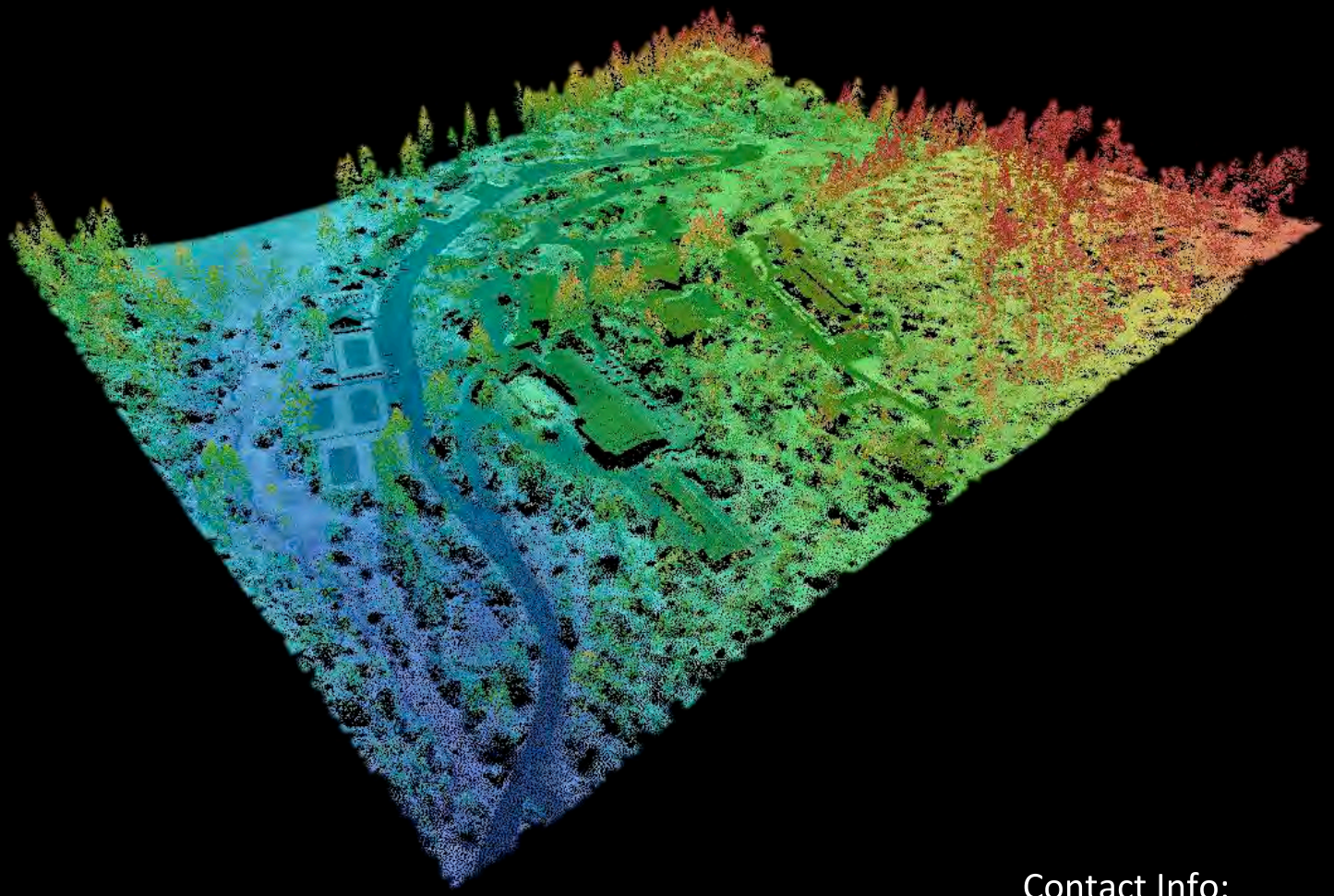
LiDAR and GIS for Trail Design

CA Trails and Greenways Conference
Tenaya Lodge, Yosemite – April 23, 2015

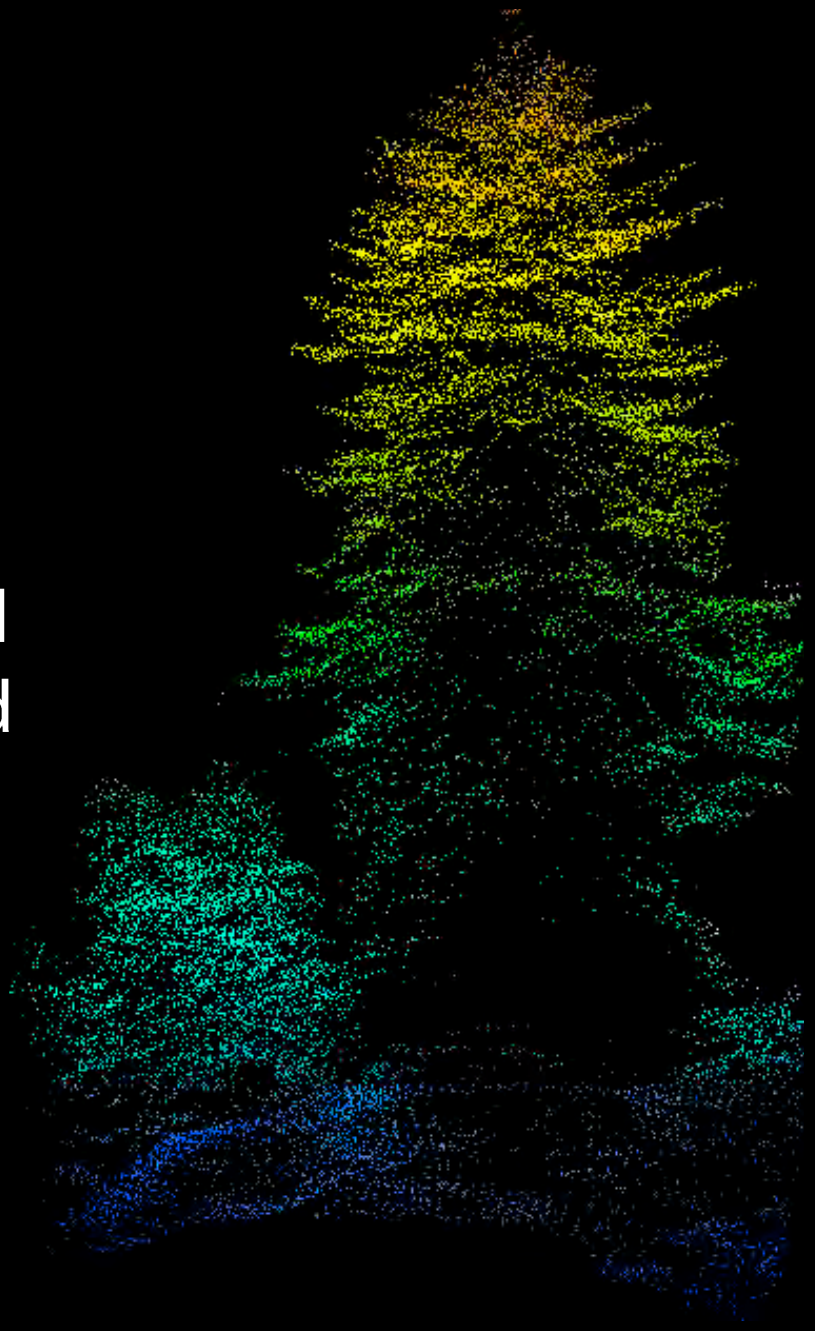


Drew Perkins

Contact Info:
trails@mbosc.org

Overview

- GIS Software and Datasets
- Getting Started with LiDAR
- Using GIS and LiDAR for trail design in the office and field
- Questions?



Free GIS Software Tools

Map Viewers

Google Earth

ArcGIS Explorer

View Imagery, USGS Topos, GPS points and other shapefiles.

Digitize new features, measure distances, and areas. Print, or share maps on-line.

Desktop GIS

Quantum GIS

Working with your data
More advanced editing
Terrain Analysis: Hillshade, Slope, Contours, stream lines…
Print Maps

GPS Utility

DNR GPS

Download tracks and waypoints from GPS to Desktop or vice versa.
(Formerly DNR Garmin)

Google Earth

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image

Google earth

Google Earth (Pro version now free)

What is it good for:

- Fast, Hi-res Imagery
- Load KML, GPS points, .shp files
- web and photo links

- Easy sharing online

Limitations:

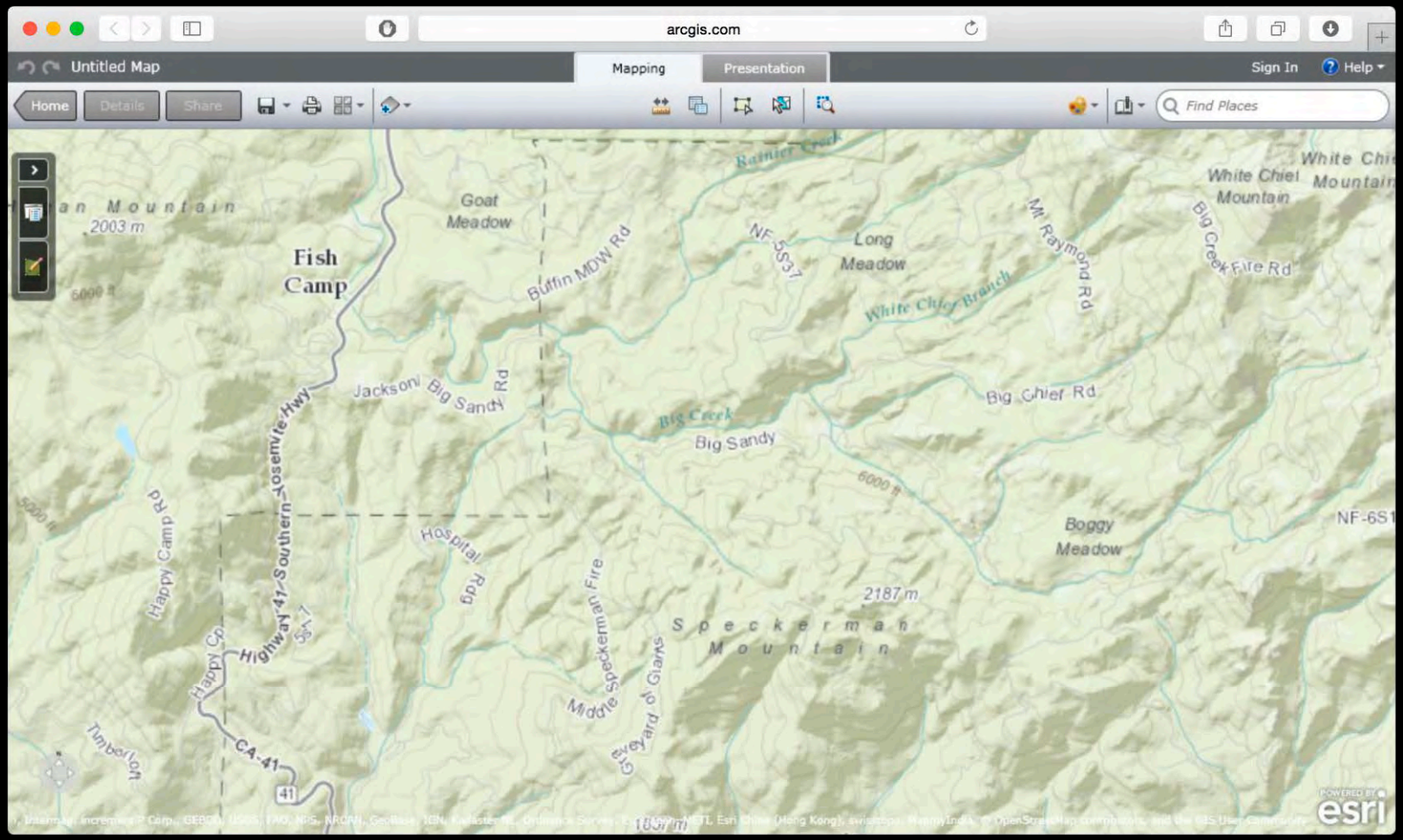
- symbology
- labeling
- analysis

- no map layout
- low quality topographic data

ArcGIS Explorer Online

ESRI's Free web or desktop GIS viewer

[ArcGIS Explorer Online]



ArcGIS Explorer

What is it good for:

- Imagery
- USGS Topo
- Upload GPS/Shapefiles

Simple Measurement, information and queries

Limitations:

- labeling
- export layers?
- analysis

no map layout tools

Low-res printed maps

Quantum GIS (QGIS)

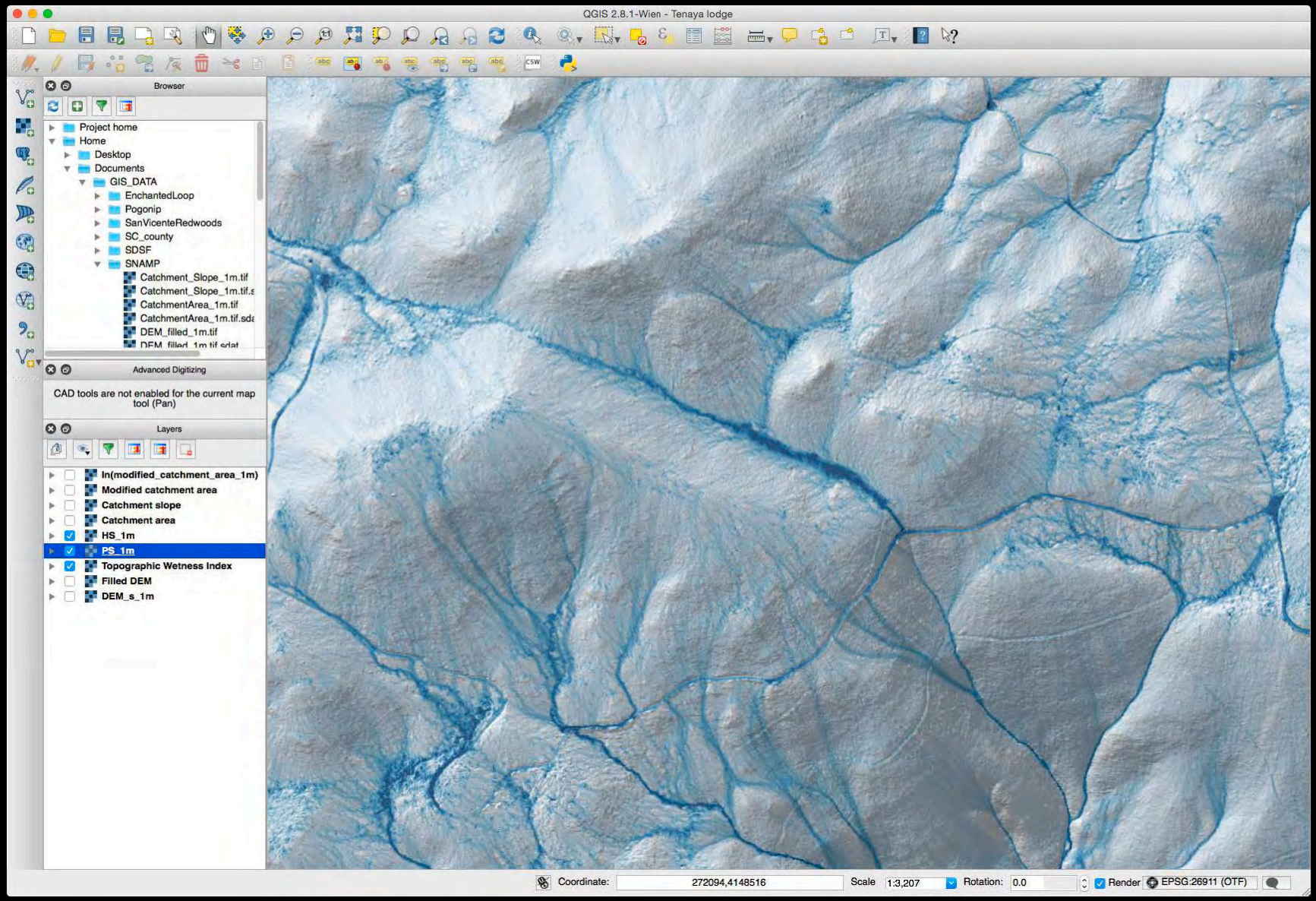
For PC or Mac, QGIS offers a full-featured desktop GIS application

Open Source: developed, updated and supported by the GIS community

(Universities, Federal Agencies, ACOE, users)

Spatial Analysis with Quantum GIS

Hillshades, slopes, and hydrology



Quantum GIS

What is it good for:

Multi-purpose

diverse file types

basic and advanced spatial analysis

It can get the job done

Limitations:

learning curve

some tools will fail

some gaps in functionality - improving

but you've got to put some time in…

Why GIS?

Trail planning and design is collaborative, iterative, and of course, spatial

GIS is a tool to organize, design/create, share, use, edit, update…and repeat

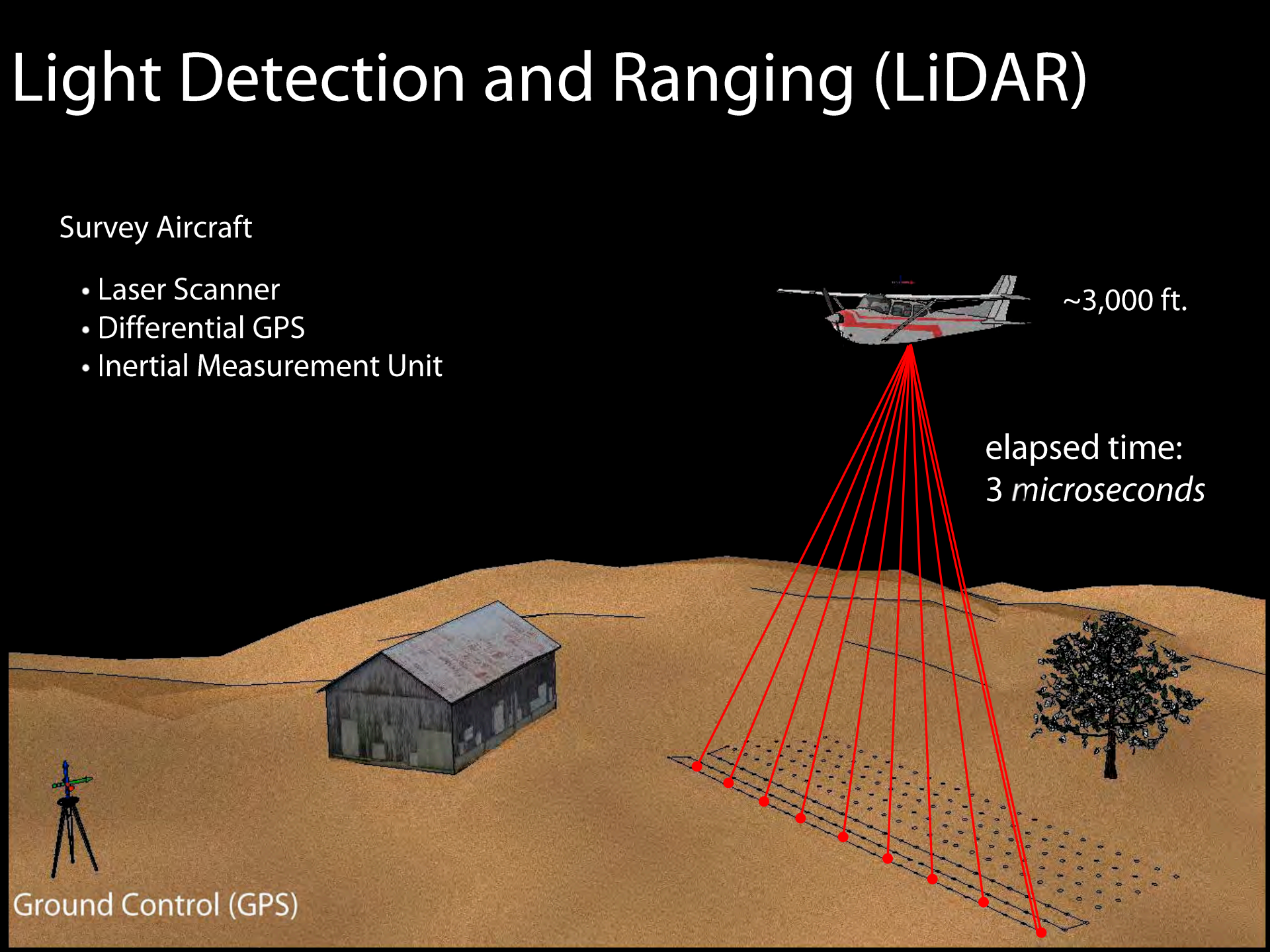
In other words, its more than mapping

When you have access to high quality data, take advantage of it!

