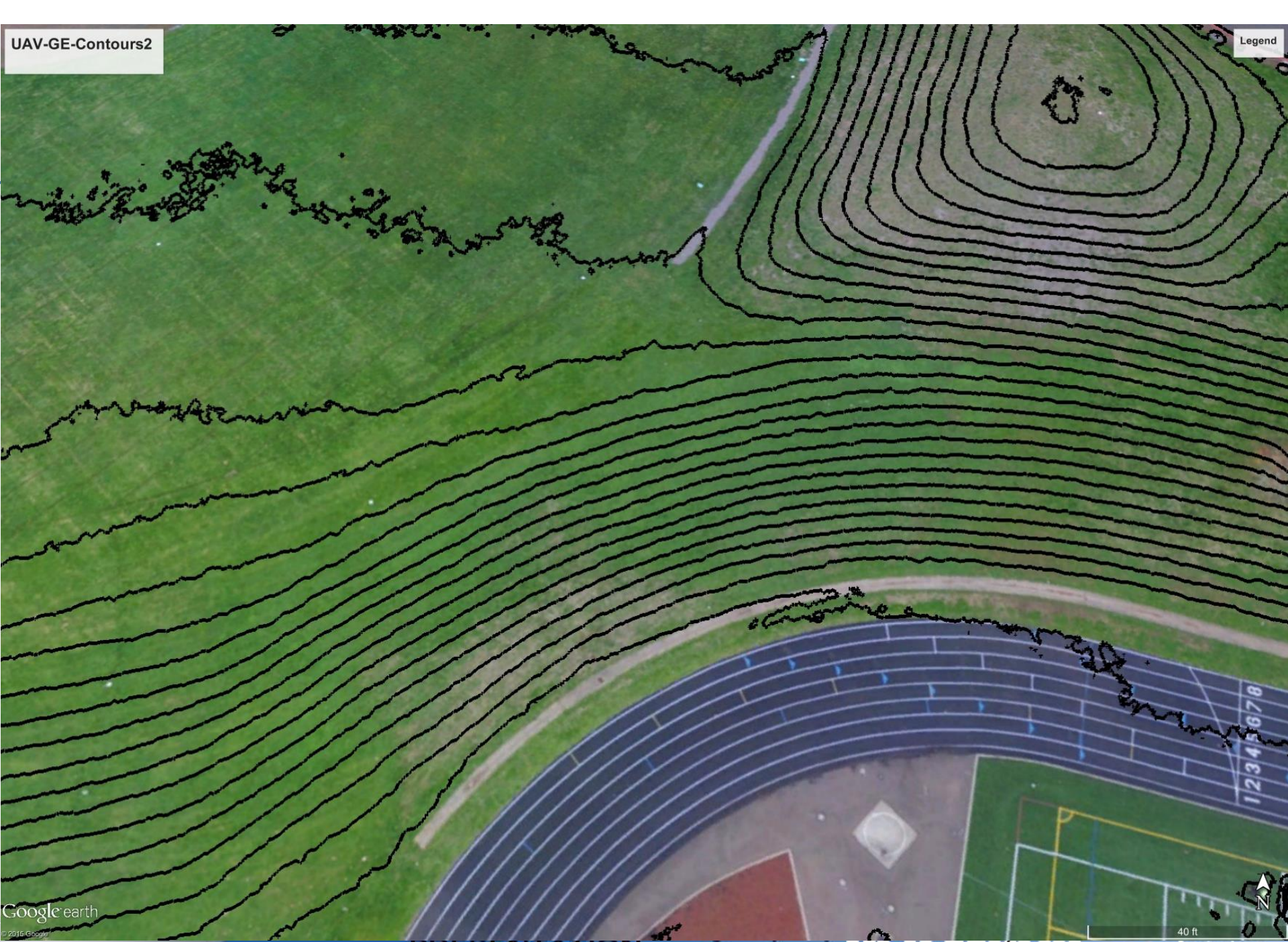
UAV-GE1

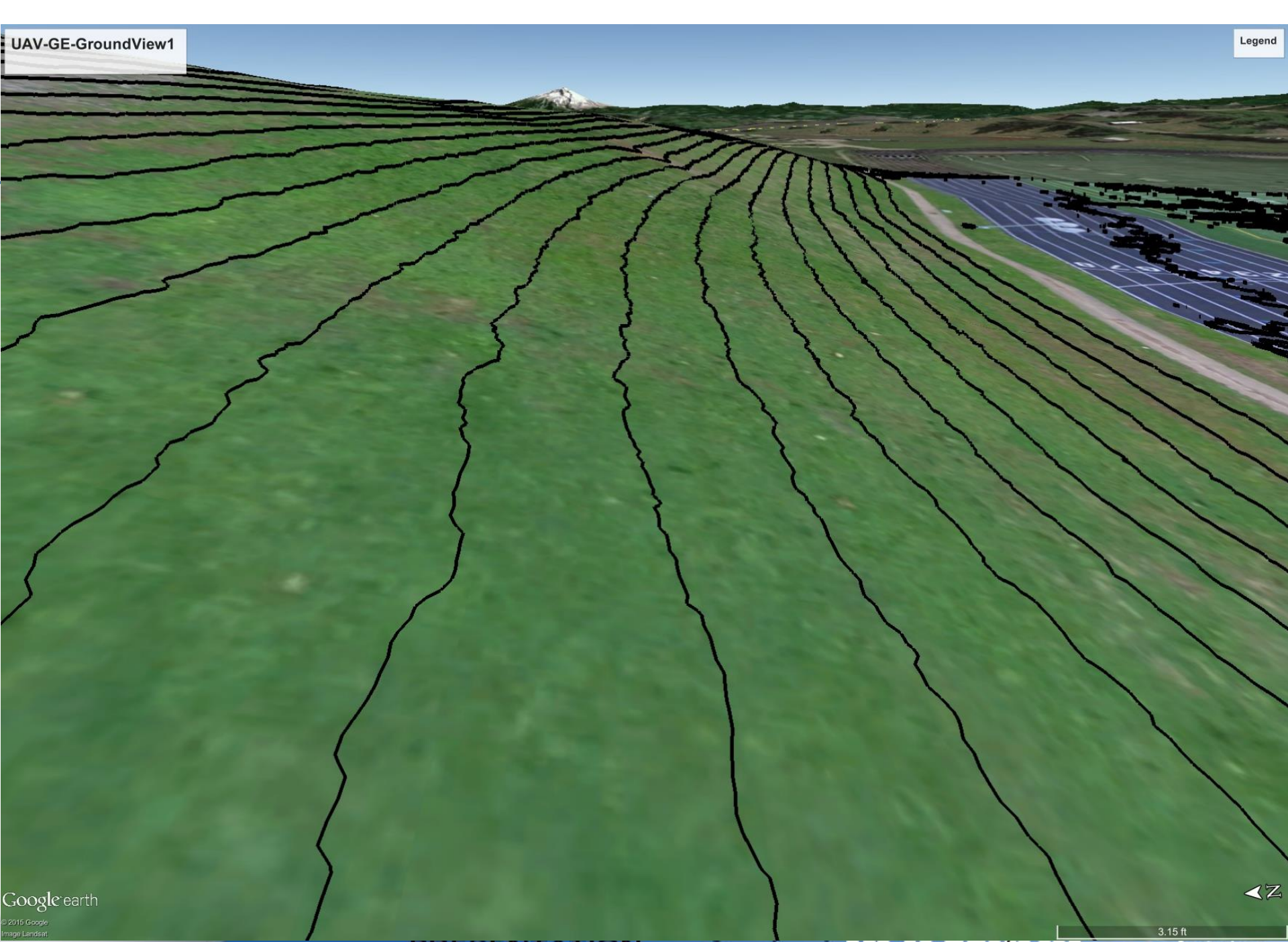
Legend











- Project WASCO. 160 acres.
- Goal: Produce orthophoto and one foot elevation contours.
- Challenges: Weather (rain, snow, temp, wind), homogeneous ground cover, batteries.
- Result: Mostly success.
- Lesson learned: Adjust camera settings to deal with low-light conditions.