Light Detection and Ranging (LiDAR)

Survey Aircraft

- Laser Scanner
- Differential GPS
- Inertial Measurement Unit



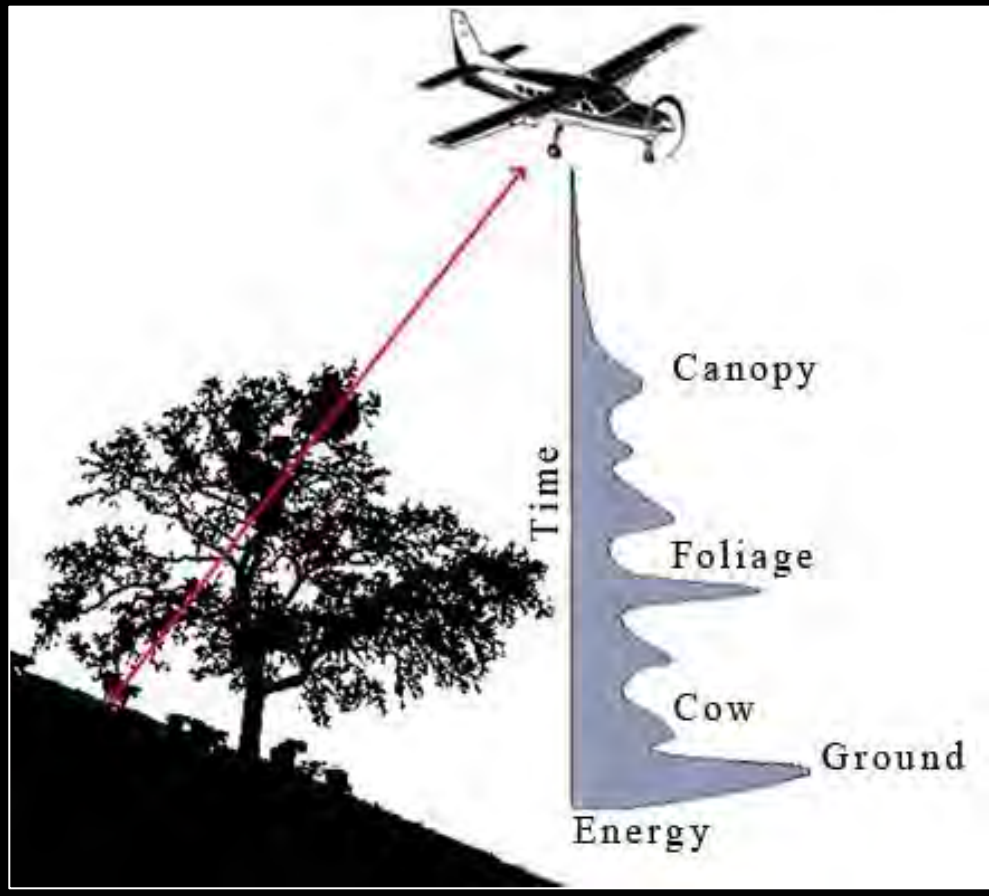
Multiple Returns

For each pulse, one or more returns

Typically, 1-4 returns per pulse

Provides vertical profile

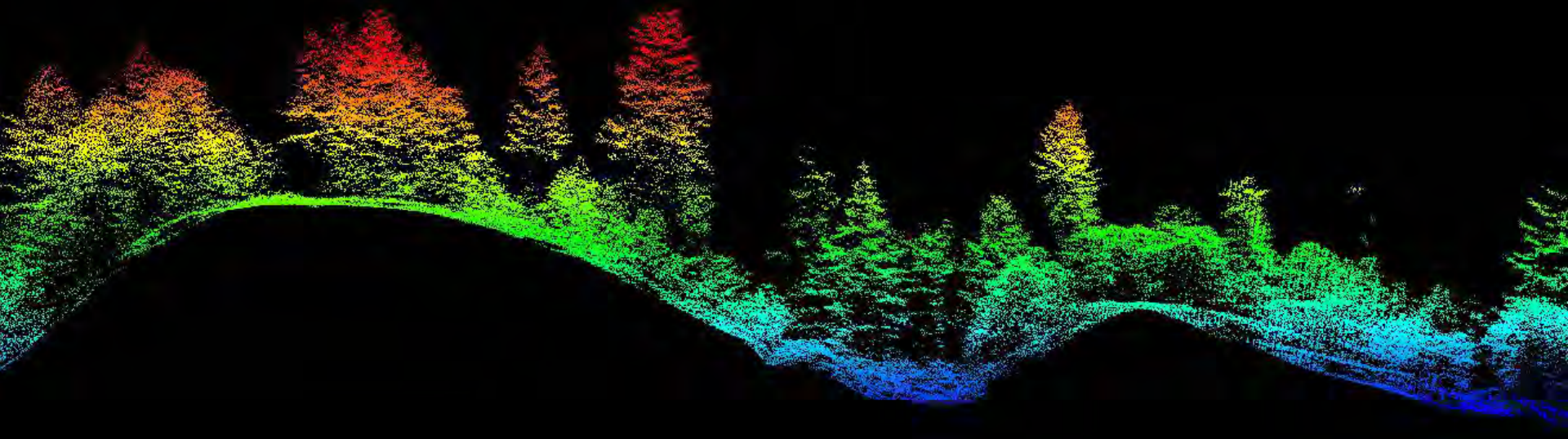
Last returns used to determine the ground surface



http://www.ensisjv.com/Portals/0/lidarimage002.jpg

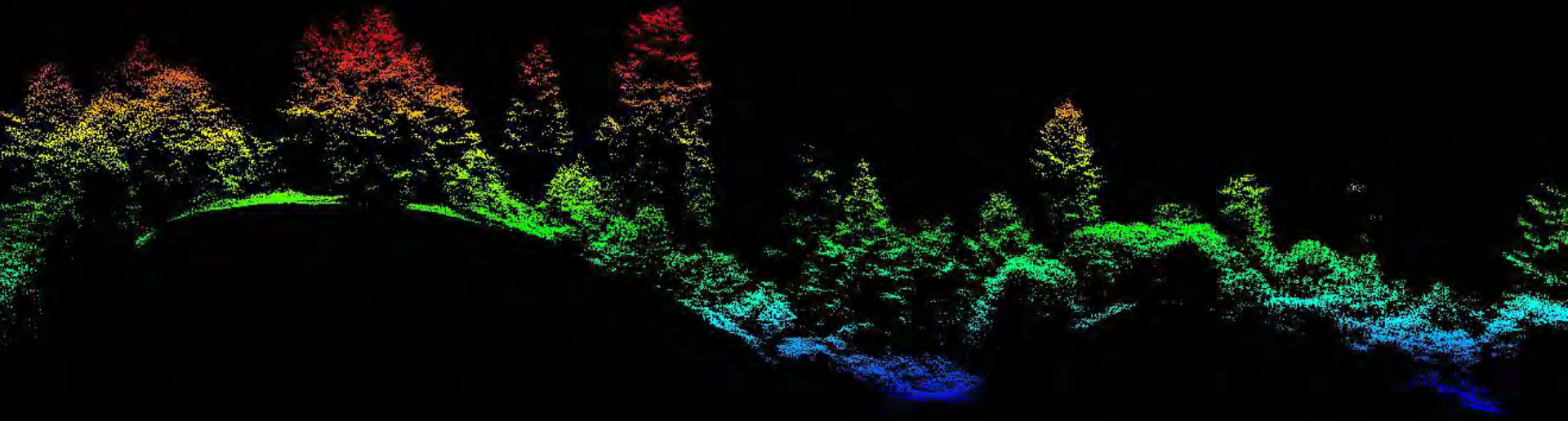
Point Cloud: Profile View

All Returns



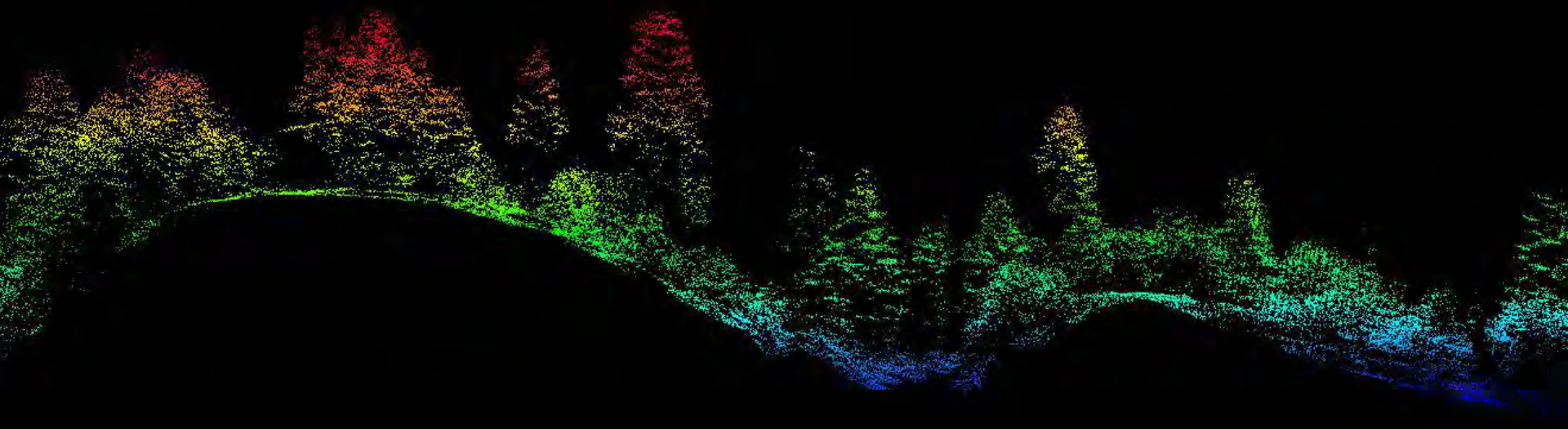
Point Cloud: Profile View

First Returns



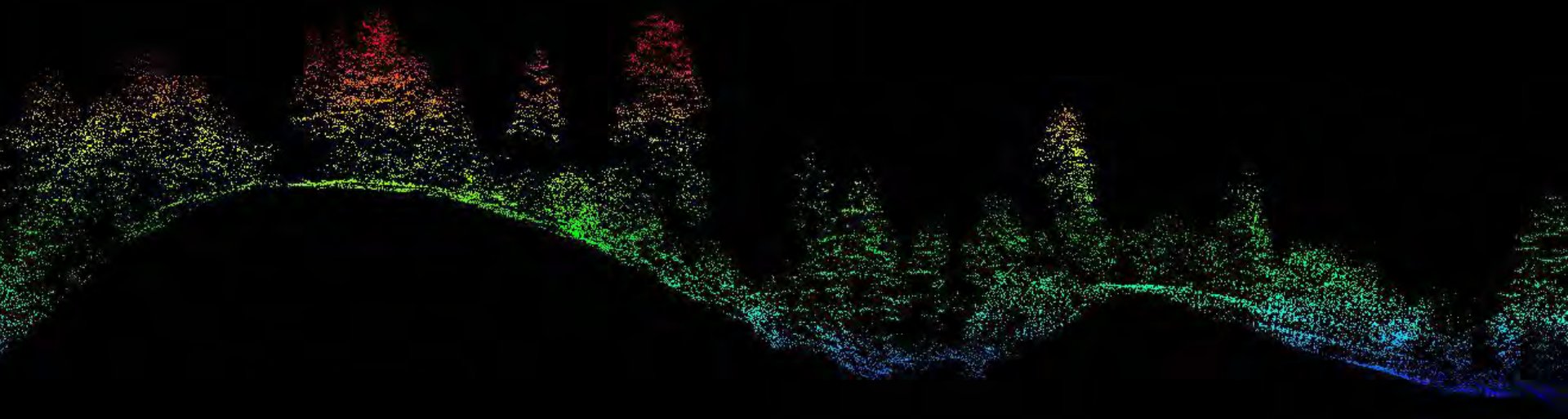
Point Cloud: Profile View

Second Returns



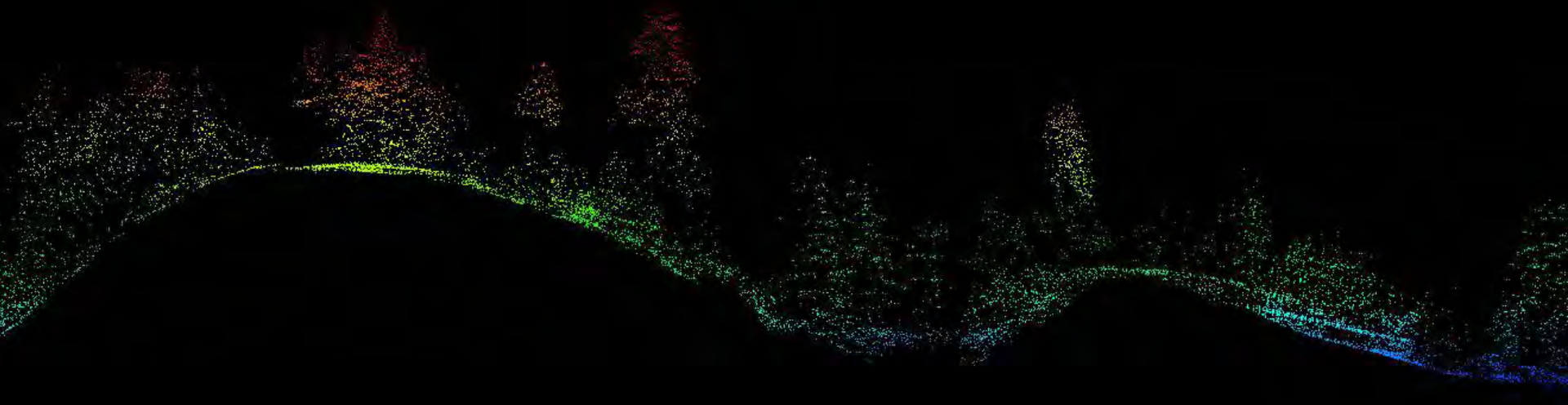
Point Cloud: Profile View

Third Returns



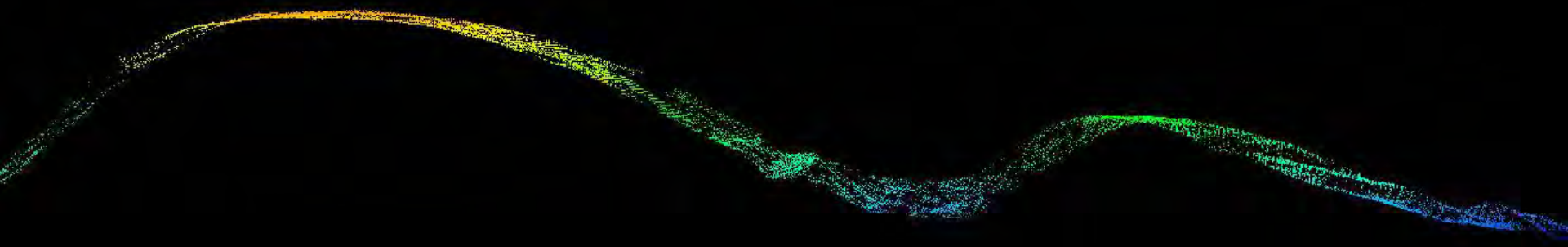
Point Cloud: Profile View

Fourth Returns



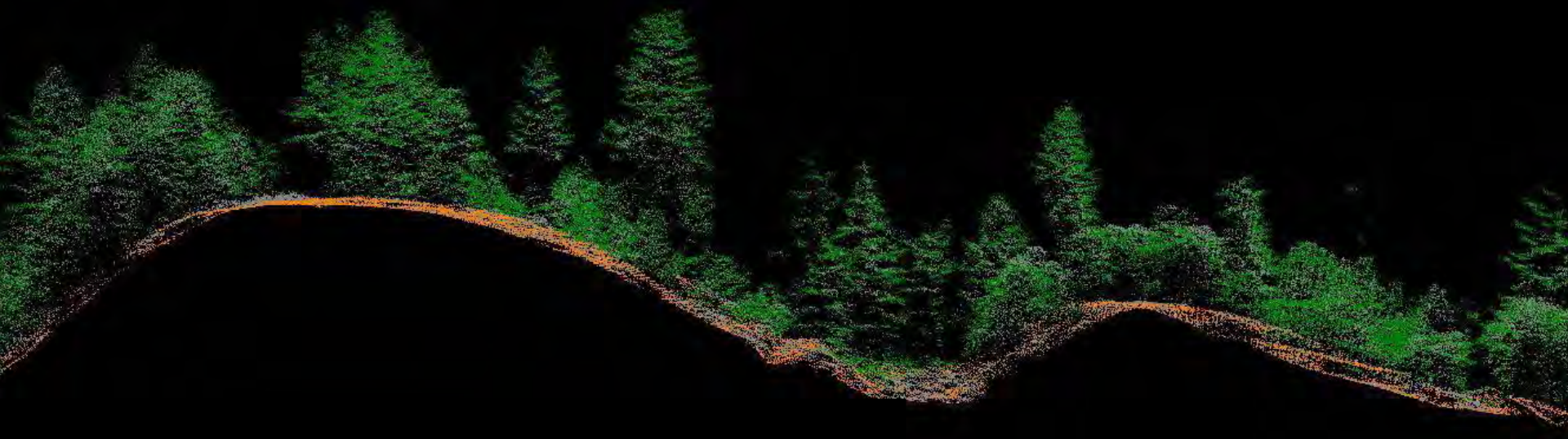
Point Cloud: Profile View

Filtered Ground Returns



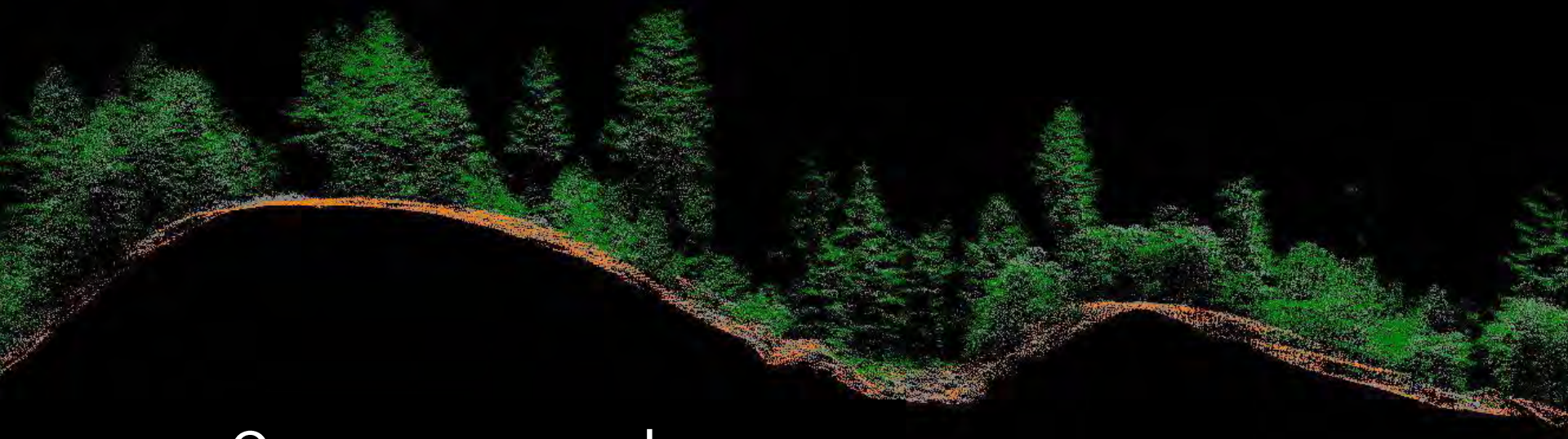
Point Cloud: Profile View

Classified Returns



Point Cloud: Profile View

Classified Returns



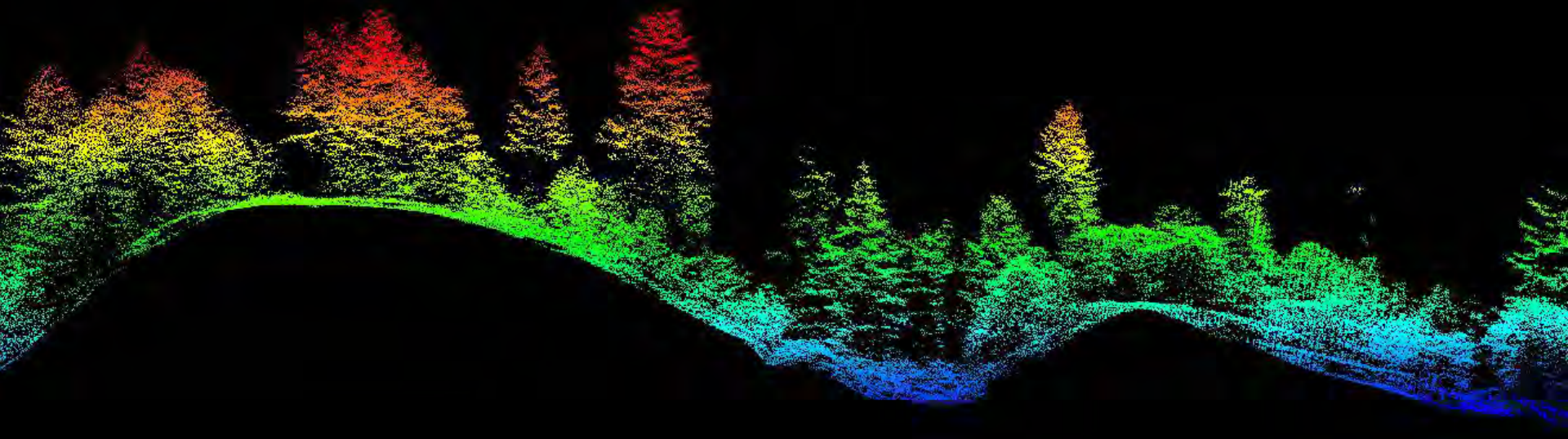
Orange = ground

Green = vegetation

Grey = unclassified

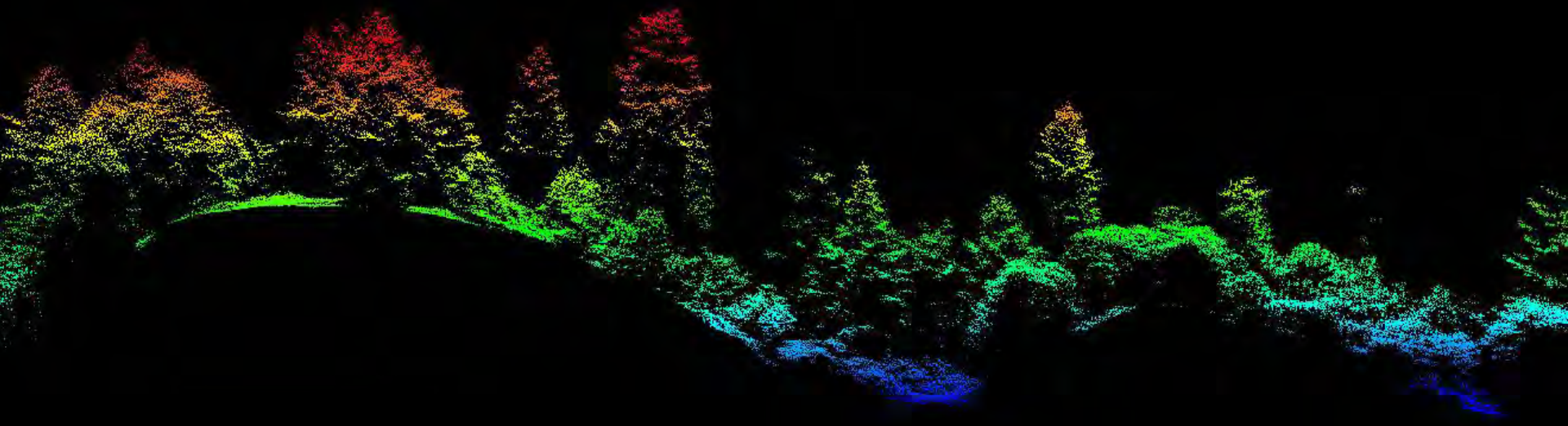
Point Cloud: Profile View

All Returns



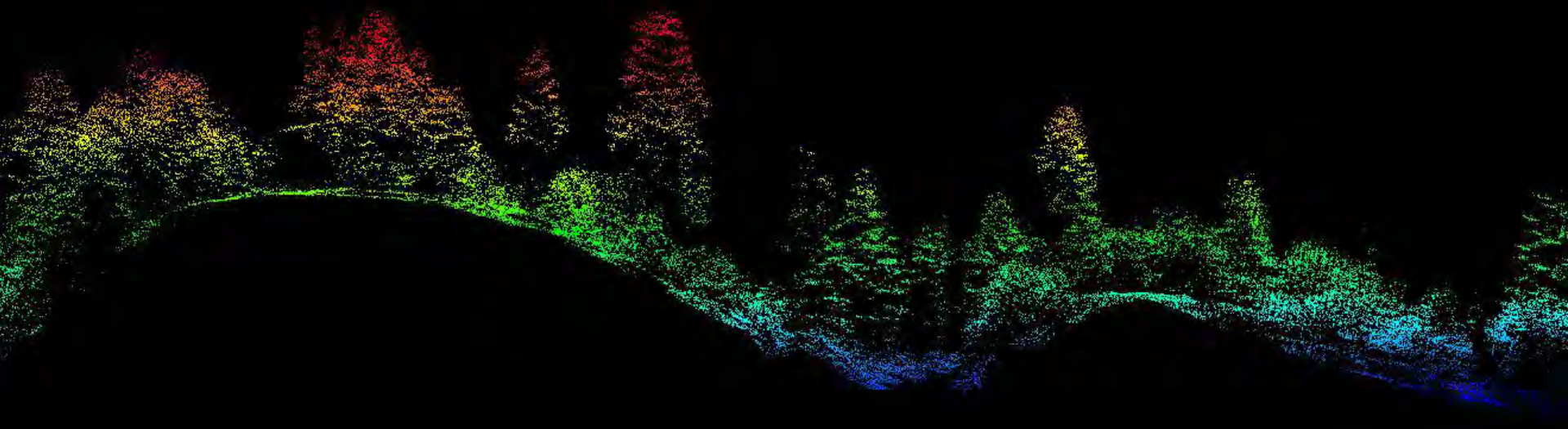
Point Cloud: Profile View

First Returns



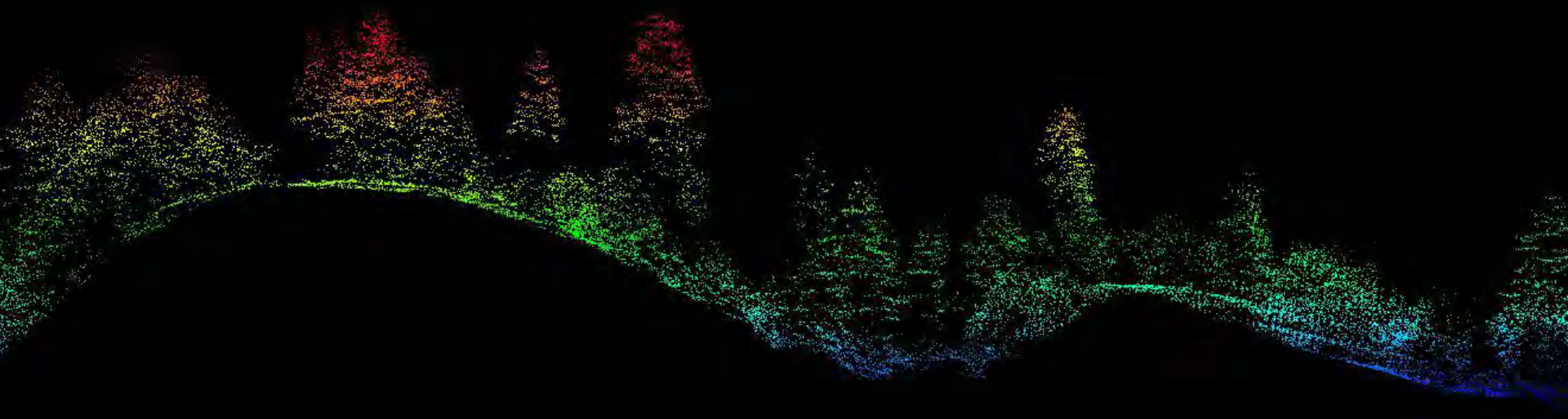
Point Cloud: Profile View

Second Returns



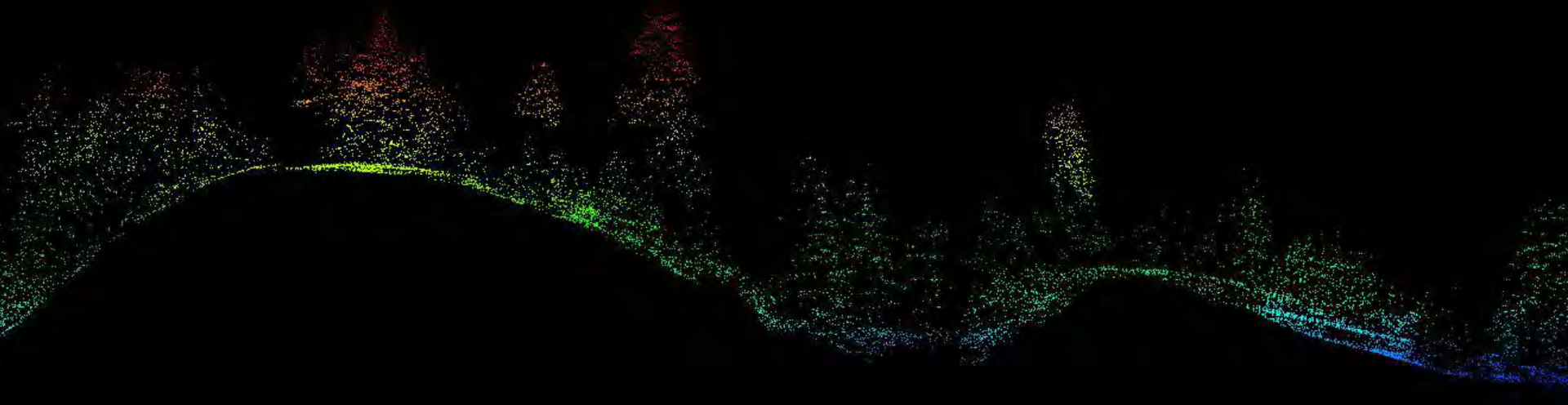
Point Cloud: Profile View

Third Returns



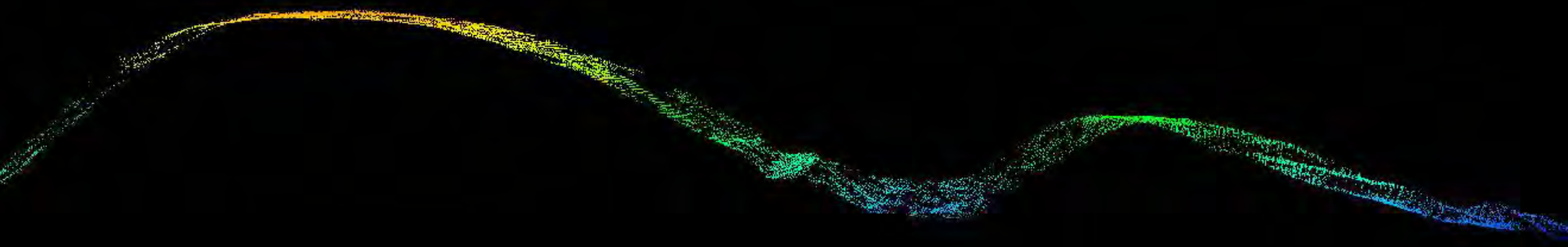
Point Cloud: Profile View

Fourth Returns