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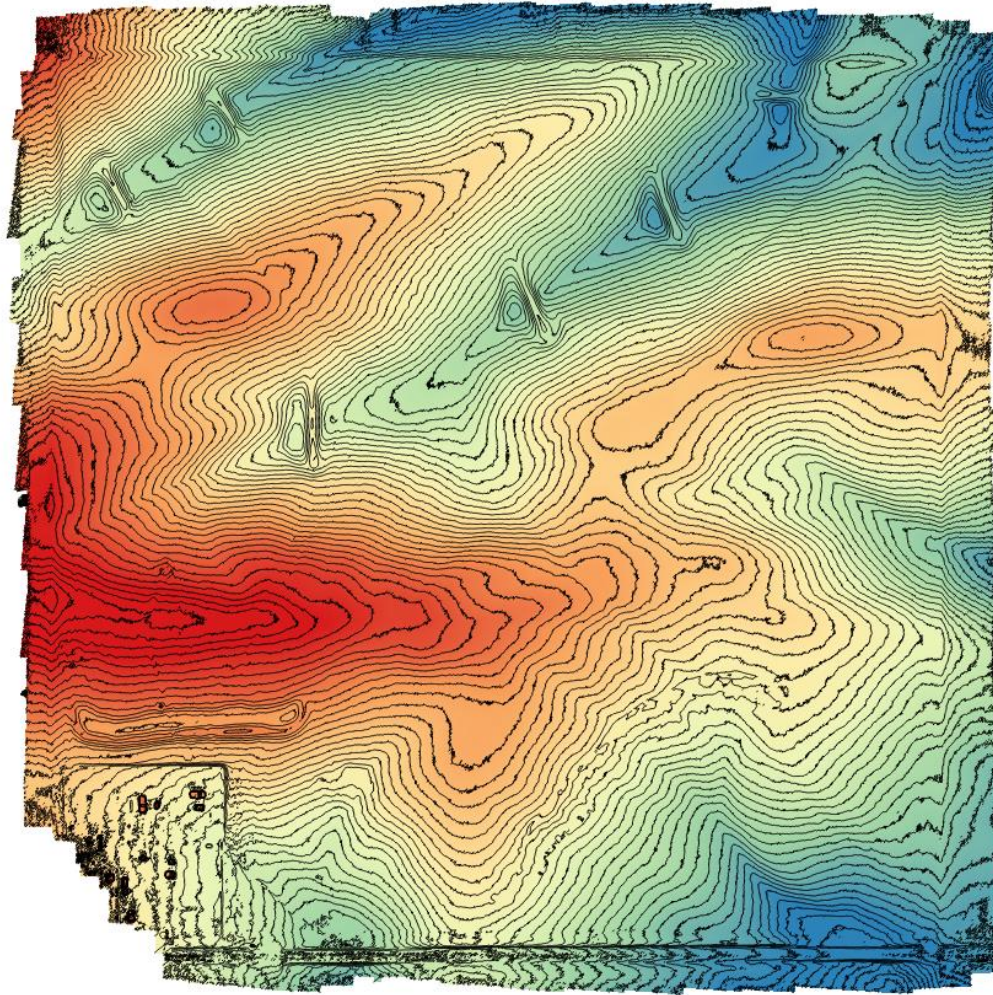
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