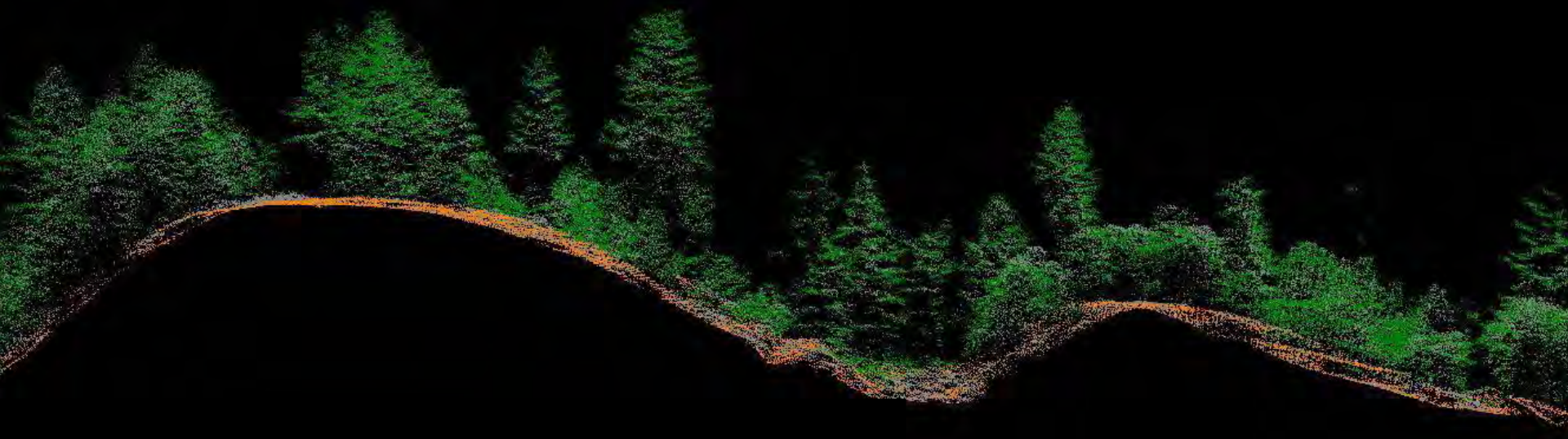
Point Cloud: Profile View

Filtered Ground Returns



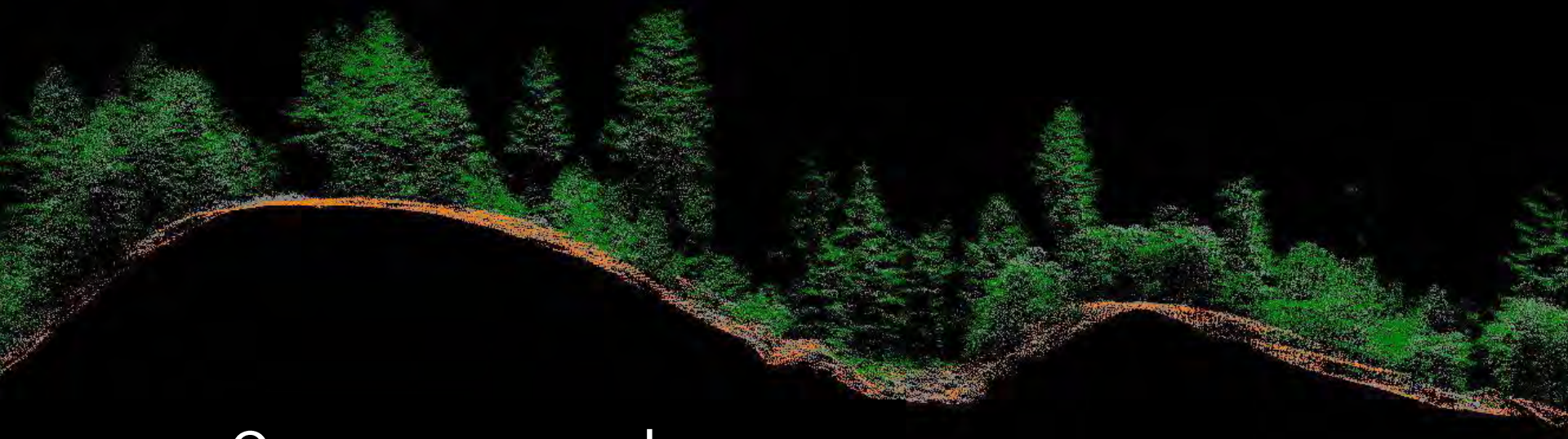
Point Cloud: Profile View

Classified Returns



Point Cloud: Profile View

Classified Returns



Orange = ground

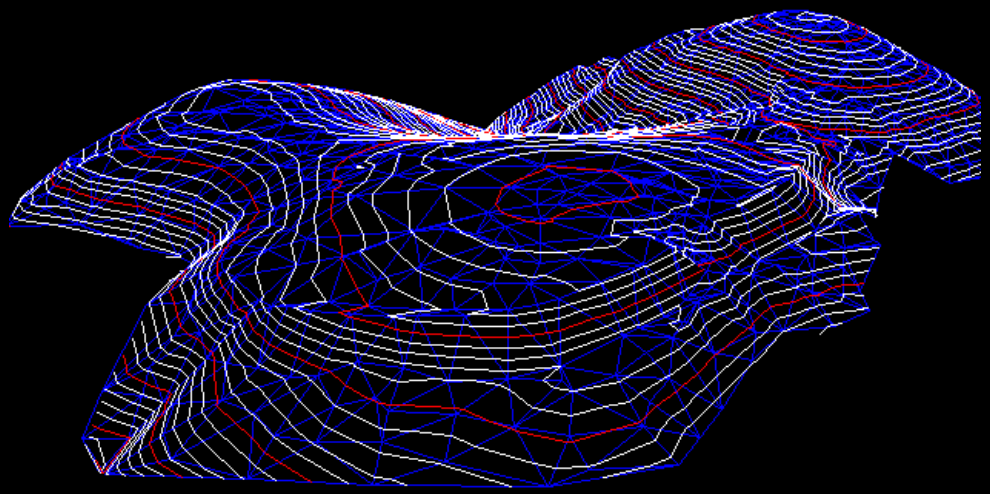
Green = vegetation

Grey = unclassified

Making a digital elevation model (DEM)

Filtered ground points are interpolated onto a grid to develop a digital elevation model. Best method depends on quality and density of ground points.

Most common method is using a TIN (triangulated irregular network) based on ground points



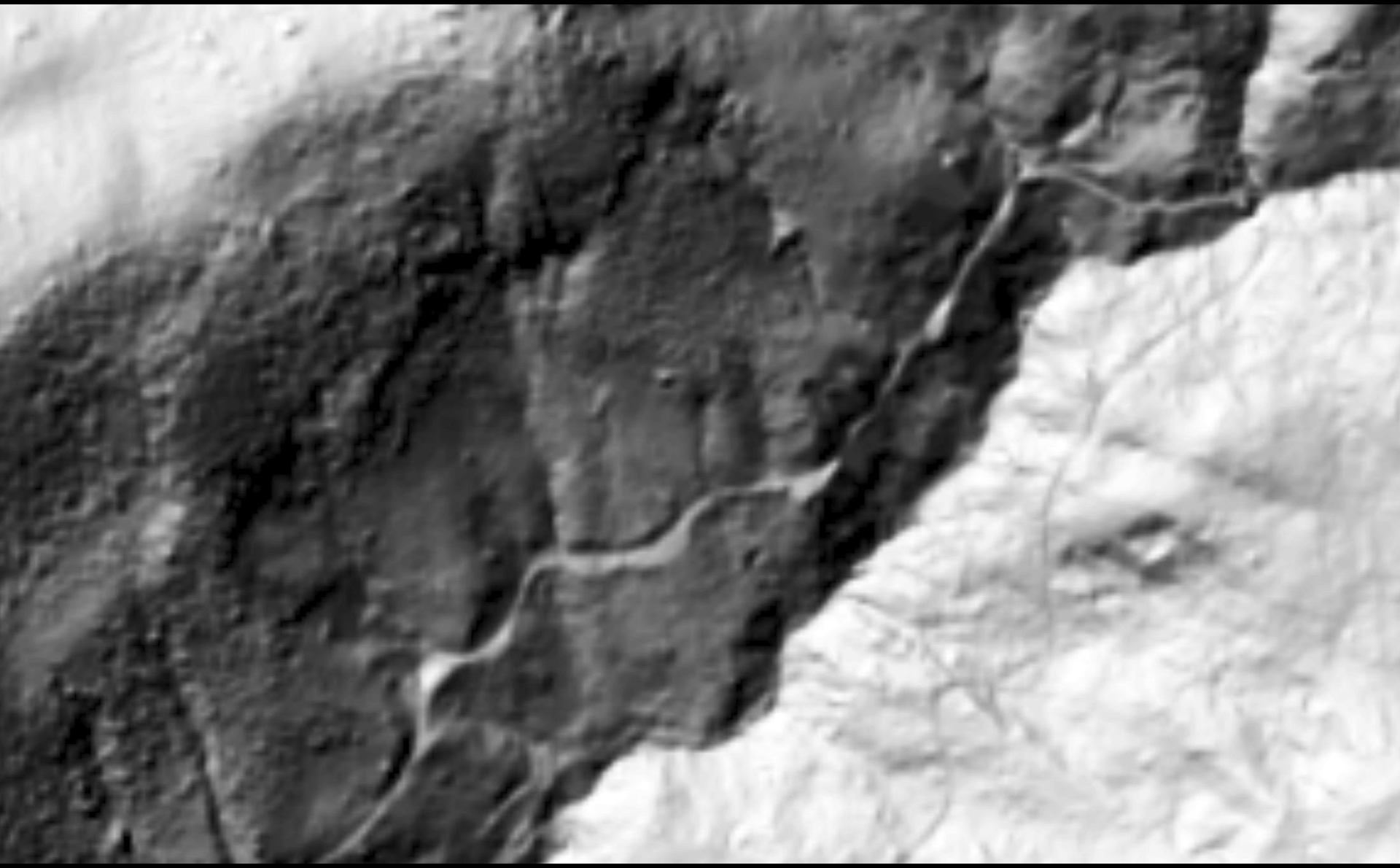
"Digitales Geländemodell" by Robert Kropf at de.wikipedia Licensed under CC BY-SA 3.0 de via Wikimedia Commons

Improvements in DEM Resolution

USGS 10 m DEM

Little Creek at Cal Poly Swanton Pacific Ranch

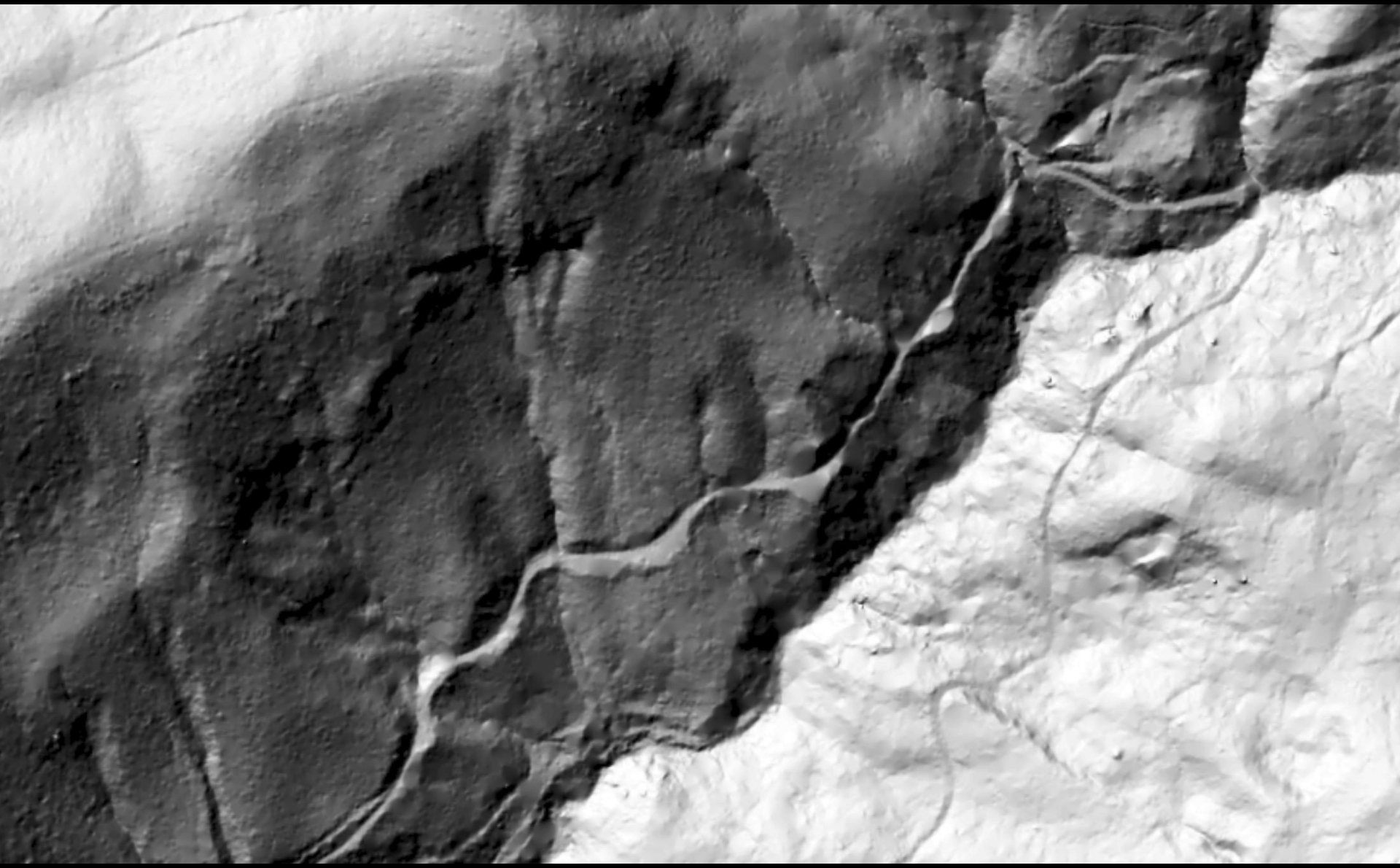
Improvements in DEM Resolution



LiDAR 3 m DEM (2002)

Little Creek at Cal Poly Swanton Pacific Ranch

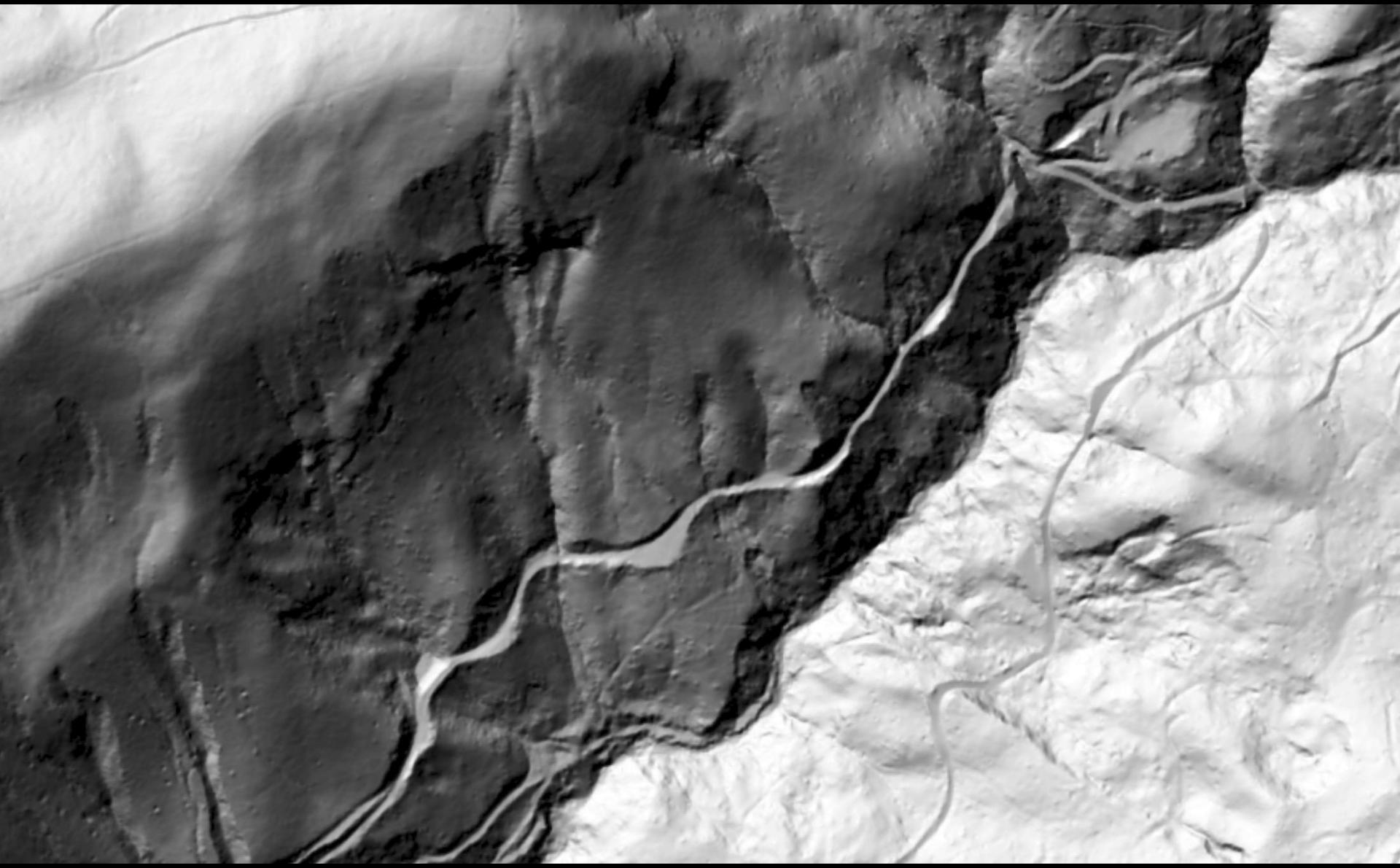
Improvements in DEM Resolution



LiDAR 1 m DEM (2008)

Little Creek at Cal Poly Swanton Pacific Ranch

Improvements in DEM Resolution

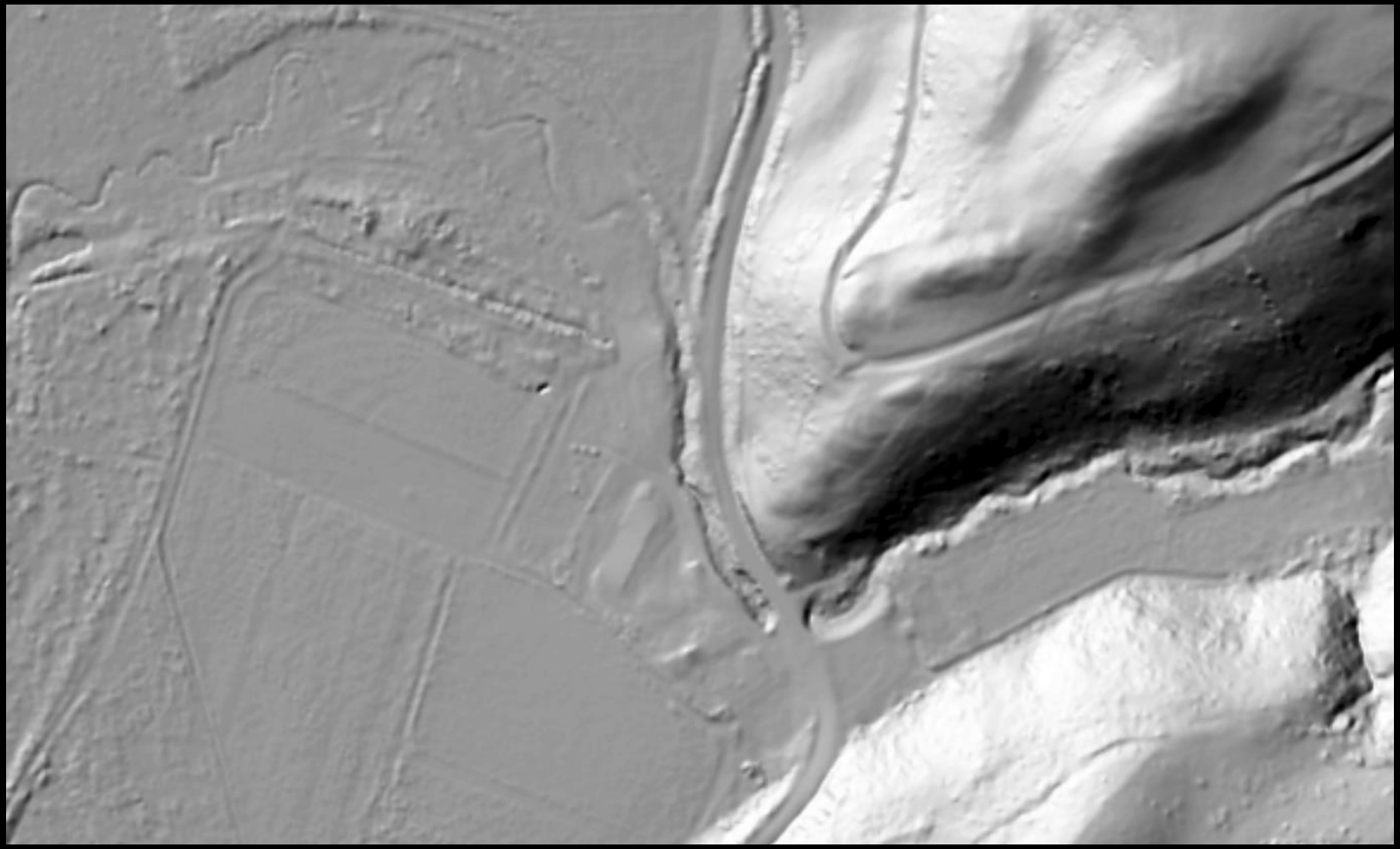


(even better) LiDAR 1 m DEM (2010)

Little Creek at Cal Poly Swanton Pacific Ranch

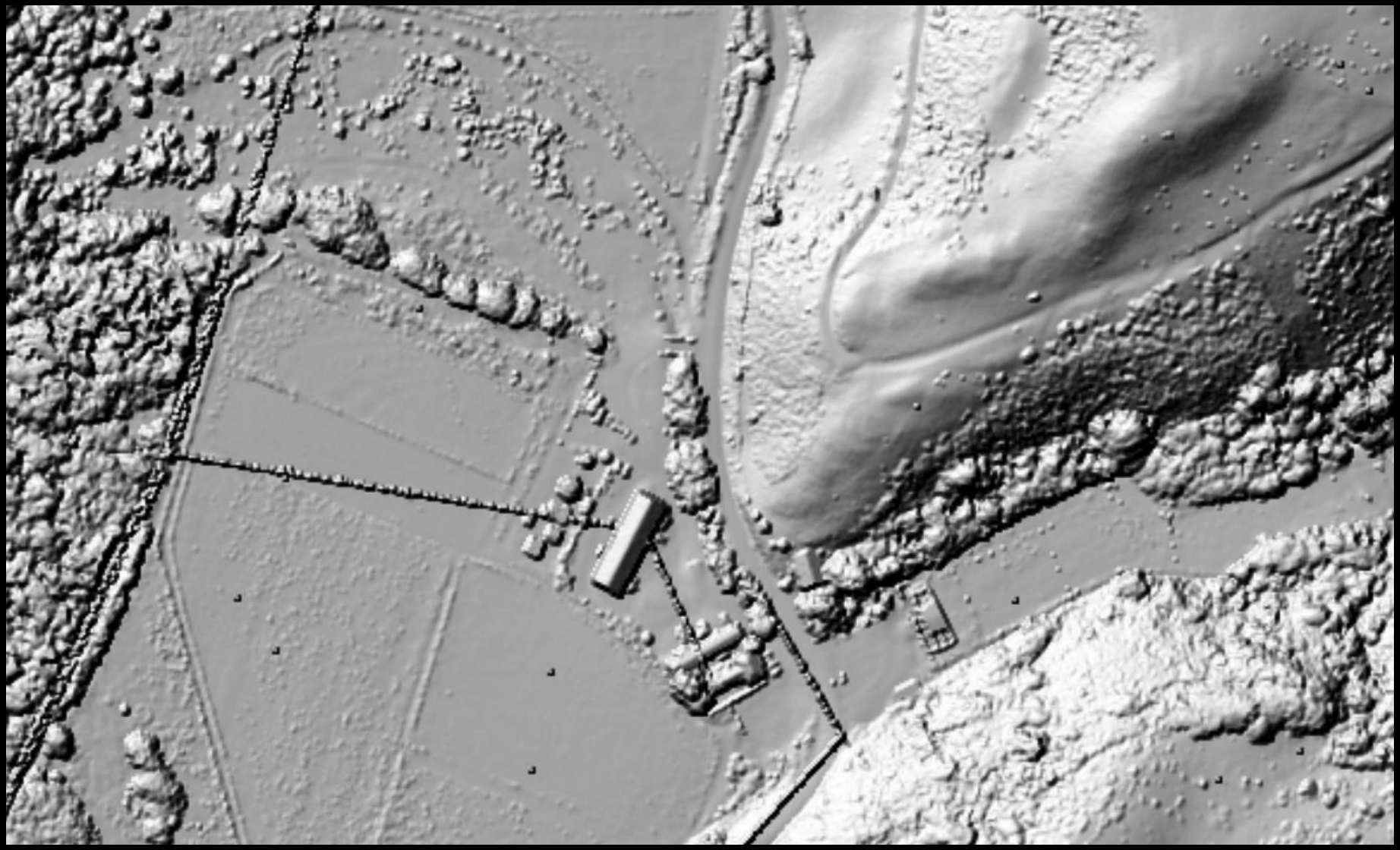
Bare Earth DEM, with hillshade

typical deliverable of vendor



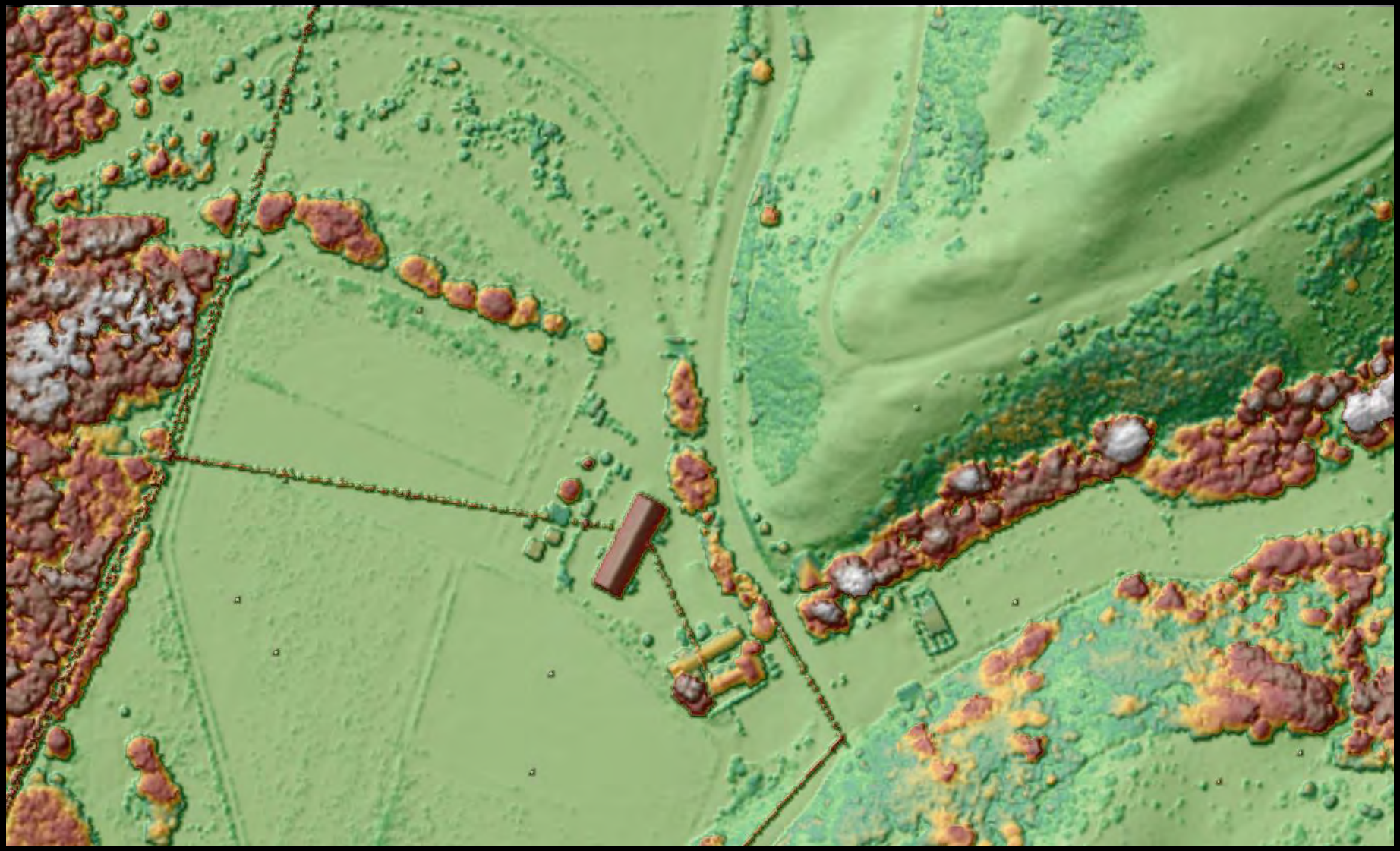
Digital Surface Model DSM

highest-hit elevation for each 1m cell



Highest Hit – Ground Surface = Height off ground

aka Canopy Height Model (CHM)



LiDAR Intensity Image

grayscale image of surface reflectance

Layer combinations

Image transparency and hillshade

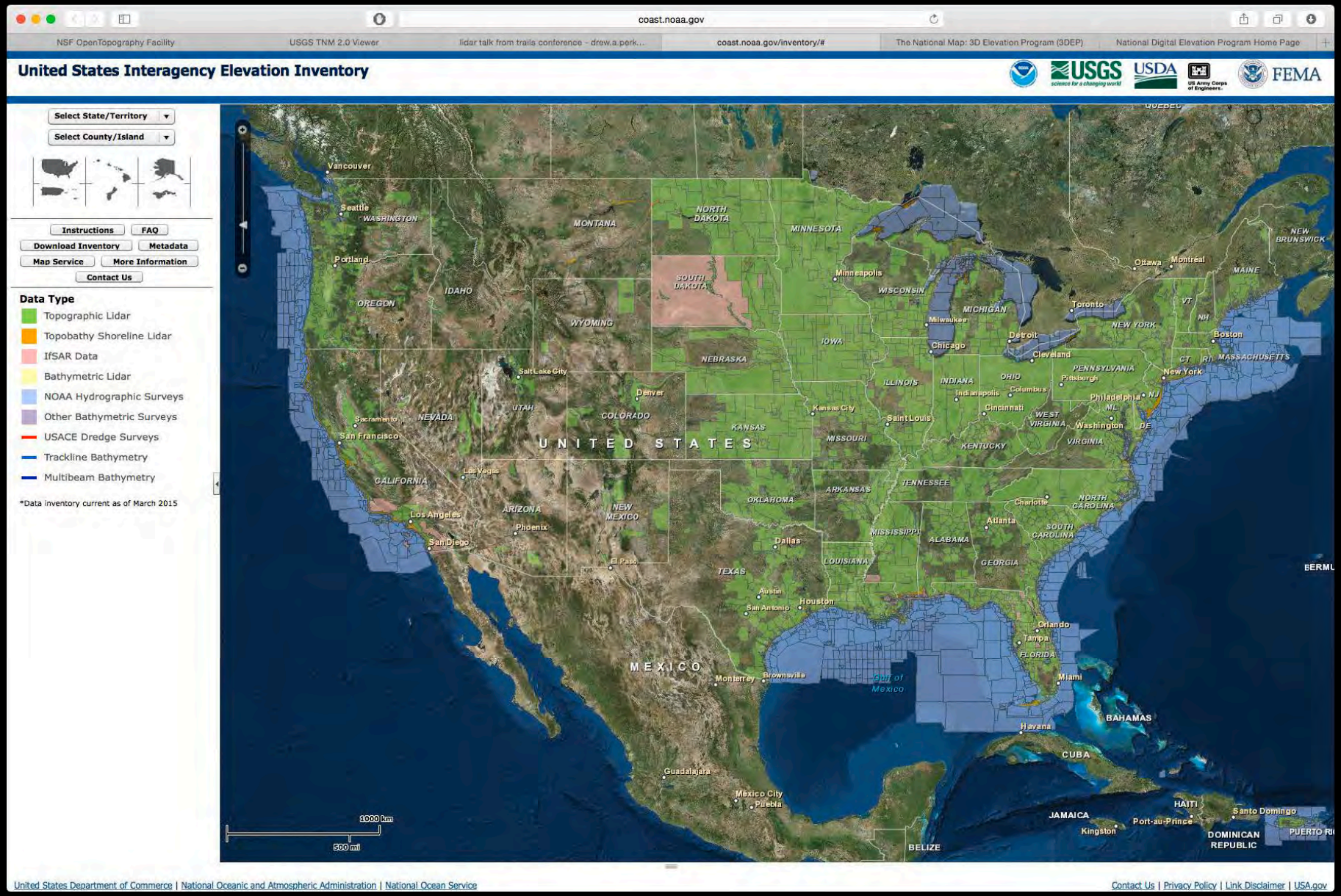
LiDAR provides both detail *and* broad landscape coverage

Bare Earth DEM (filtering in progress)

LiDAR provides both detail *and* broad landscape coverage

Canopy Height Layer

United States Interagency Elevation Inventory



United States Interagency Elevation Inventory

Select State/Territory

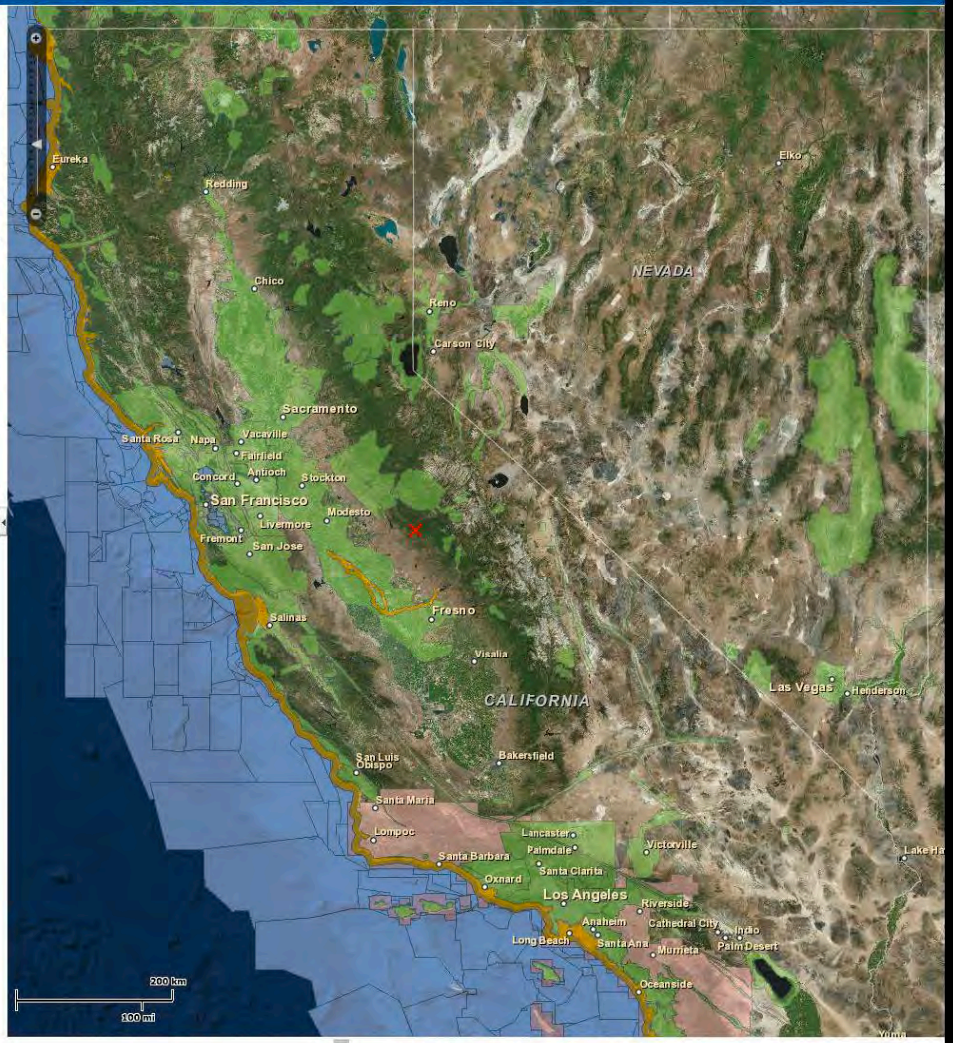
Select County/Island

Instructions | FAQ | Download Inventory | Metadata | Map Service | More Information | Contact Us

Data Type

- Topographic Lidar
- Topobathy Shoreline Lidar
- IfSAR Data
- Bathymetric Lidar
- NOAA Hydrographic Surveys
- Other Bathymetric Surveys
- USACE Dredge Surveys
- Trackline Bathymetry
- Multibeam Bathymetry

*Data inventory current as of March 2015



Topographic | Bathymetric | Clear Data

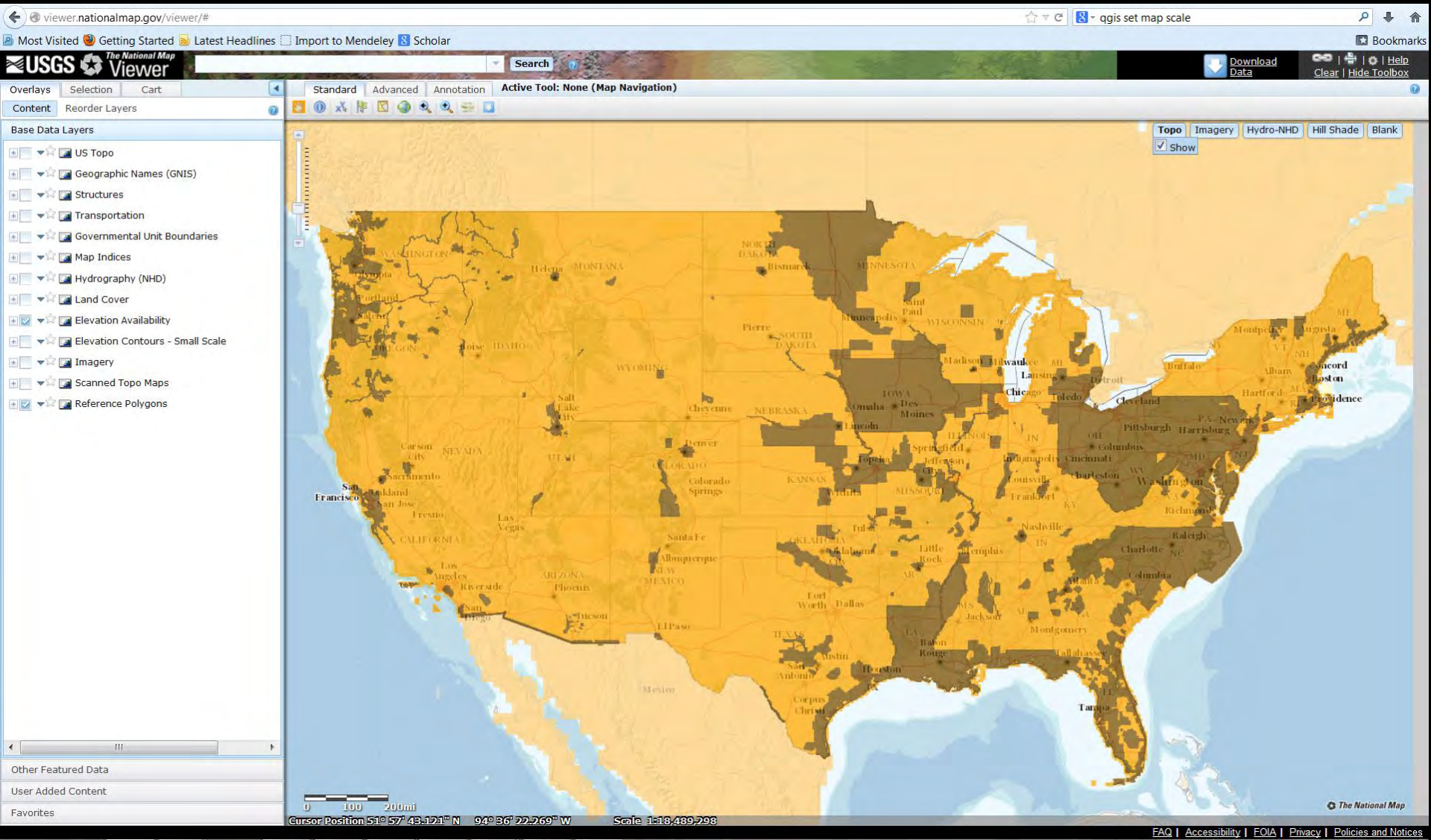
Current Location: 37.542819 , -119.972151

Print Report

Data Set Name	Data Access	Metadata Access	Collection Date	Project Status	Restrictions	Data Type	Vertical Accuracy	Horizontal Accuracy	Point Spacing	Vertical Datum	Horizontal Datum	Pr

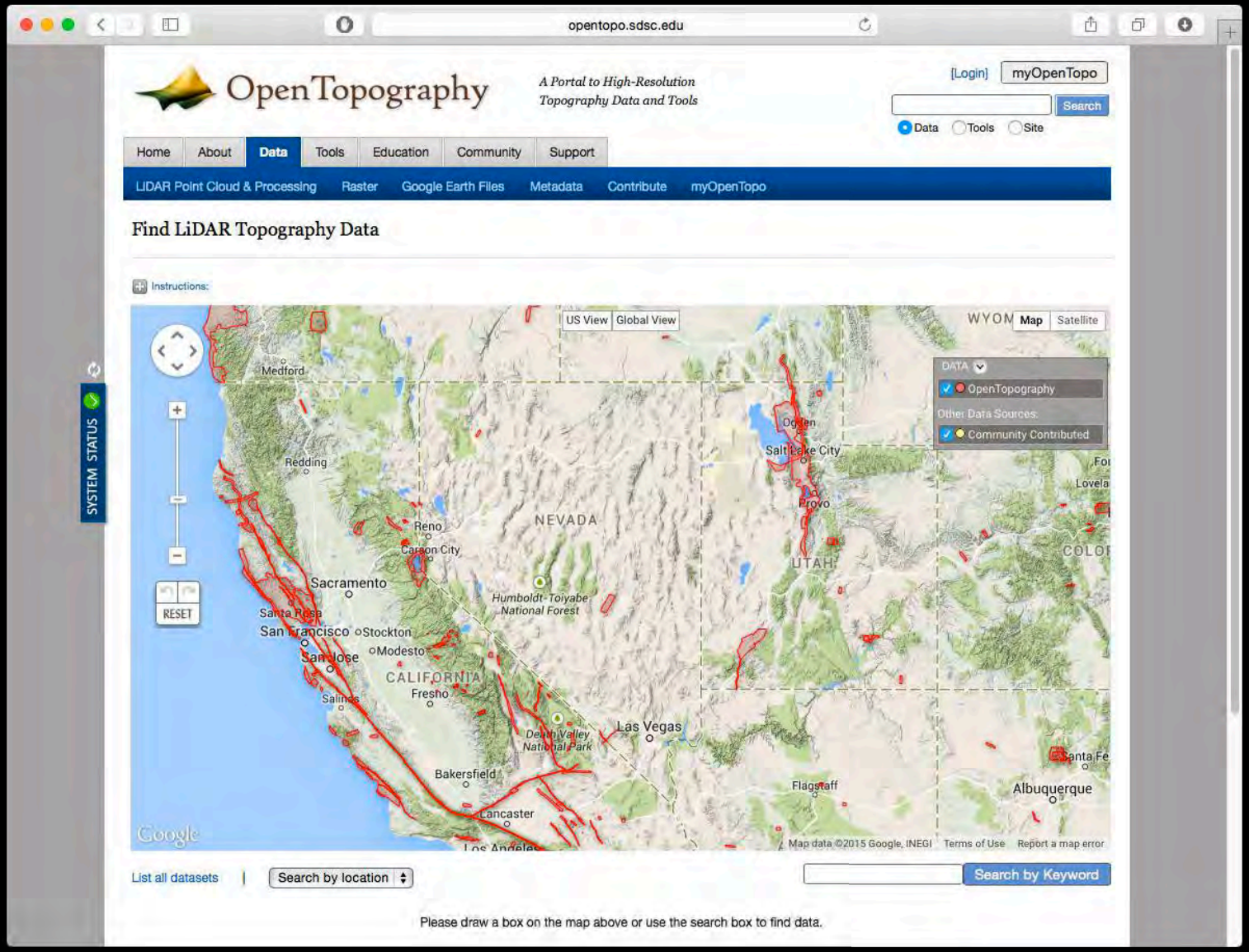
Where is LiDAR Available?