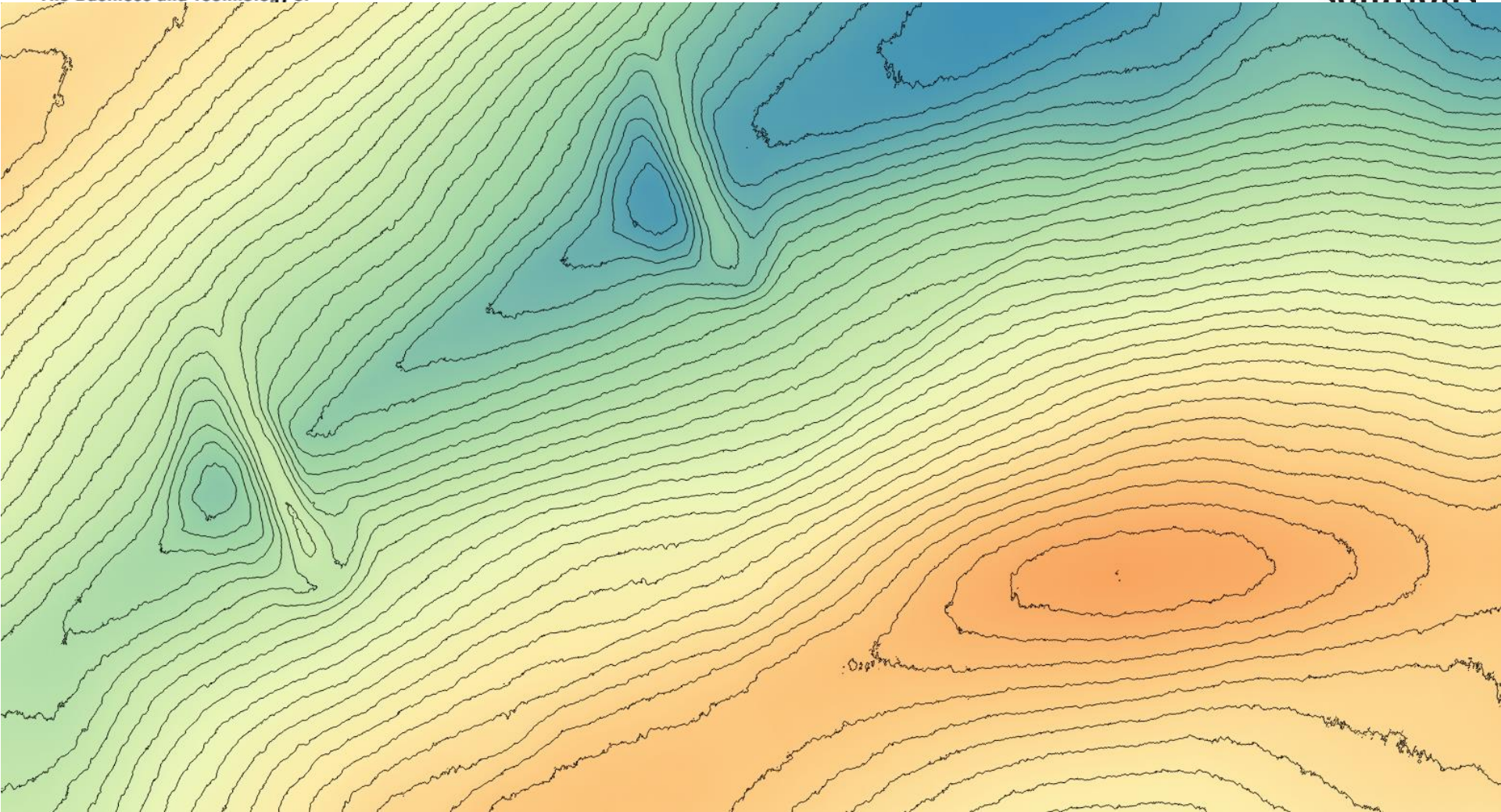
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Third Mission