The [USGS National Map]



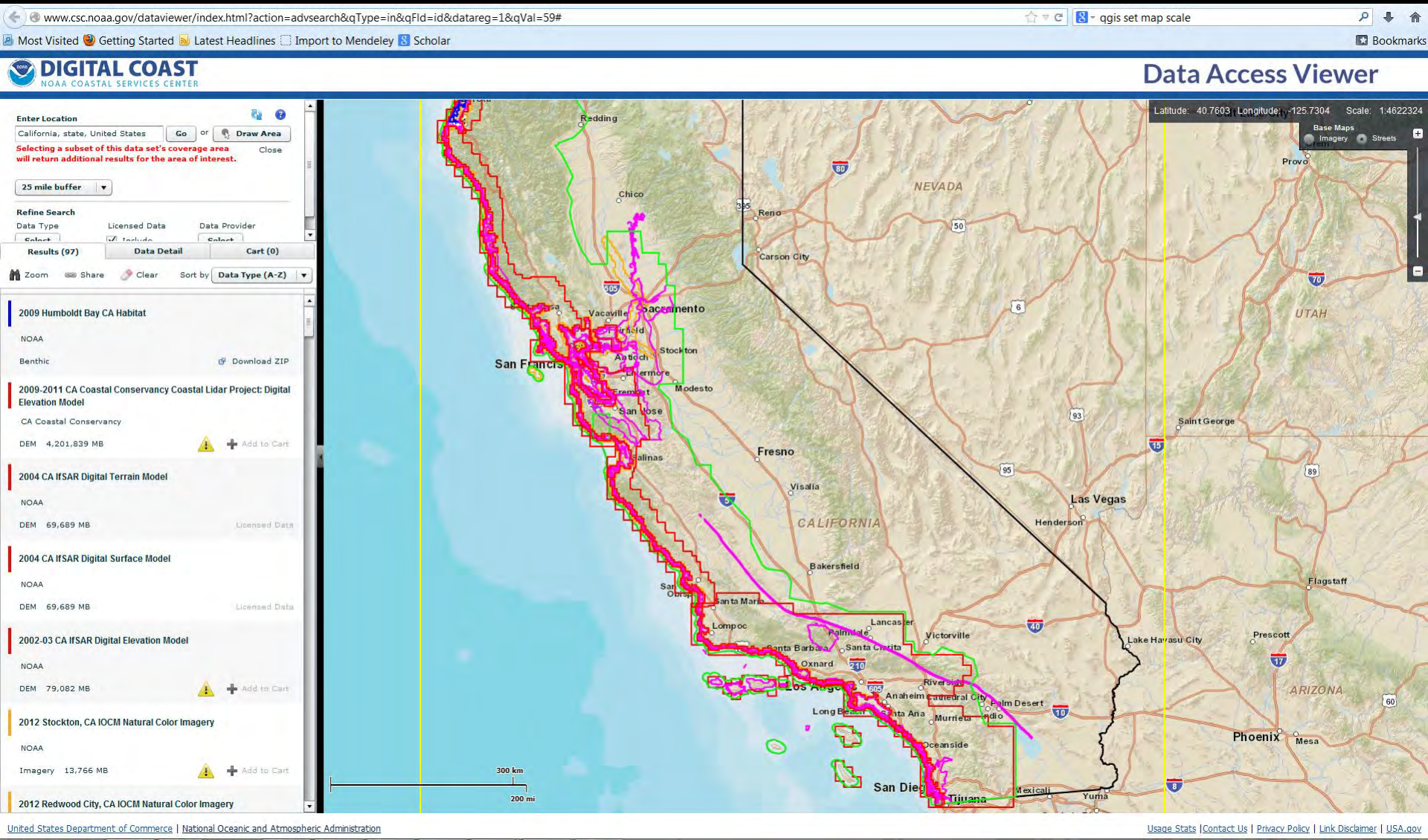
Where is LiDAR Available?

NSF Opentopography.org



Where is LiDAR Available?

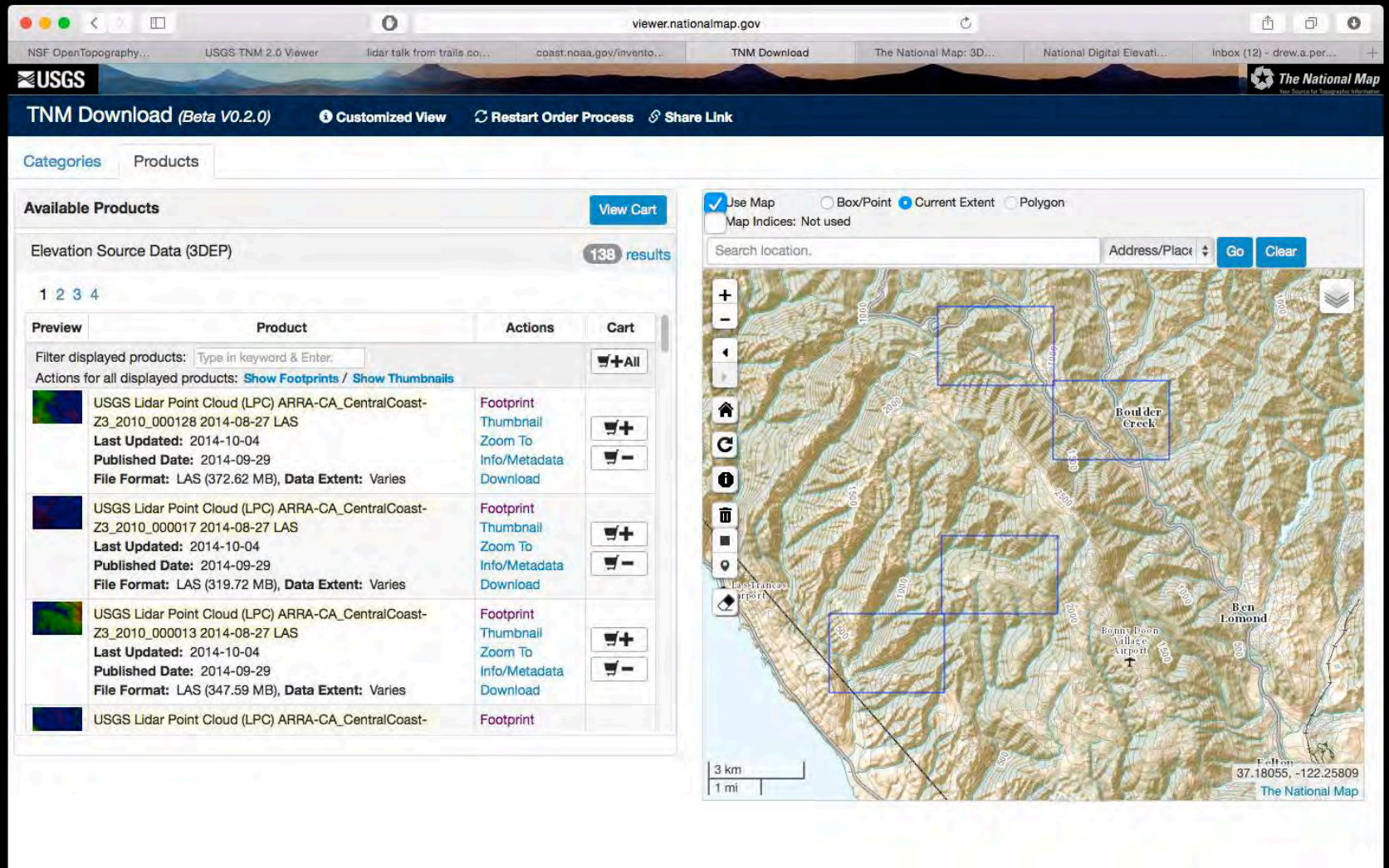
[NOAA Digital Coast Data Access Viewer]



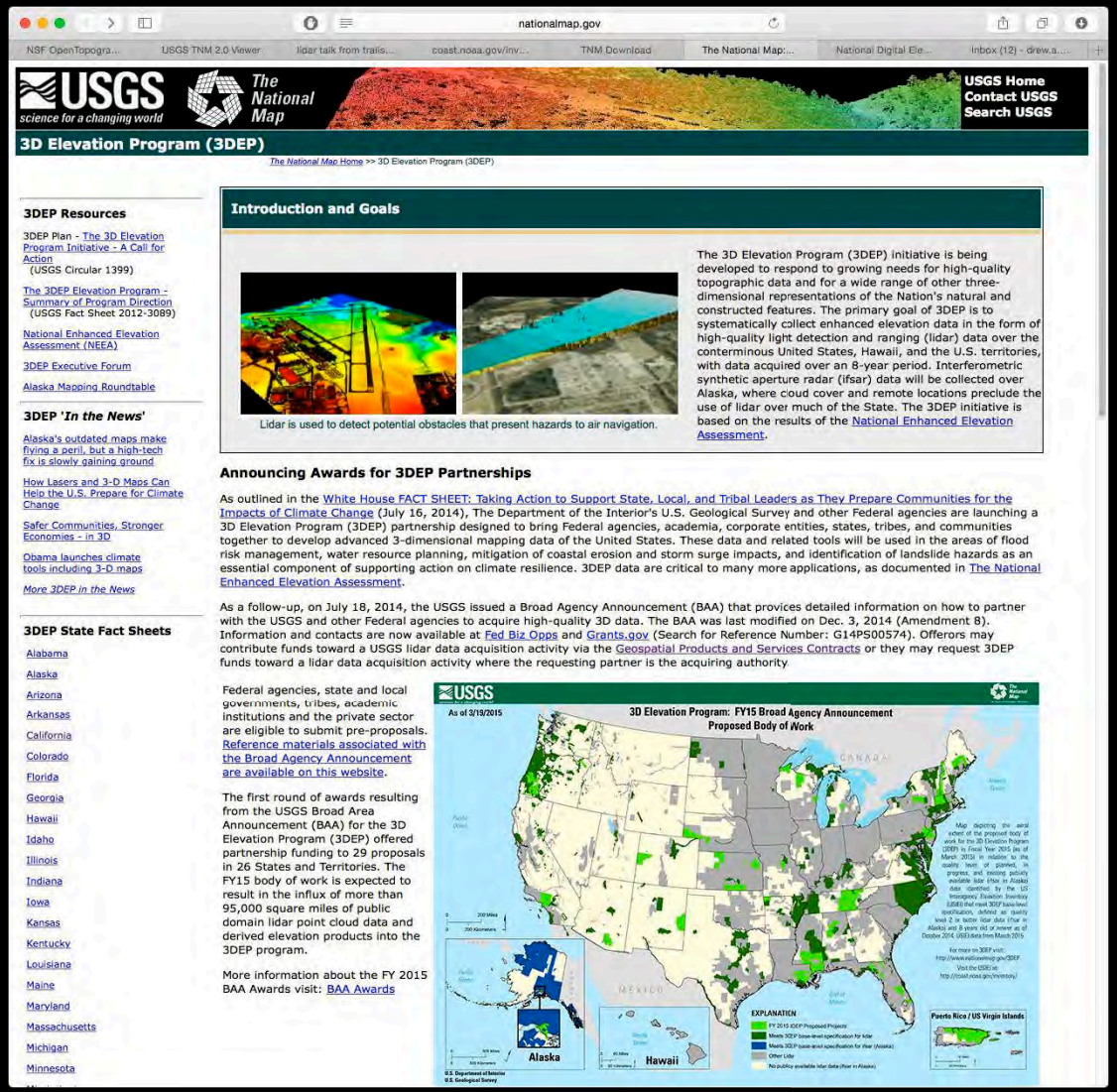
Only available data may be point cloud (.las) and would need processing to create usable products

MCC-LiDAR - filtering algorithm optimized for forested areas

LASTools - wide range of point cloud tools including filtering and DEM creation



More LiDAR data coming soon



Other sources to investigate:

Research studies (forestry, botany, landscape ecology, fire, tectonics, geomophology, hydrology)

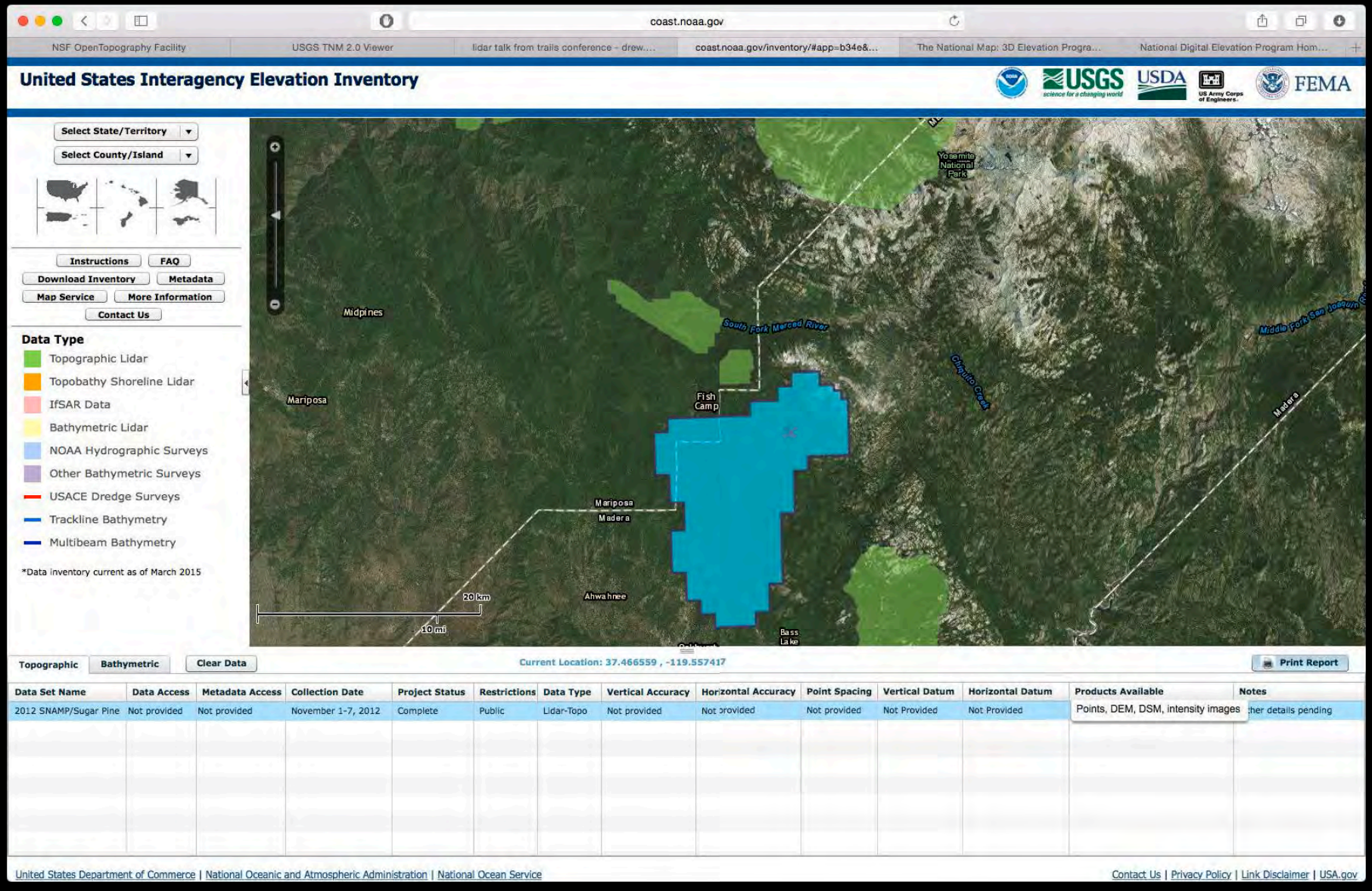
County GIS departments

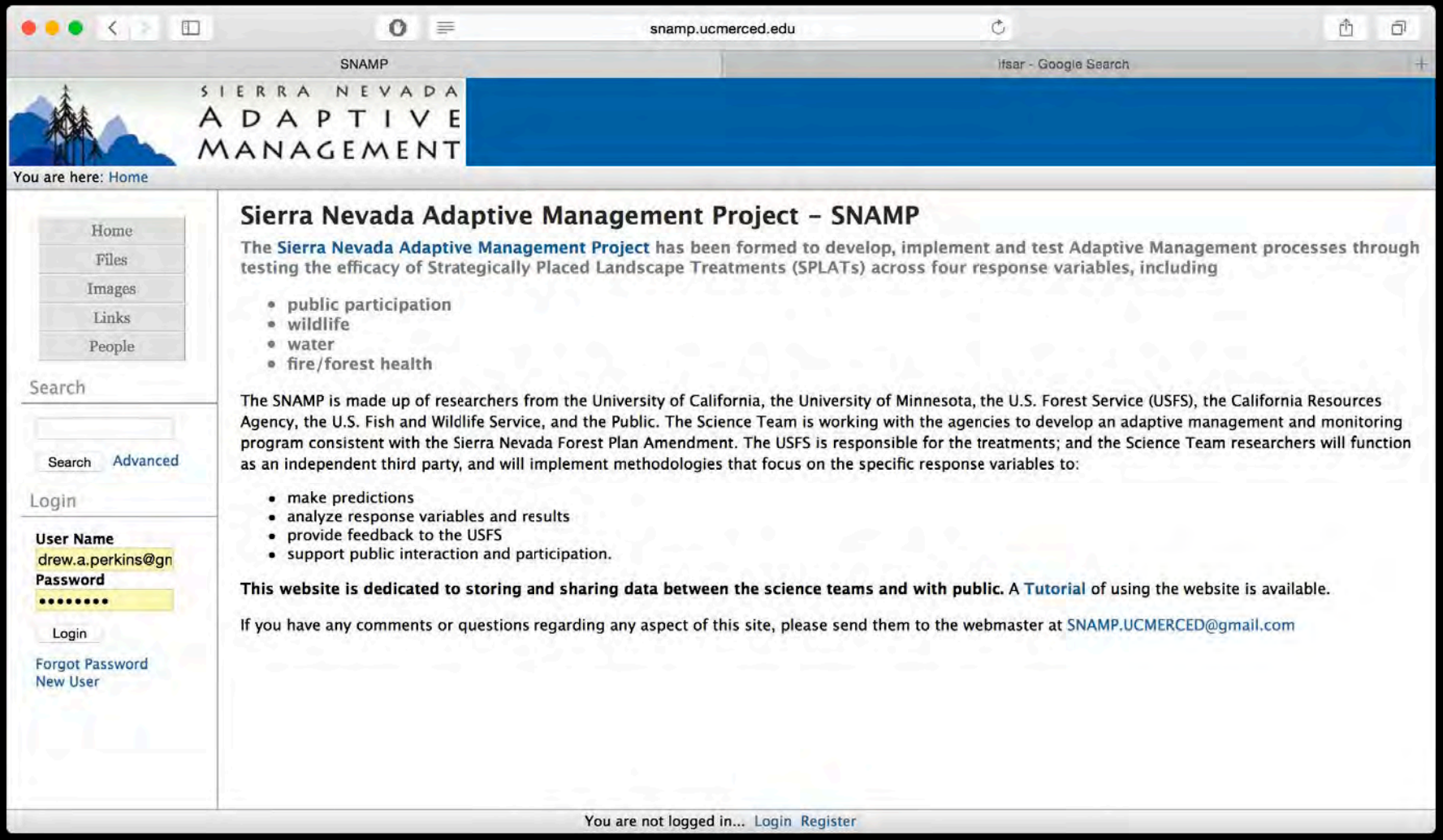
Don’t have data and want it?

Ask around and build up a coalition that would benefit from the data.

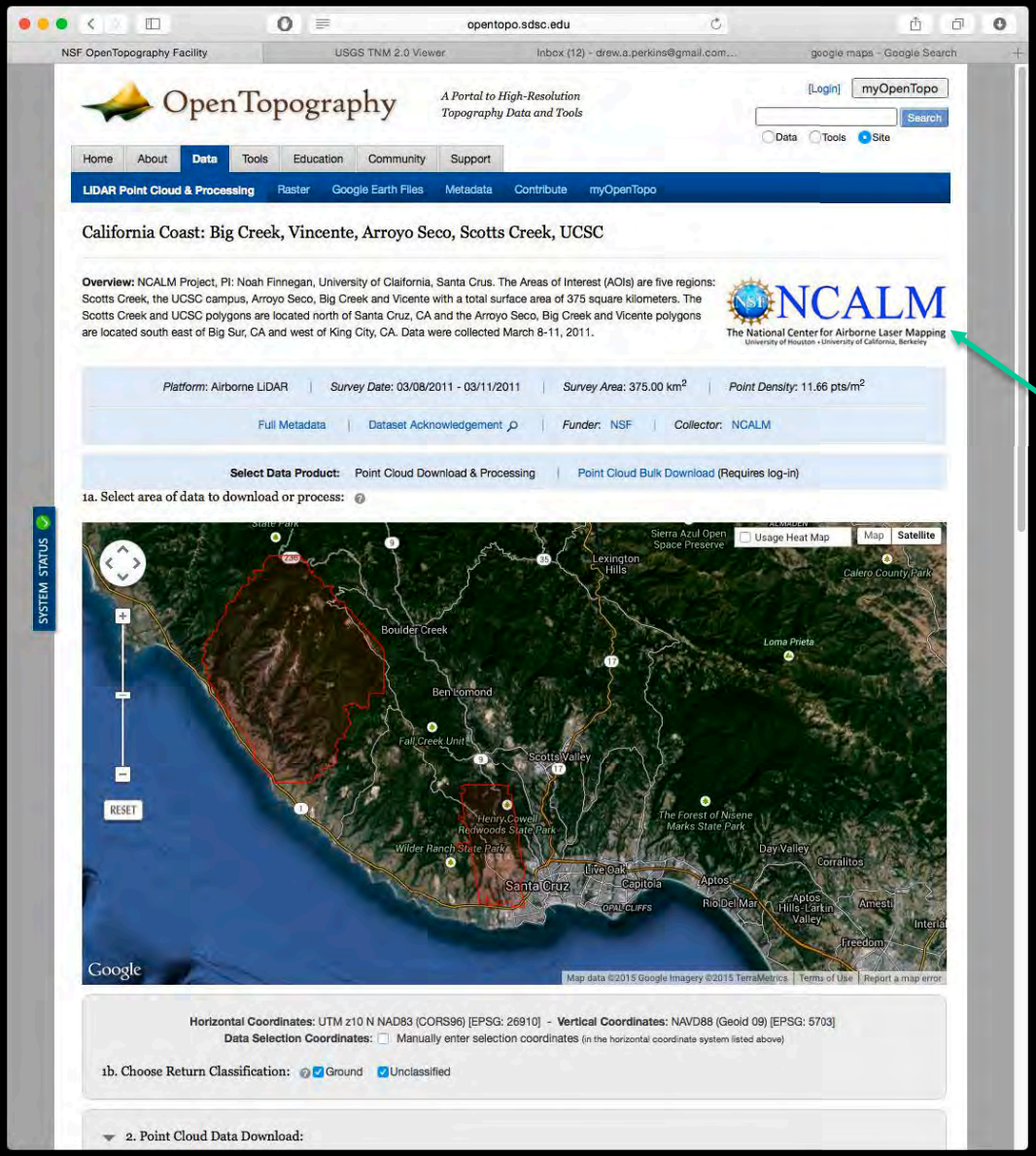
Accessing and using LiDAR with Open Source GIS tools