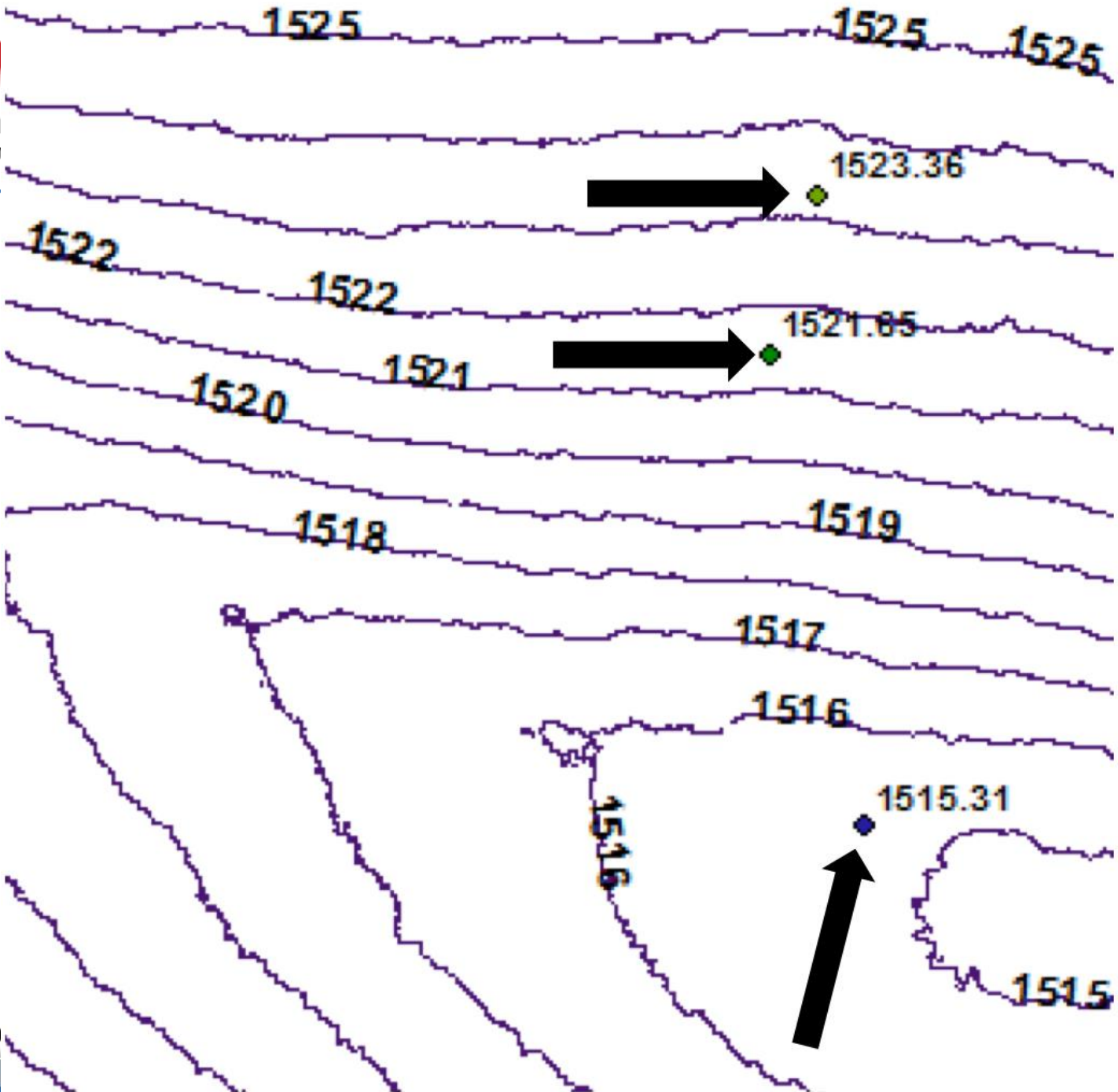


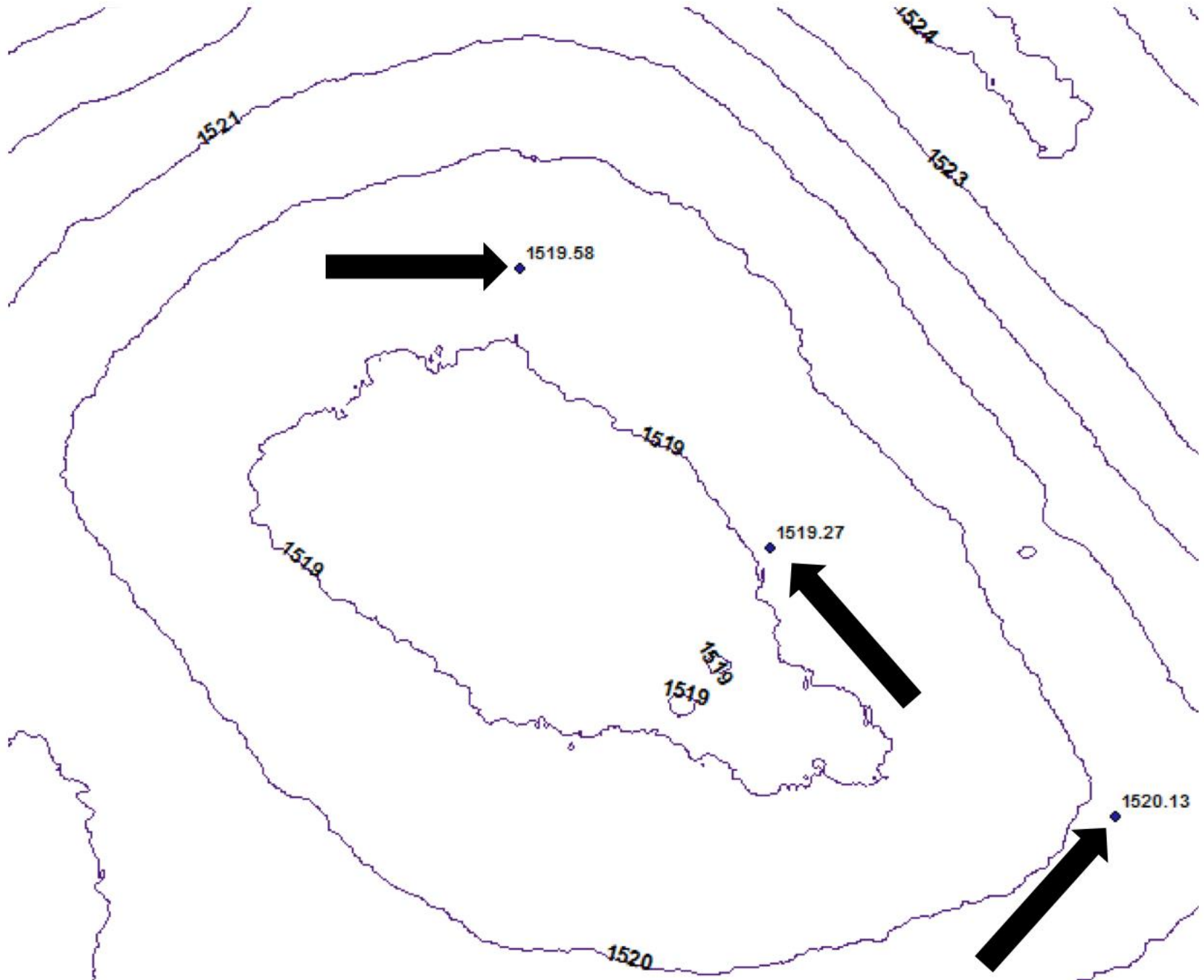


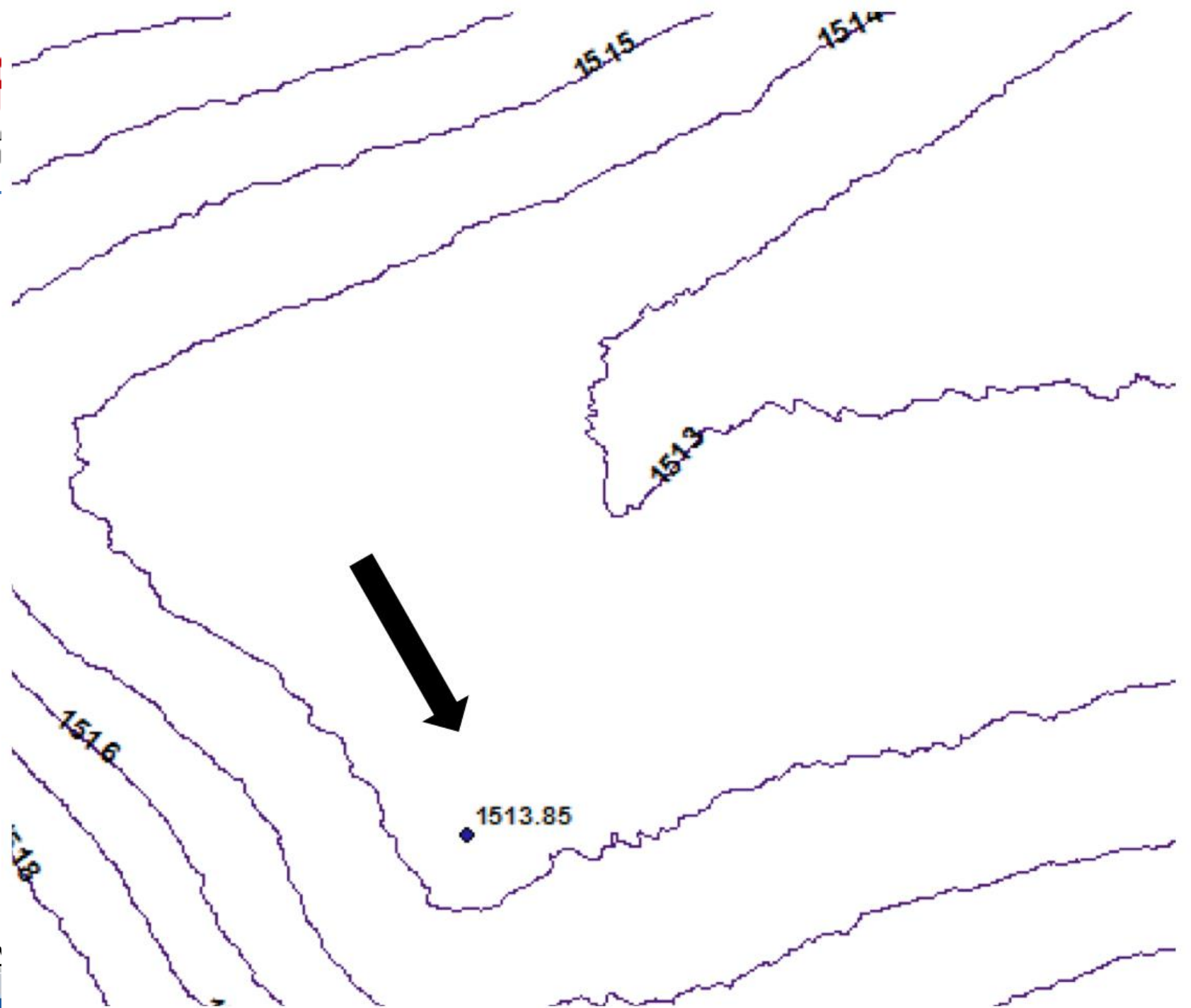
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- Project KAN. ~300 acres.
- Goal: Produce orthophoto and one foot elevation contours.
- Challenges: Weather (rain, wind), batteries, timing (low-tide), birds, image processing.
- Result: In progress.
- Lesson learned: Adjust camera settings to deal with variable-light conditions.







UAS GOTCHAS

- Batteries.
- UAS and Controller (tablet computer)
- 300 acre project was at least 9 UAS battery swaps. On-site charging takes one hour per pack. Multi-pack charger is valuable.
- Set hard limit on battery time. Battery capacity is 23 minutes. I set to 18 minutes.

- Weather.
- Wind, rain and snow are a problem.
- Ideally wind below 10mph.
- No rain.
- Ground can't be blanketed by snow/dirt.
Images won't match up.
- Camera control for varied light conditions.

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- Processing a lot of images takes a lot of horsepower.
- 300 acres produces about 3,000 JPG images @ 5MB each (12MP camera) when flown in one direction at 80% overlap.
- A dedicated high-end “gaming” computer is still take a few hours to process the data.

Comments?

Questions?



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