United States Interagency Elevation Inventory

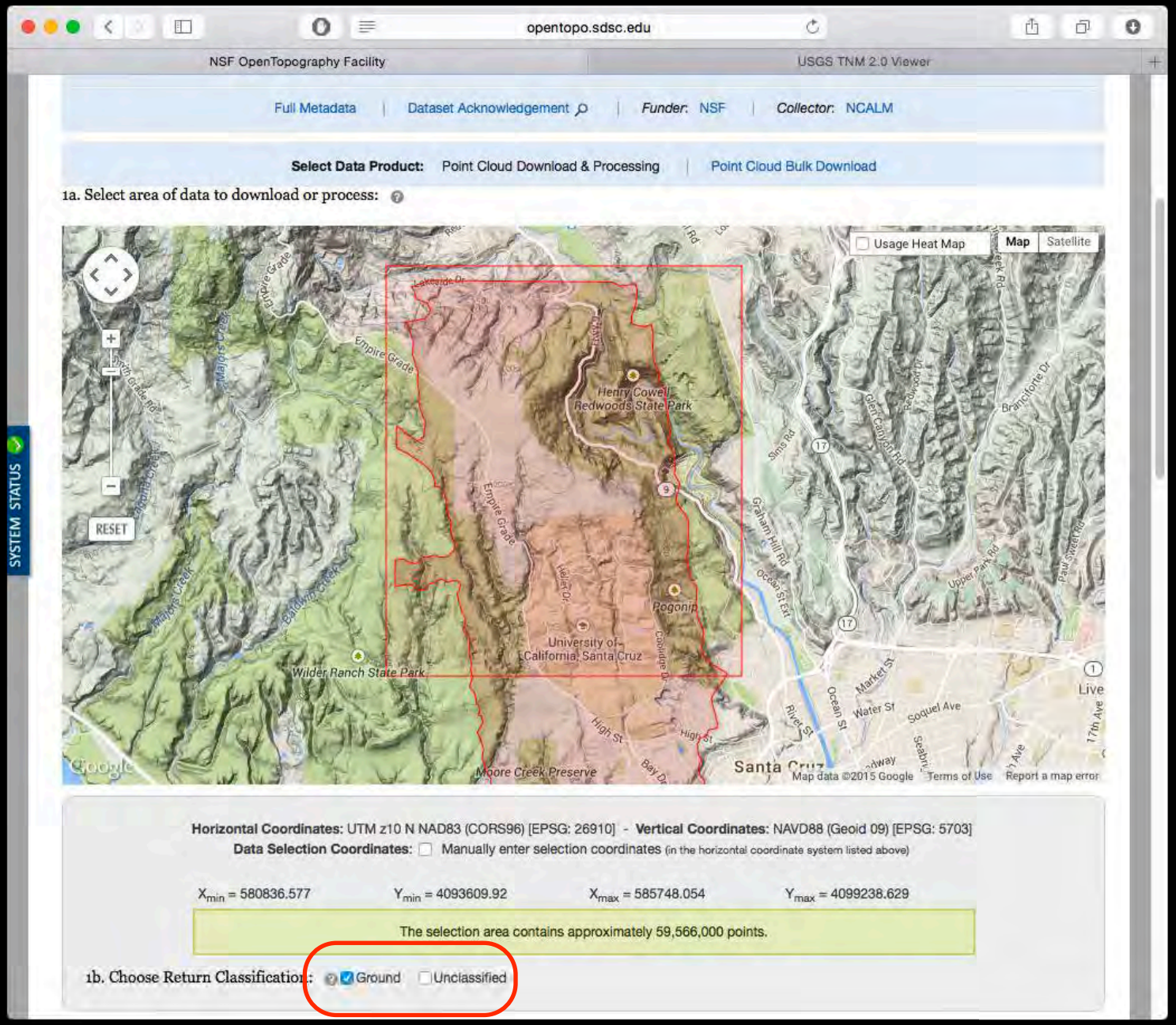



snamp.ucmerced.edu
SNAMP
ifsar - Google Search
SIERRA NEVADA
ADAPTIVE
MANAGEMENT
You are here: Home
Home
Files
Images
Links
People
Search
Search
Advanced
Login
User Name
drew.a.perkins@gn
Password
Login
Forgot Password
New User
Sierra Nevada Adaptive Management Project - SNAMP
The Sierra Nevada Adaptive Management Project has been formed to develop, implement and test Adaptive Management processes through testing the efficacy of Strategically Placed Landscape Treatments (SPLATs) across four response variables, including
public participation
wildlife
water
fire/forest health
The SNAMP is made up of researchers from the University of California, the University of Minnesota, the U.S. Forest Service (USFS), the California Resources Agency, the U.S. Fish and Wildlife Service, and the Public. The Science Team is working with the agencies to develop an adaptive management and monitoring program consistent with the Sierra Nevada Forest Plan Amendment. The USFS is responsible for the treatments; and the Science Team researchers will function as an independent third party, and will implement methodologies that focus on the specific response variables to:
make predictions
analyze response variables and results
provide feedback to the USFS
support public interaction and participation.
This website is dedicated to storing and sharing data between the science teams and with public. A Tutorial of using the website is available.
If you have any comments or questions regarding any aspect of this site, please send them to the webmaster at SNAMP.UCMERCED@gmail.com
You are not logged in... Login Register

I'll use an example from Santa Cruz to demonstrate using OpenTopography to obtain data.



NCALM = National Center for Airborne Laser Mapping



Ground Returns

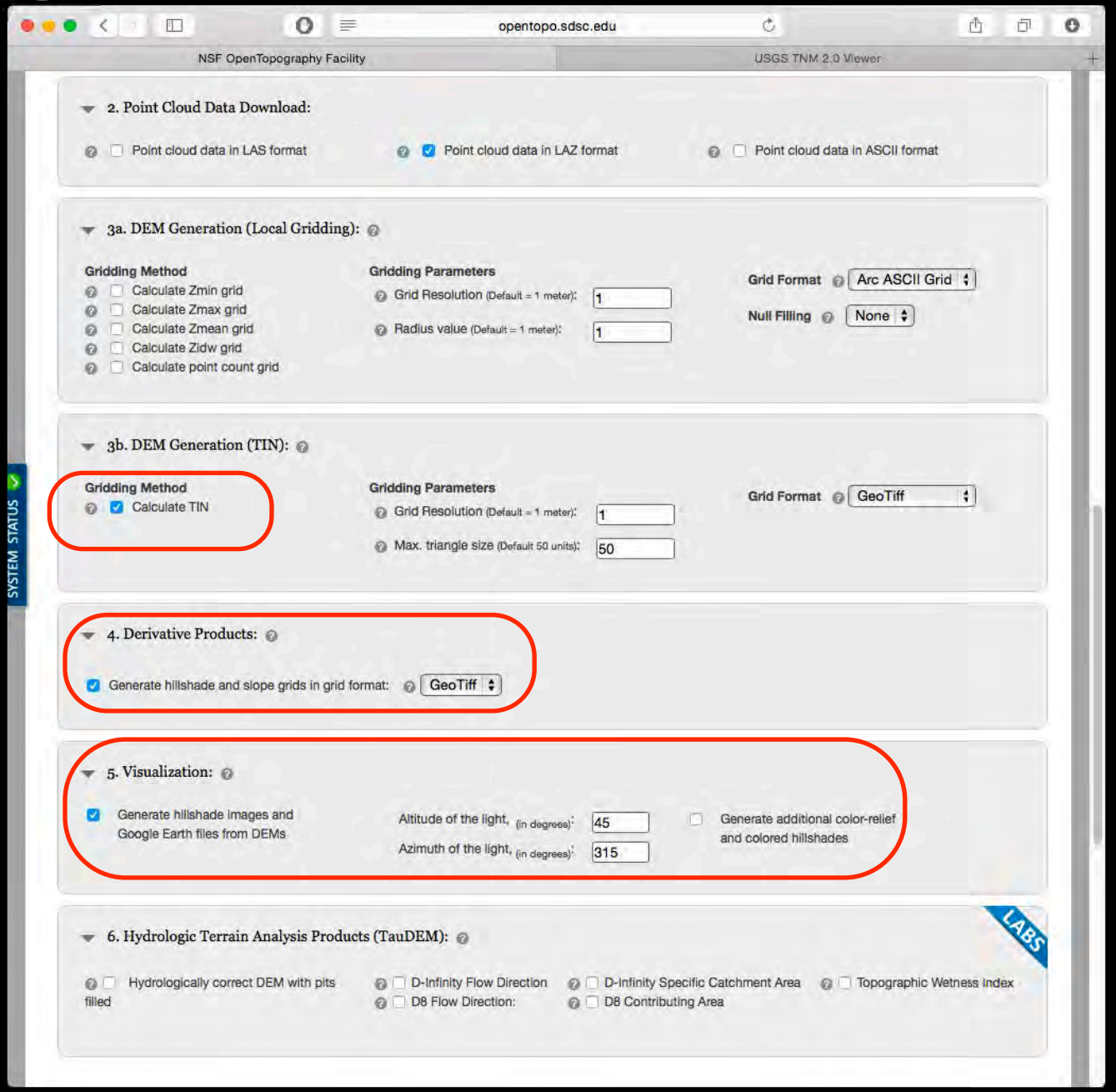
Select Options

We do want to generate a DEM (using a TIN).

And the hillshade and slope layer

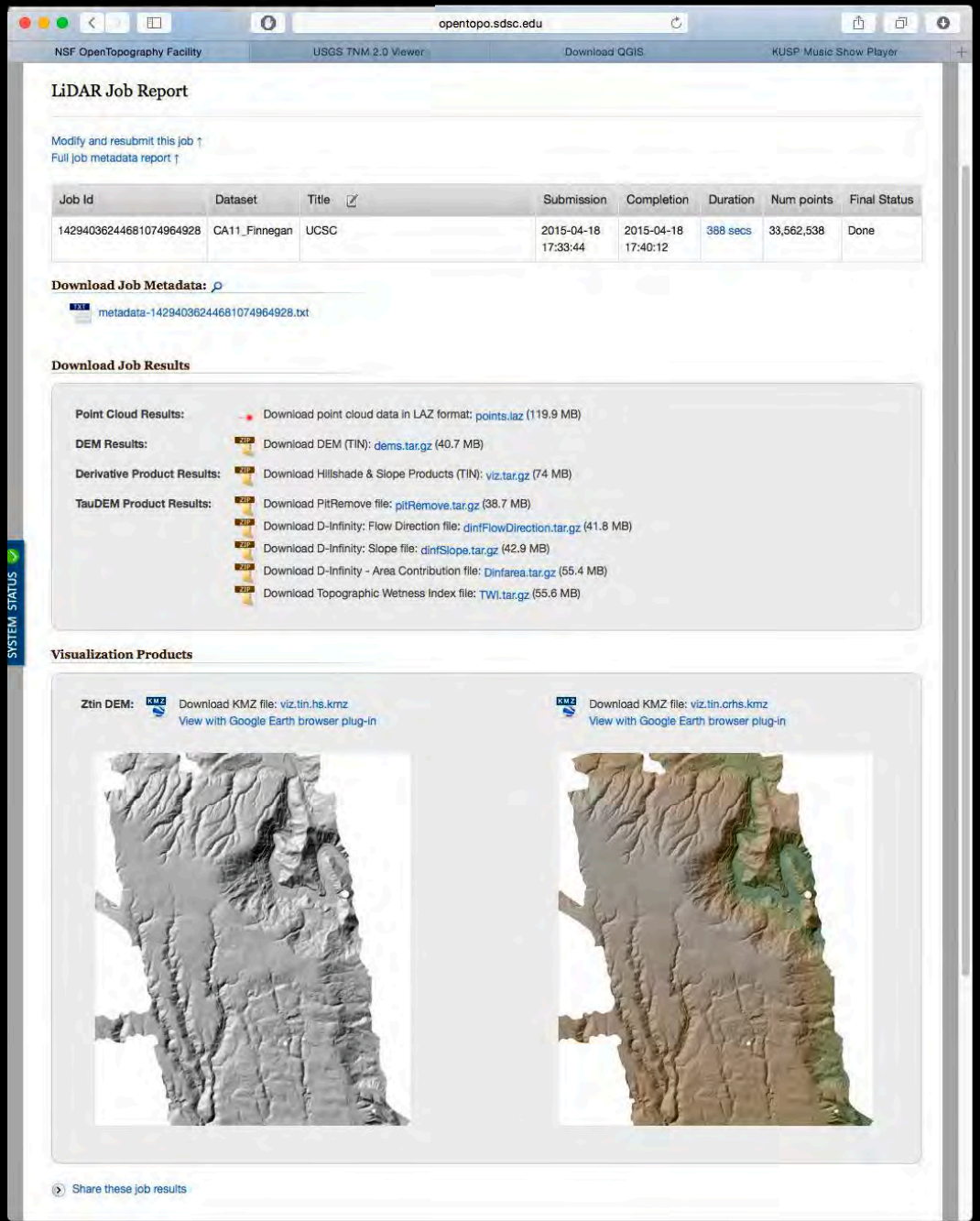
It can even produce KML versions to send and share in Google Earth

Hydrologic analysis products done server side as well



…6 minutes later, data delivered.

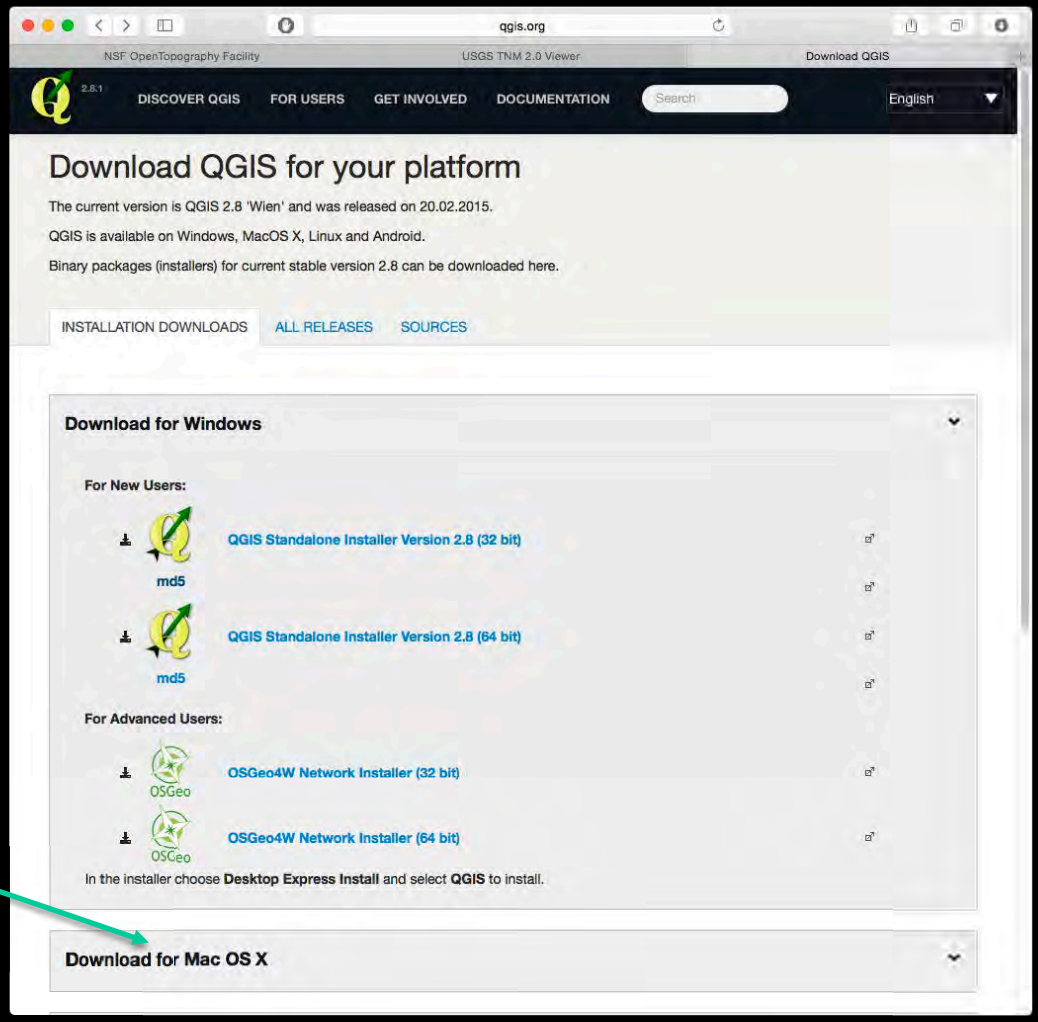
…now we need some software.



Open Source Mapping Software

at QGIS.org you can download “standalone” or OSGeo4W Your Open Source Compass

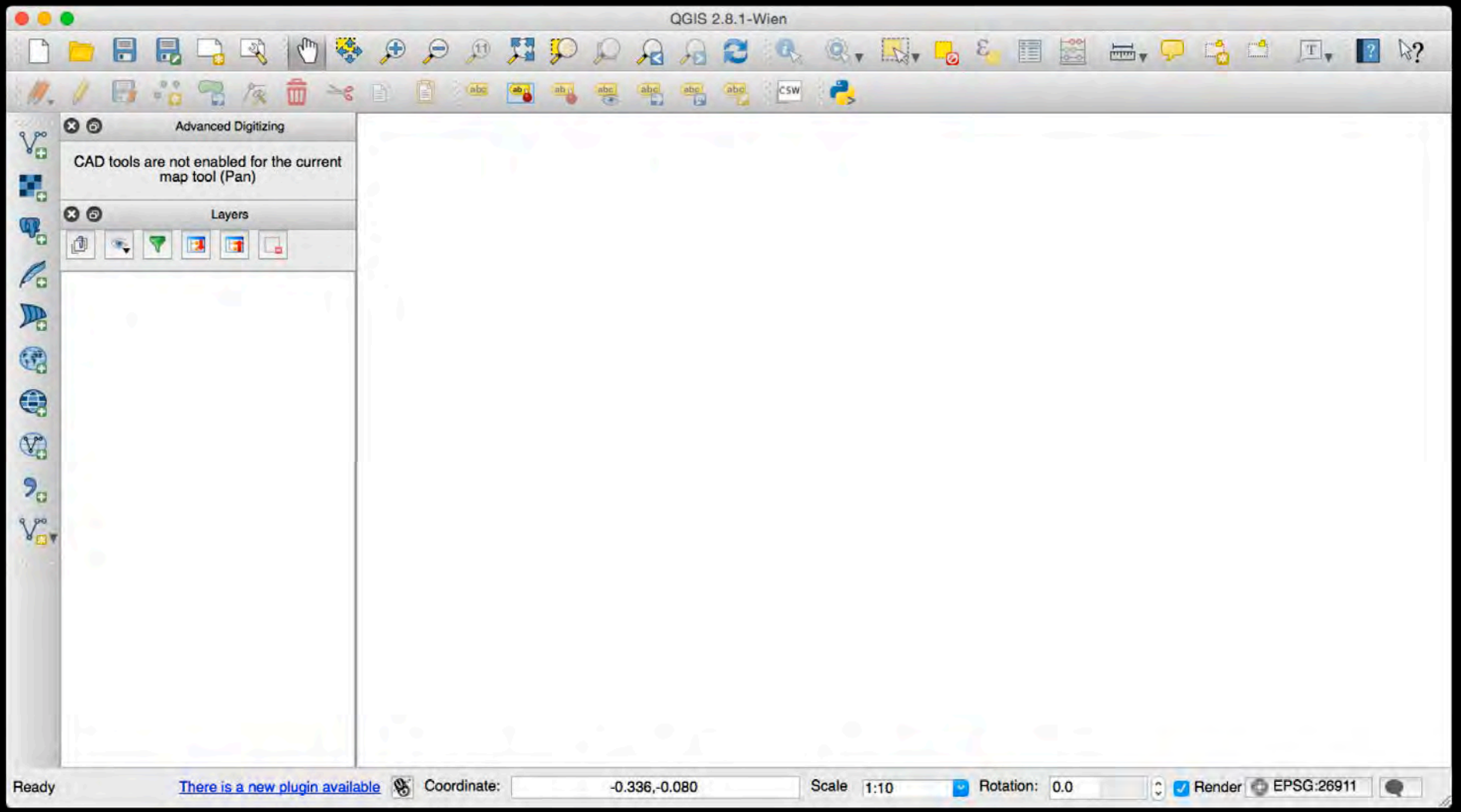
This single installer contains many open source GIS packages, including QGIS.



Also available for Mac (and Linux) but a bit more complicated to install

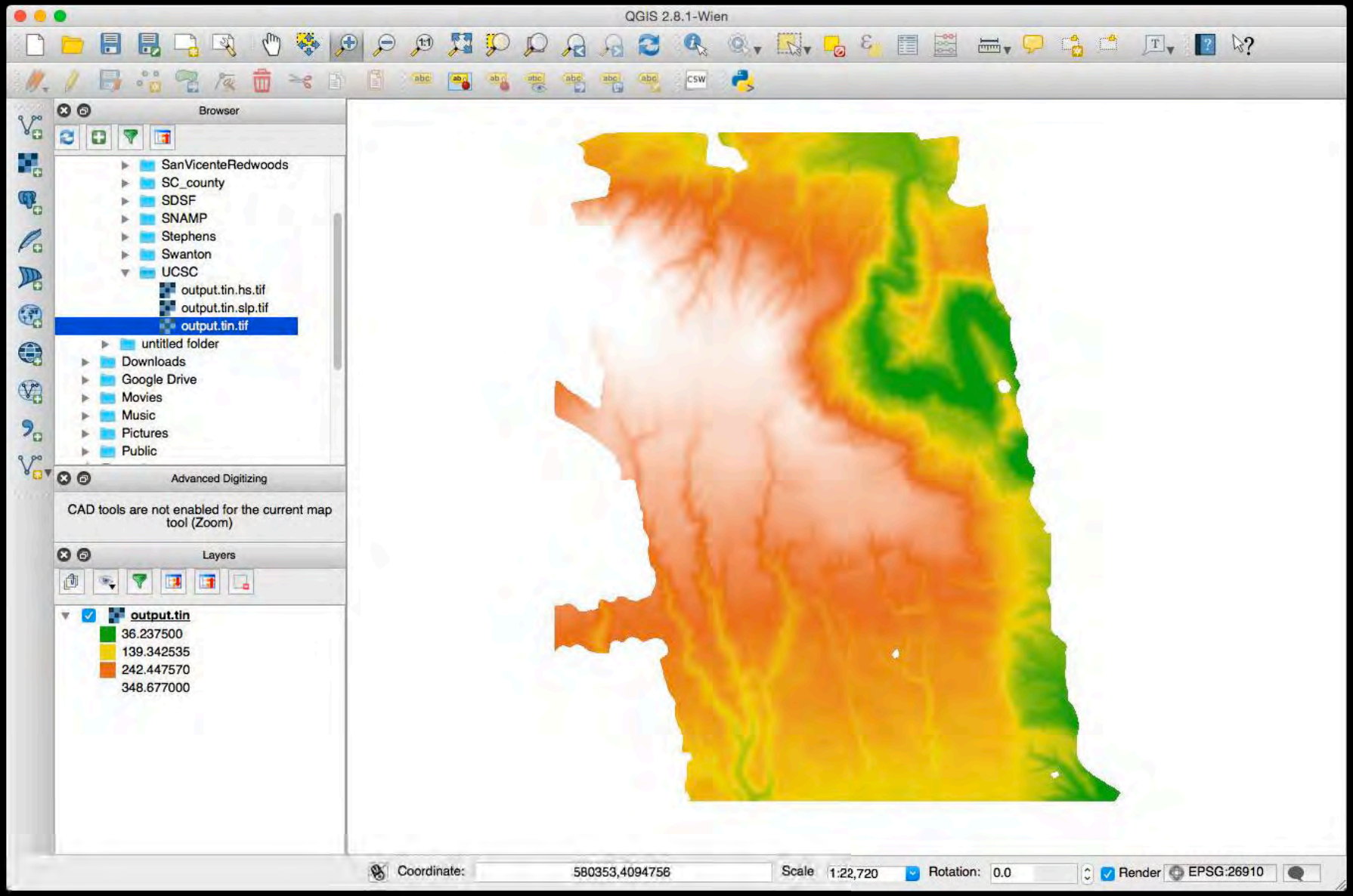
Quantum GIS

Once installed, QGIS looks like a fully-functional GIS, and it is.



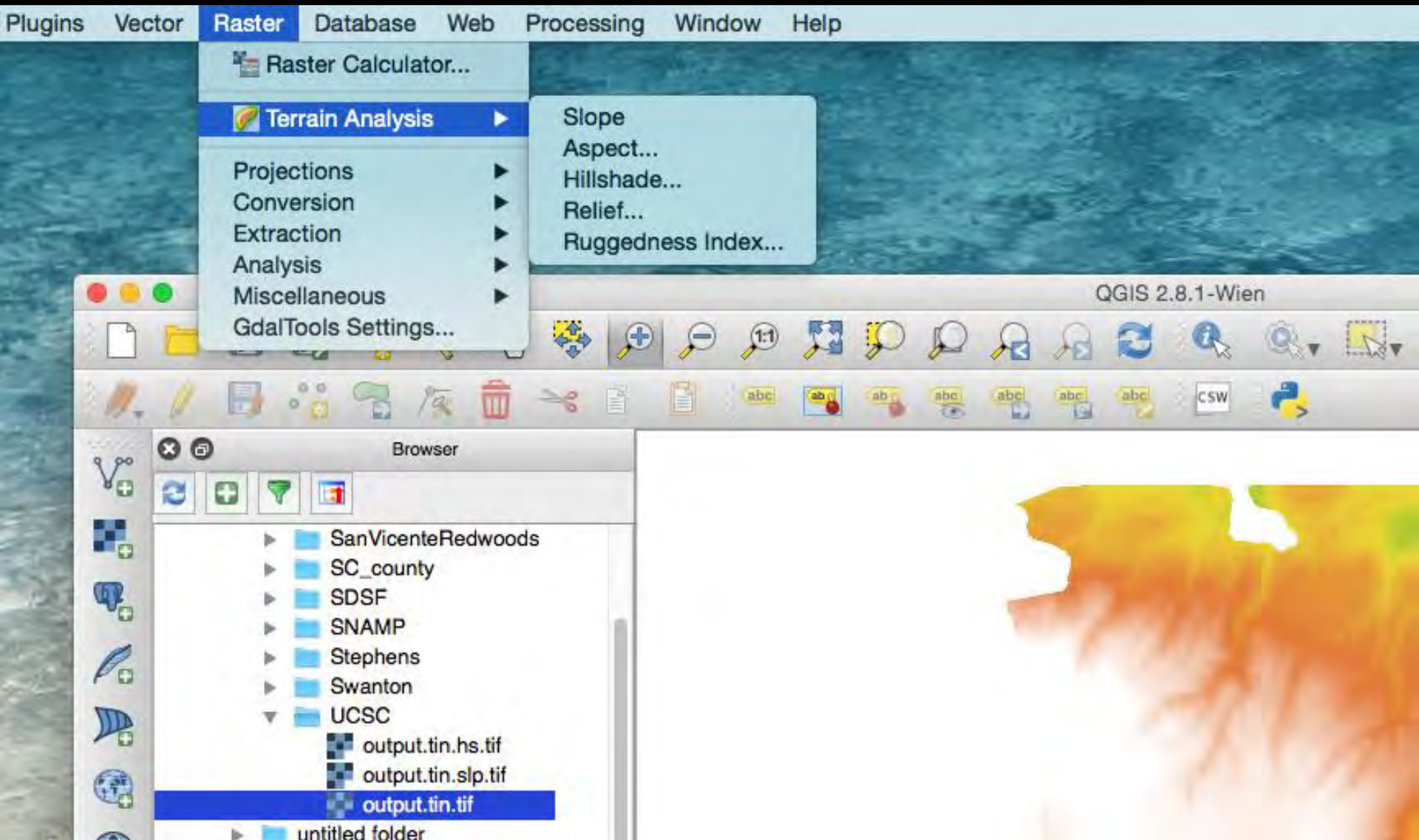
DEM, Hillshade, and Slope

Add Raster to bring in the OpenTopography DEM



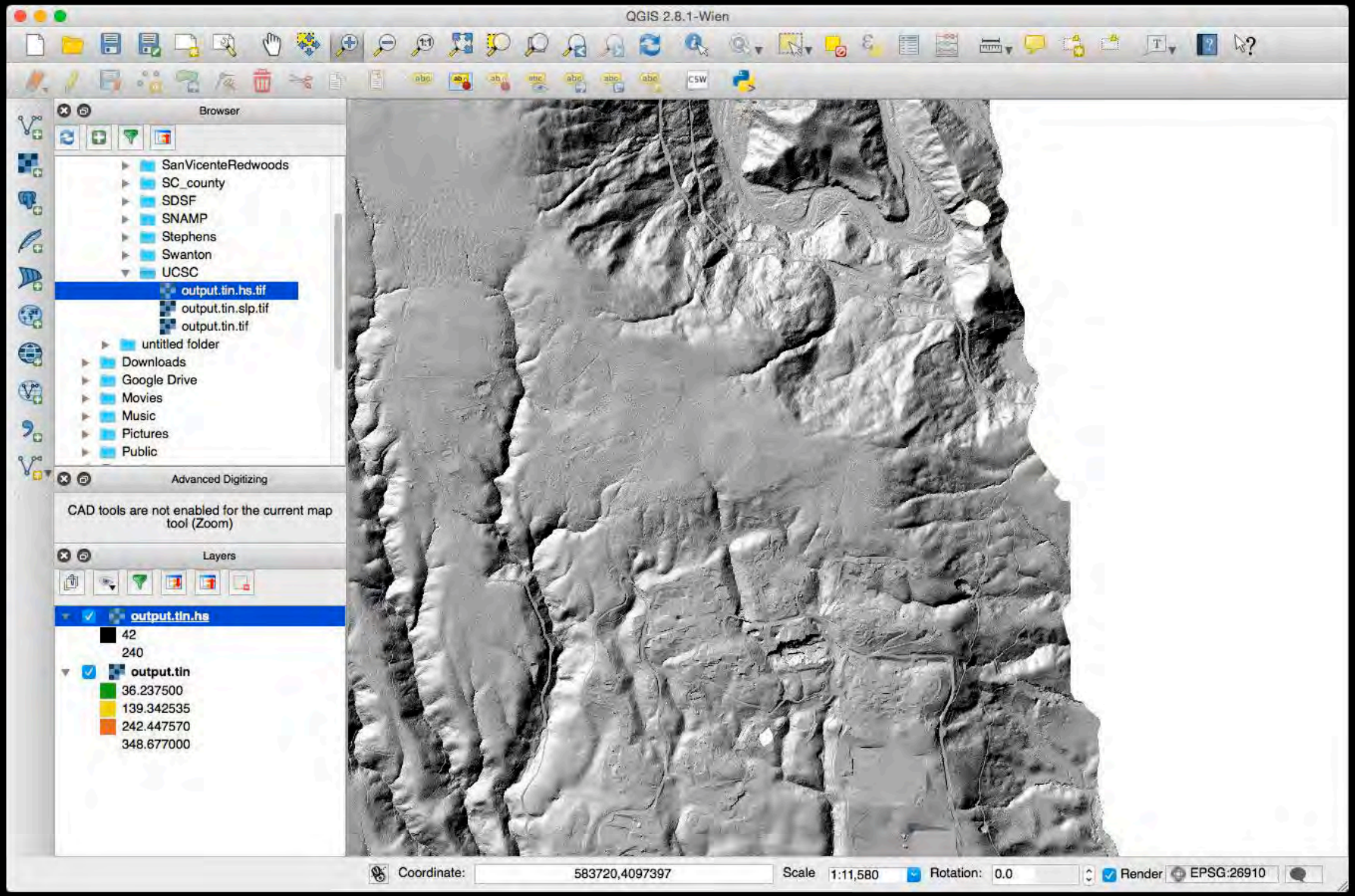
DEM, Hillshade and Slope

Raster Analysis to build Hillshade



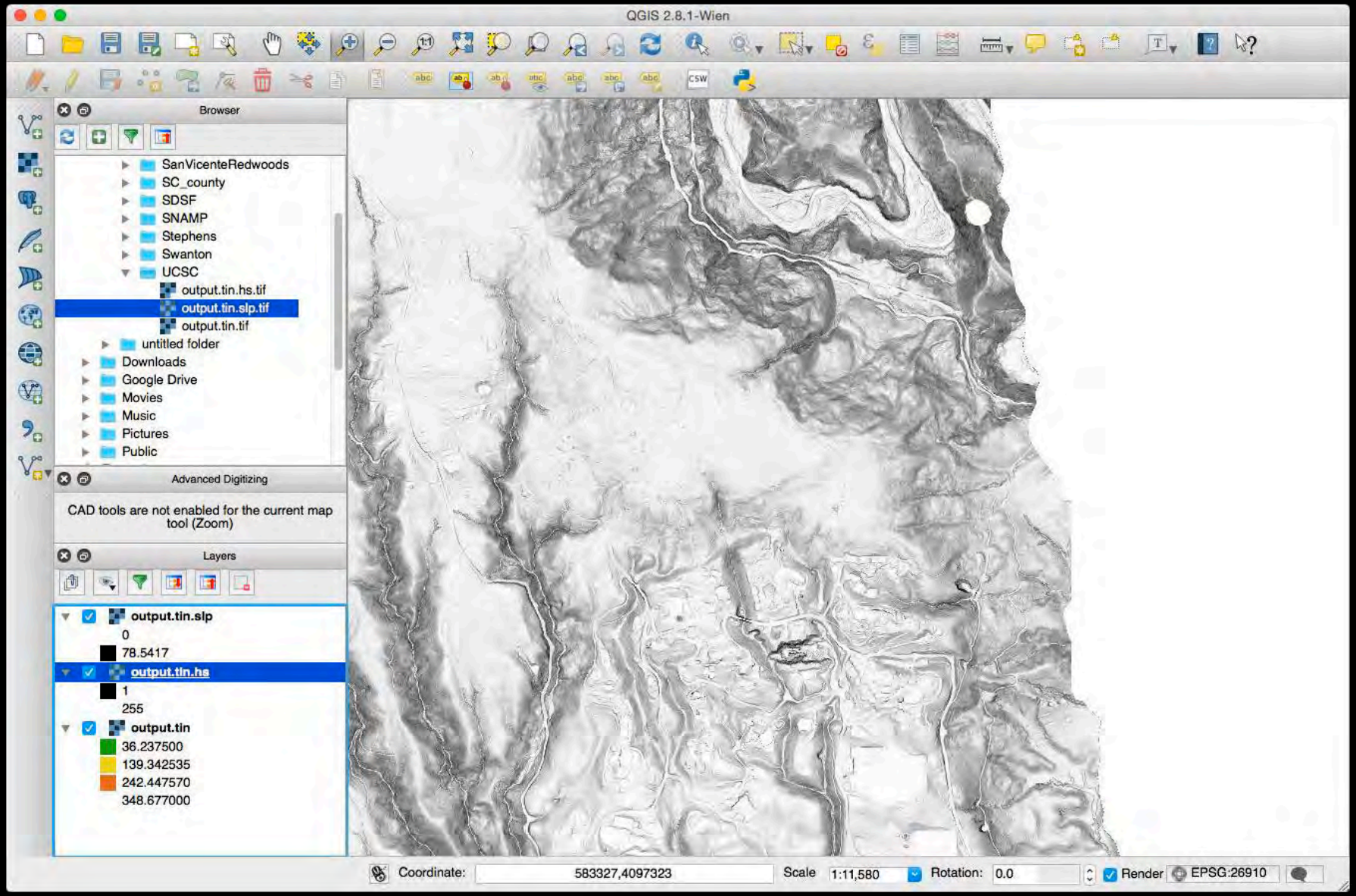
DEM, Hillshade and Slope

Raster Analysis to build Hillshade



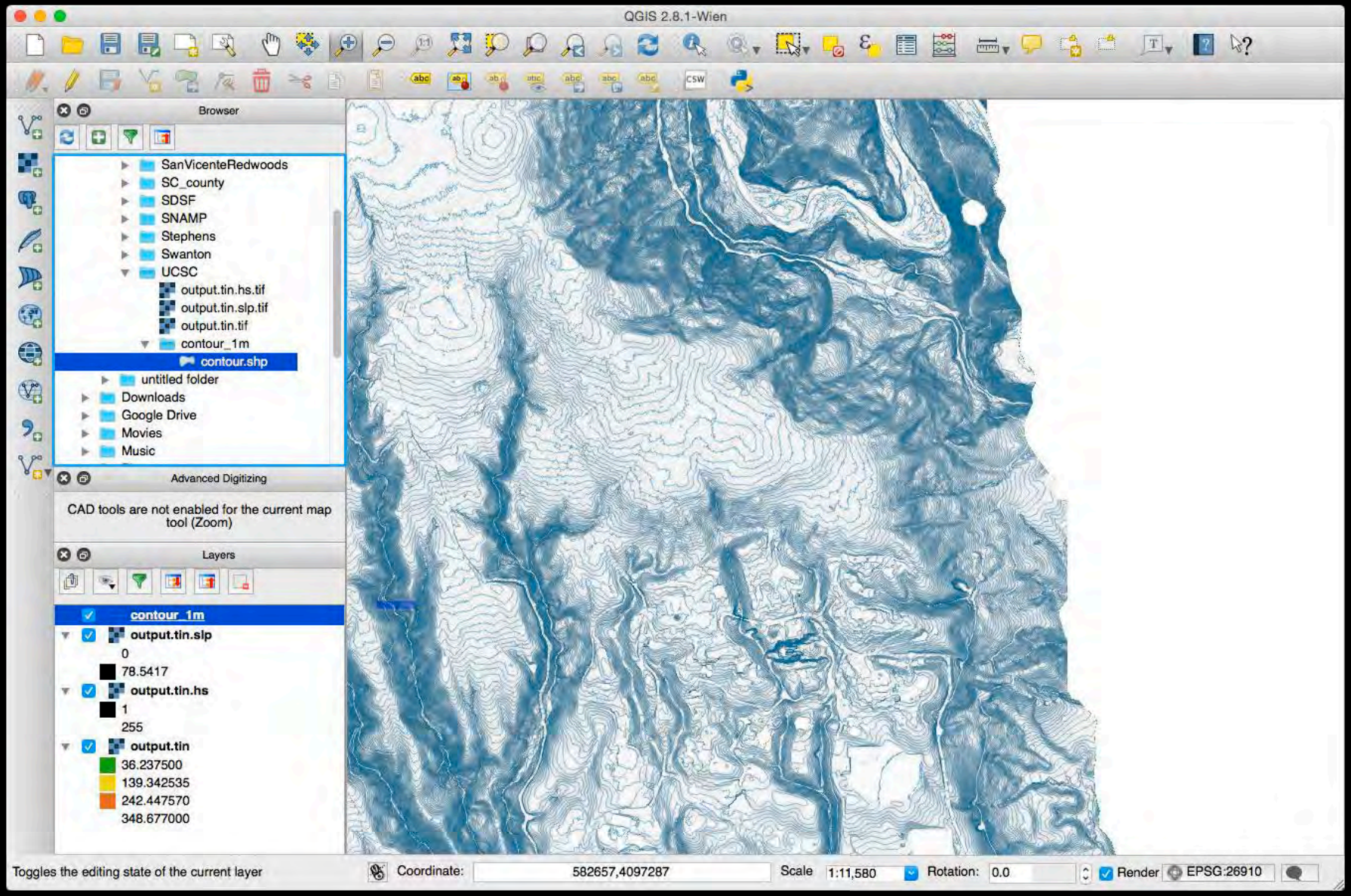
DEM, Hillshade and Slope

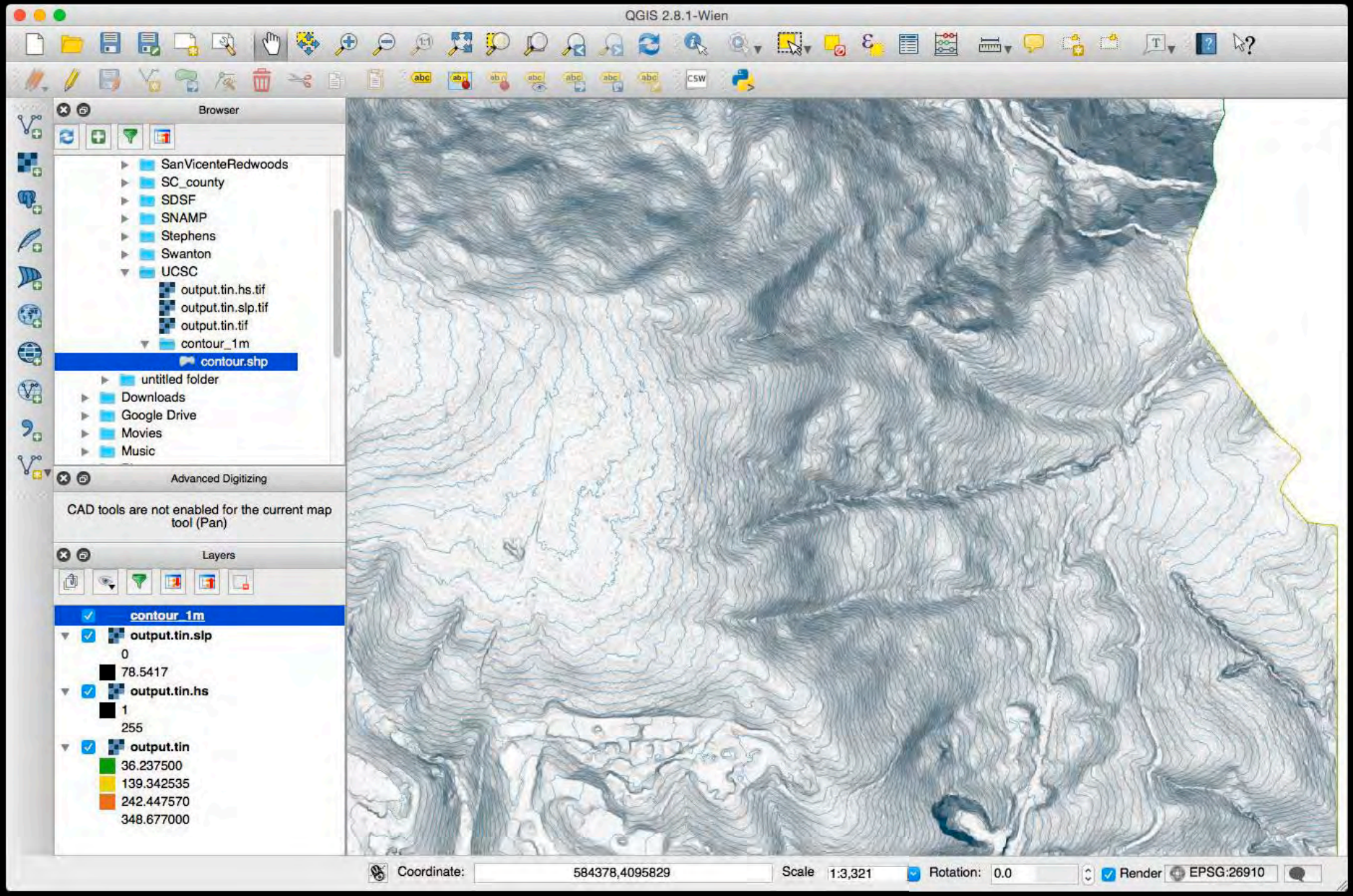
Raster Analysis to build Slope layer



2m Contours

Can also generate contours




QGIS 2.8.1-Wien
Browser
SanVicenteRedwoods
SC_county
SDSF
SNAMP
Stephens
Swanton
UCSC
output.tin.hs.tif
output.tin.slp.tif
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contour_1m
contour.shp
untitled folder
Downloads
Google Drive
Movies
Music
Advanced Digitizing
CAD tools are not enabled for the current map tool (Pan)
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contour_1m
output.tin.slp
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output.tin.hs
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255
output.tin
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139.342535
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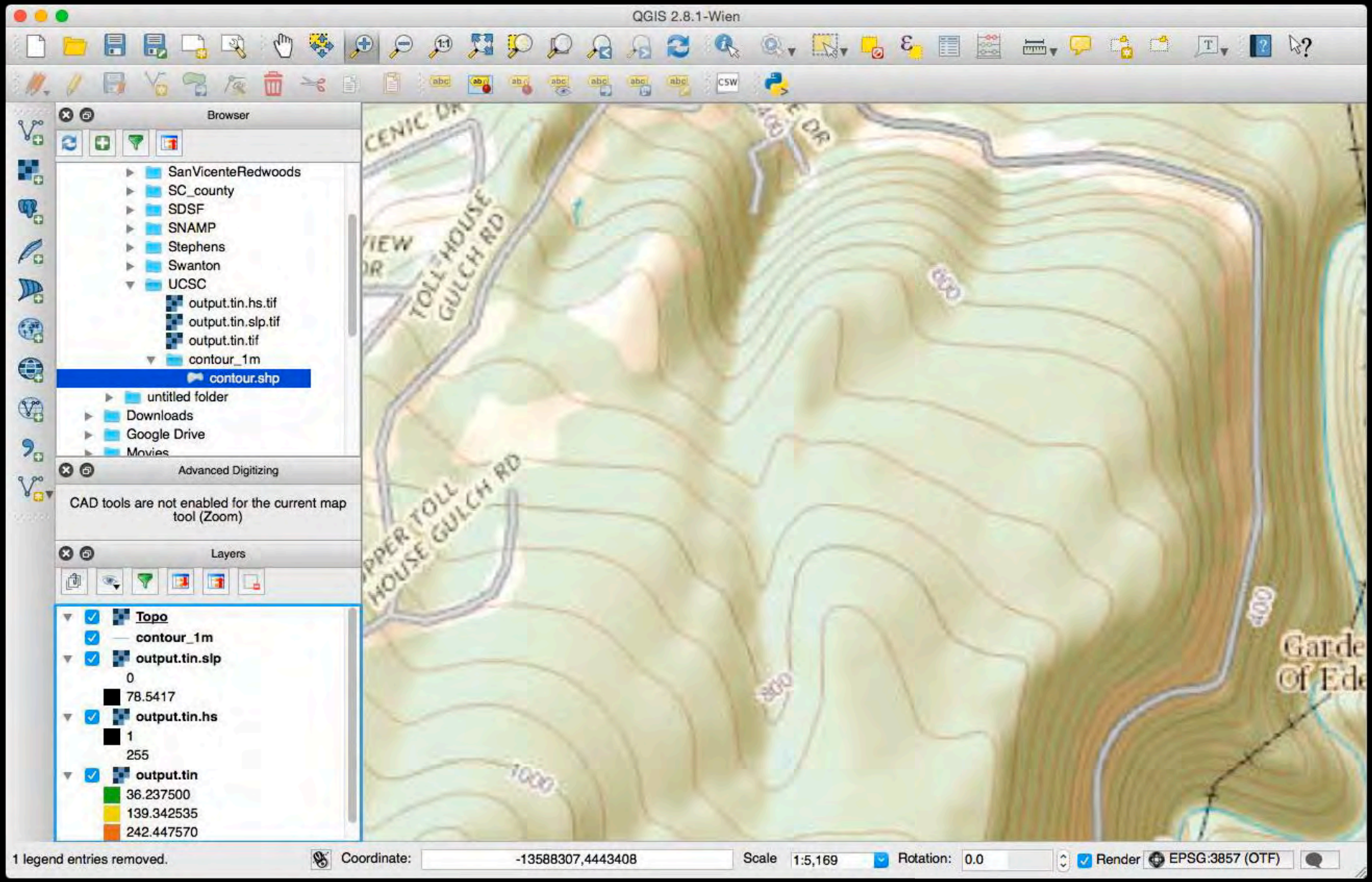
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242.447570
TOLL HOUSE GULCH RD
UPPER TOLL HOUSE GULCH RD
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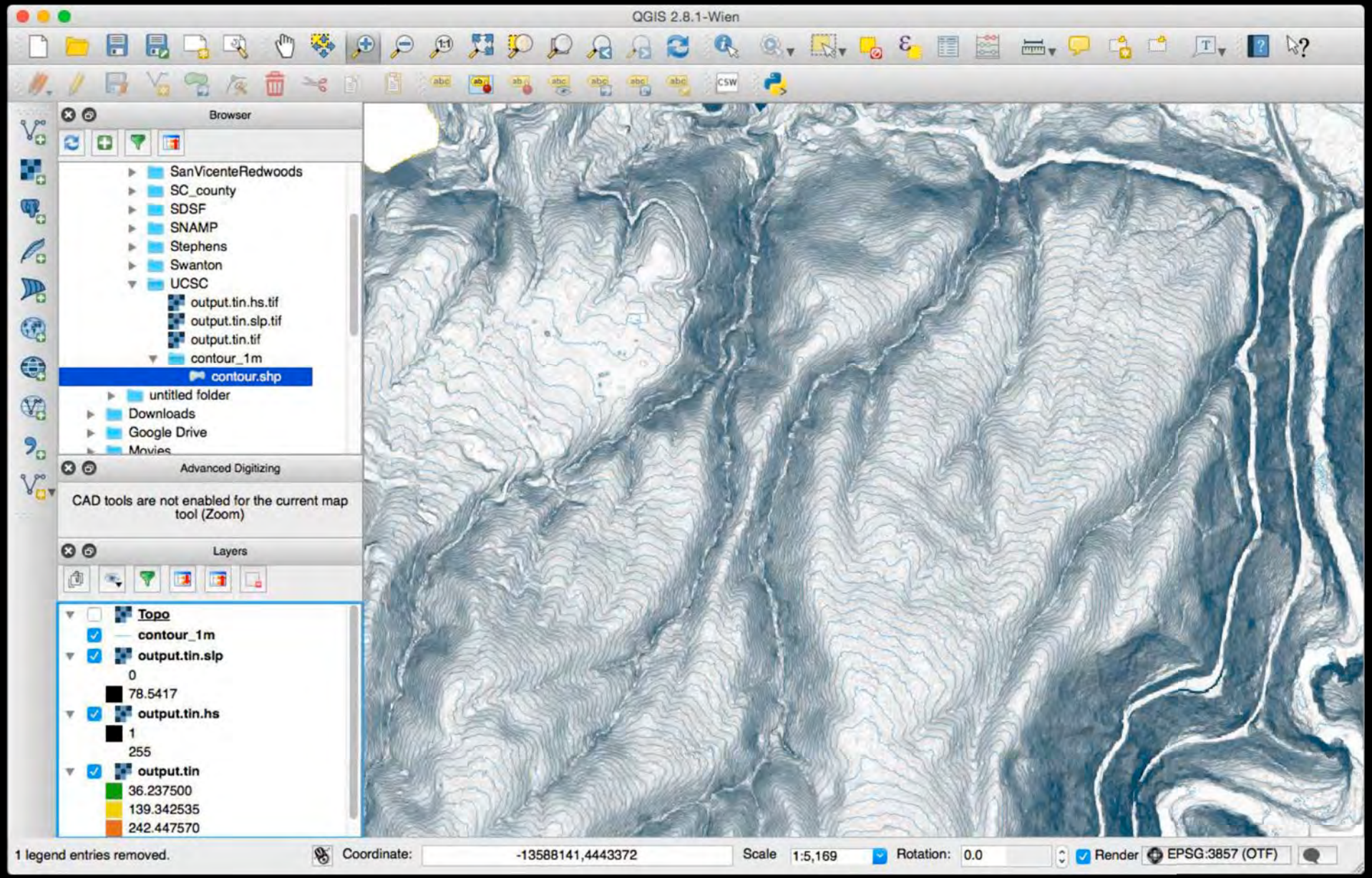
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Movies
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242.447570
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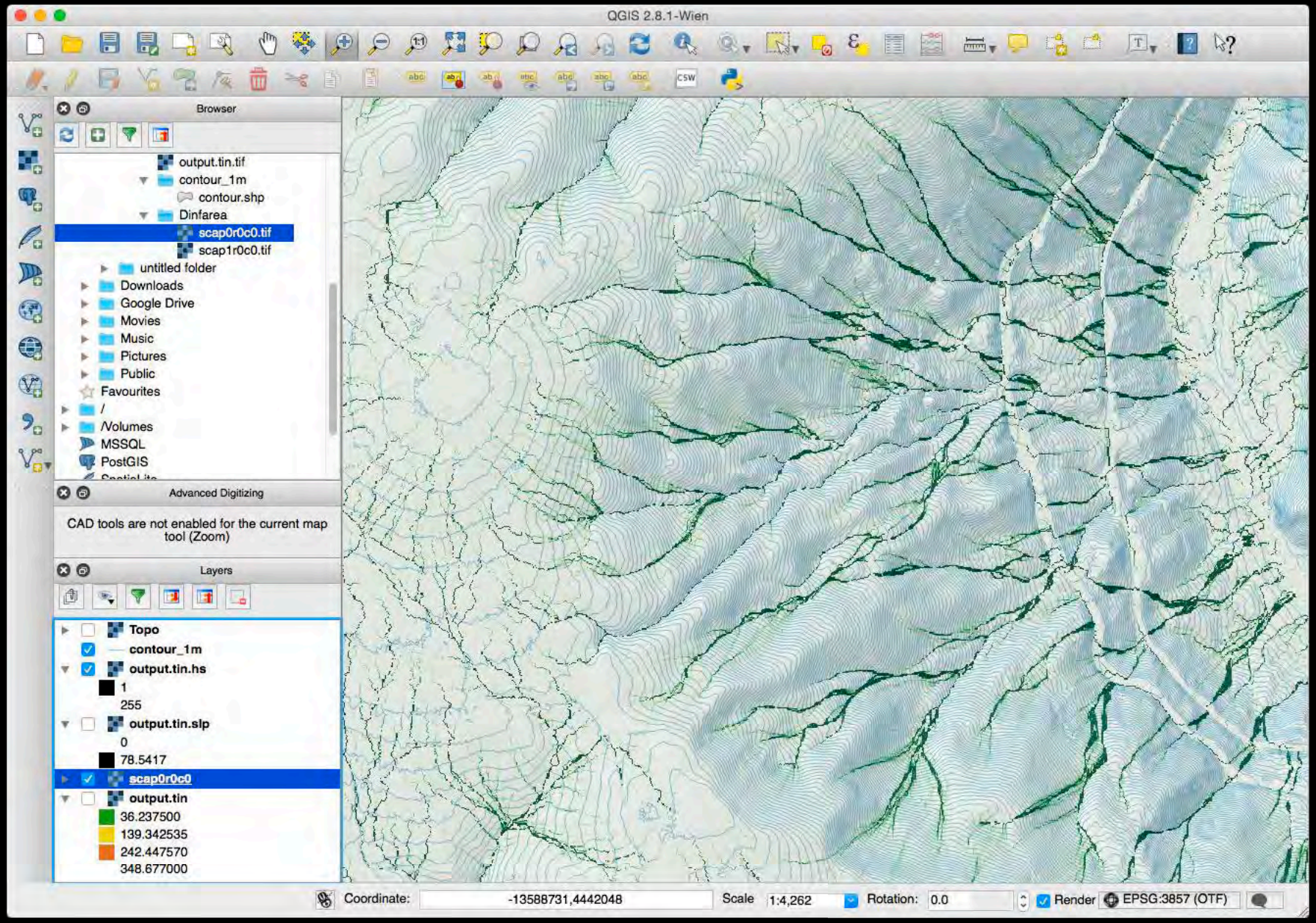
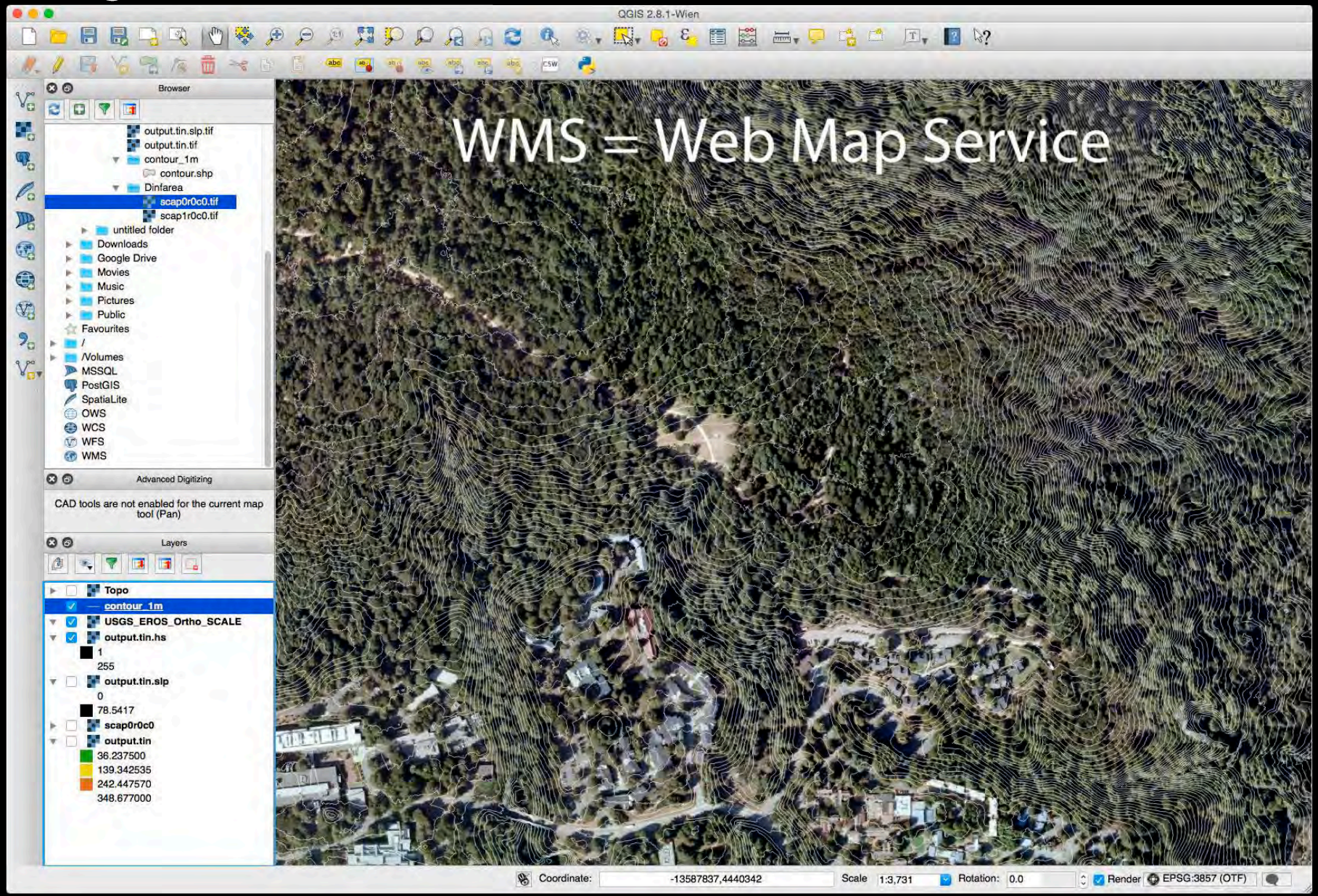
EPSG:3857 (OTF)

Raster hydrology tools are built in to QGIS



USGS Topo Maps and Imagery are available “streaming” through WMS connections



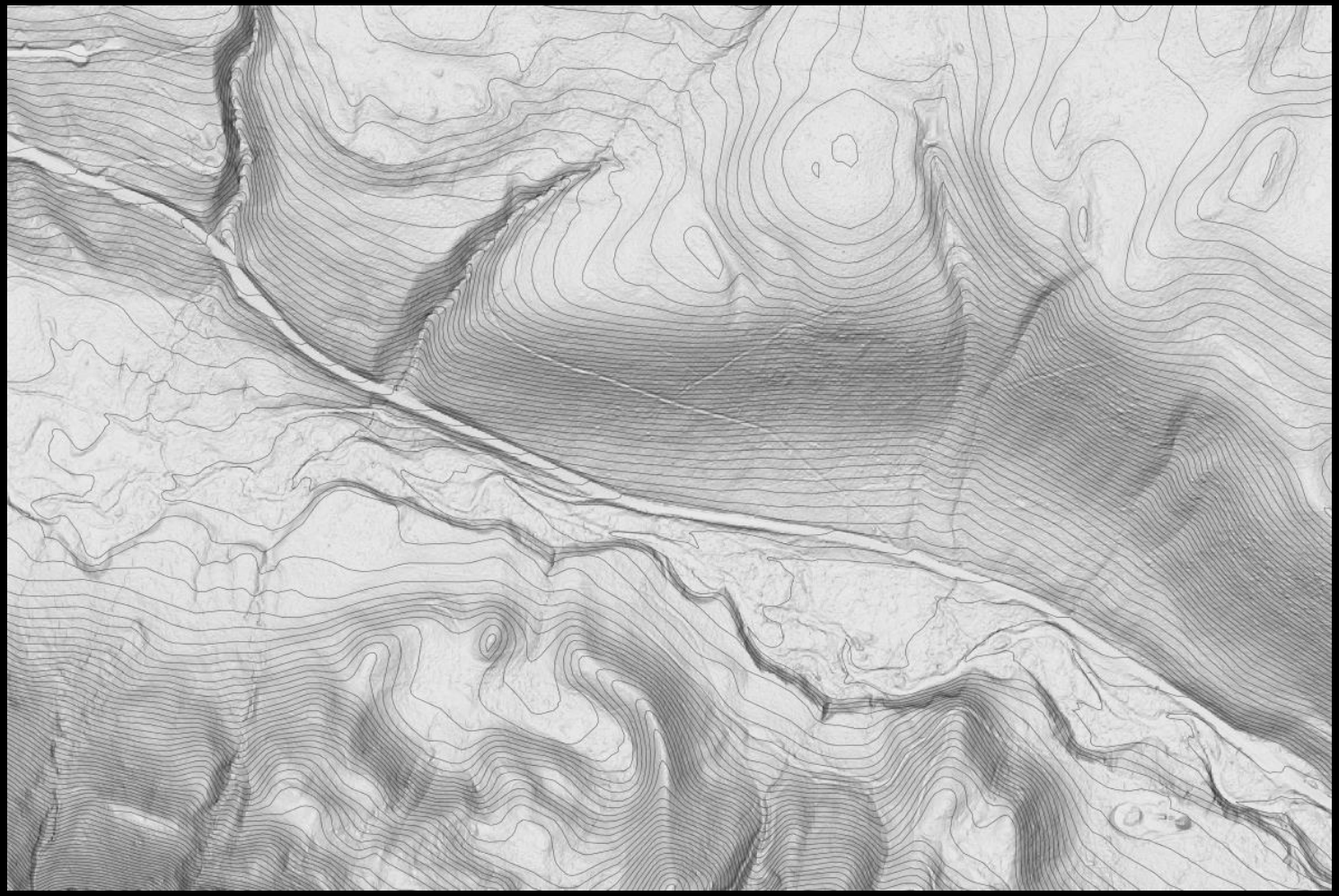
Why GIS?

Powerful software (and not always expensive)

It can be an aid to design, sharing, communication, organization, and orienteering.

Helps you take advantage of high quality data that may be available. High quality data makes office and field time more efficient and effective.

Using LiDAR data for trail layout



Overview

Trail design process

Demonstrate using LiDAR data to lay out some potential trails.

General trail design process

Determine trail purpose and develop specifications.

- Trail type, user types, start point, destination
- Traffic level and season of use
- Soil characteristics
- **Grade**, width, trail character (primitive, manicured)
- maintenance requirements and resources
- construction method (hand built vs machine built), paid labor or volunteer labor
- **budget**.

General trail design process

Purpose and specifications define control points.

Determine potential positive and negative control points.

\+ Viewpoints, interesting biologic, geologic or cultural features, connections to existing infrastructure, good stream crossing locations, passes, etc.

– Wet areas, bedrock or very shallow soils, erosive soils, cliffs, gullies, bad stream crossing locations, biologically sensitive areas, archeological resources, etc.

Valencia Peak Trail Reroute
Montana de Oro State Park

Emma McCrary Trail
Santa Cruz, CA

Colorado Trail
Durango, CO
GRAYSILL MINES
NOTICE
SAN JUAN
HISTORICAL MARKER

General trail design process

Develop and refine potential trail corridors, trying to connect positive control points

and avoid negative control points...

while meeting grade requirements and staying within the construction budget.

General trail design process

There is no perfect alignment and there are almost an infinite number of ways to connect two points with a trail.

Good trail design is mastering the art of compromise.

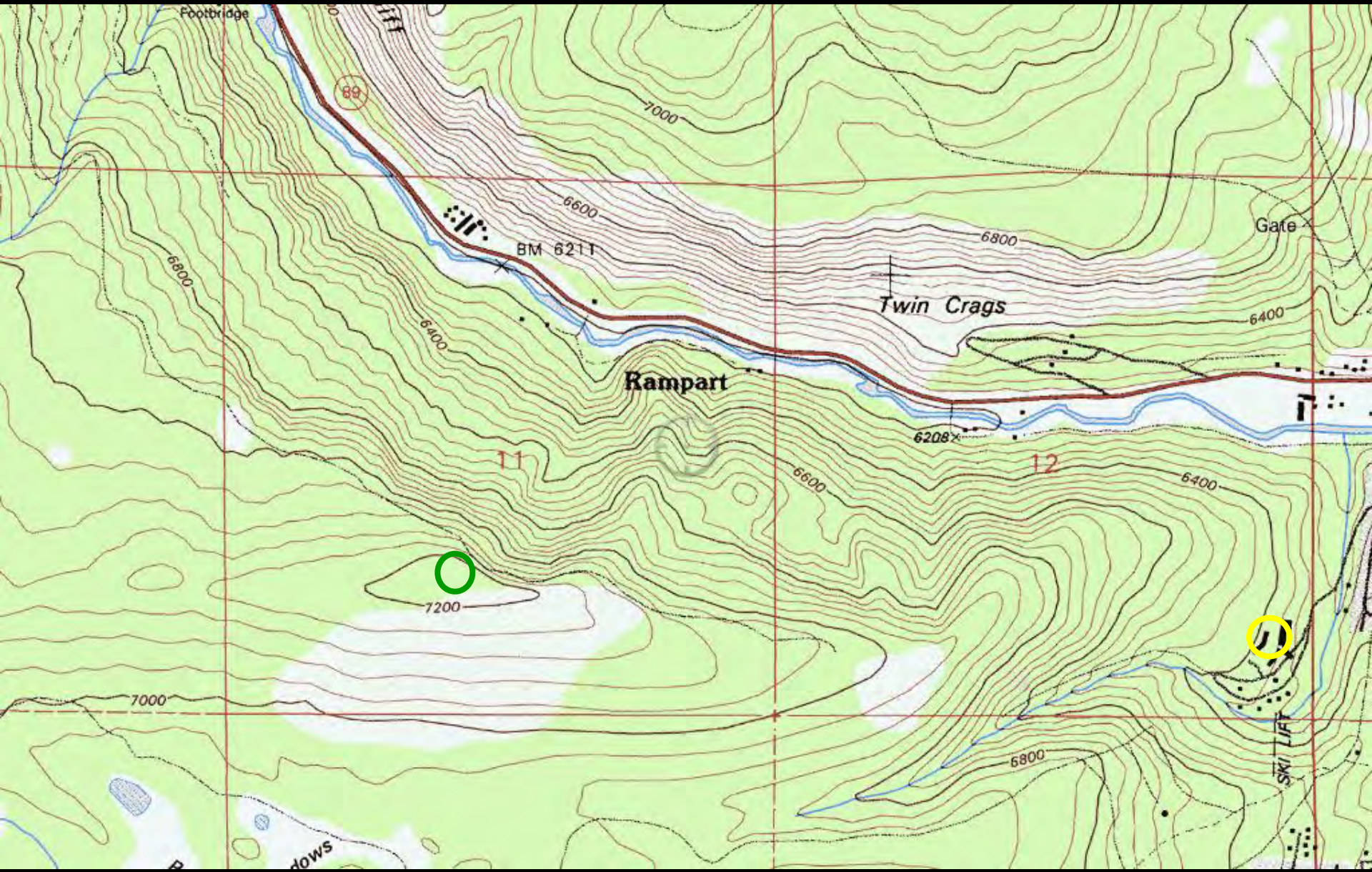
Balance ease and cost of construction, user enjoyment and experience, and future maintenance requirements.

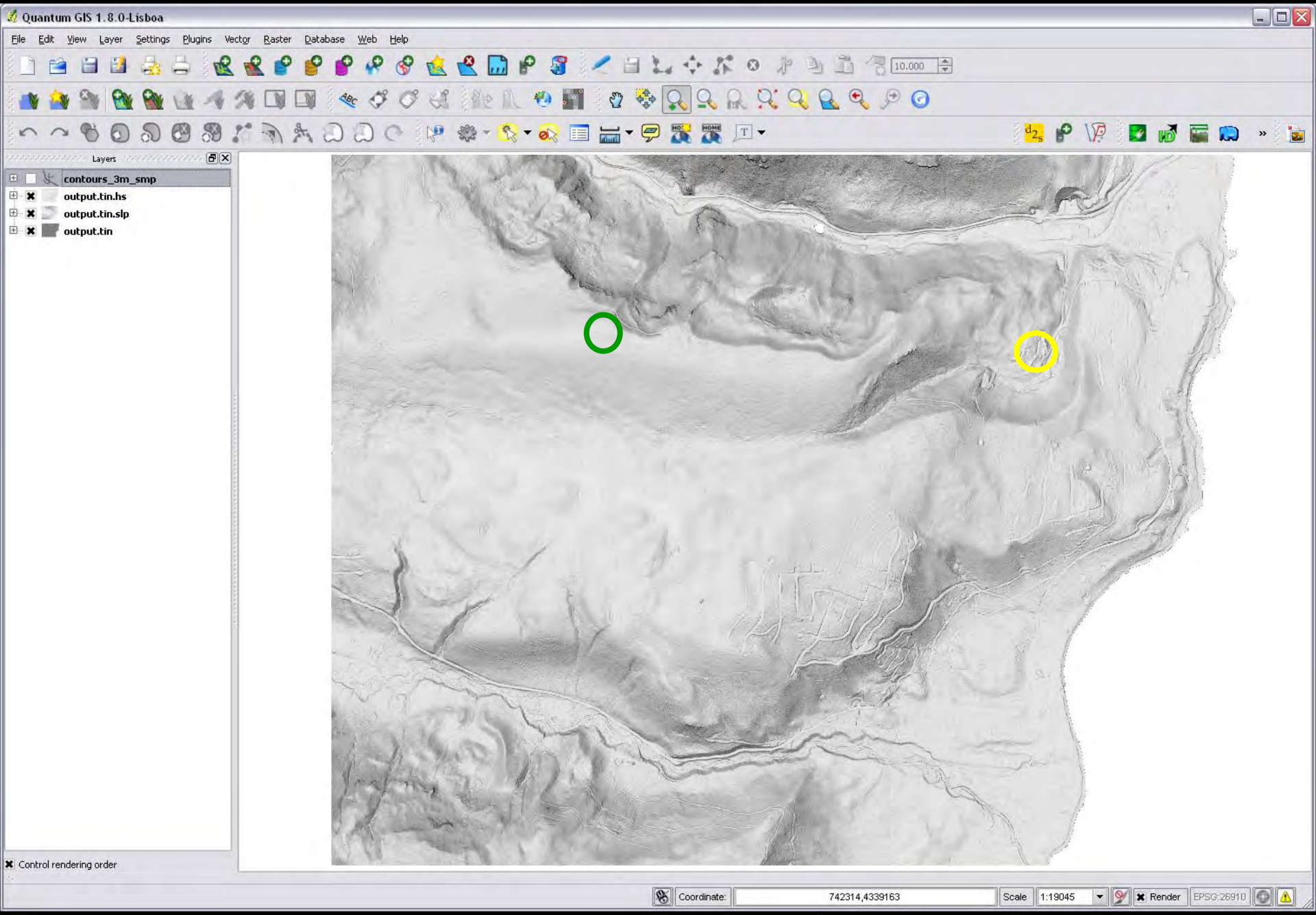
How can LiDAR be used as a **tool**?

We will design an imaginary trail to demonstrate how LiDAR data can be used in this process

Specs:

- 4’ wide, multi-use, two way
- Maximum corridor grade 6%
- Obey “half rule” (trail grade never steeper than half sideslope)
- Avoid challenging construction


Footbridge
89
1000
6600
6800
BM 6211
Gate
Twin Crags
6400
Rampart
6208
11
12
7200
7000
SKI LIFT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output.tin.slp
output.tin
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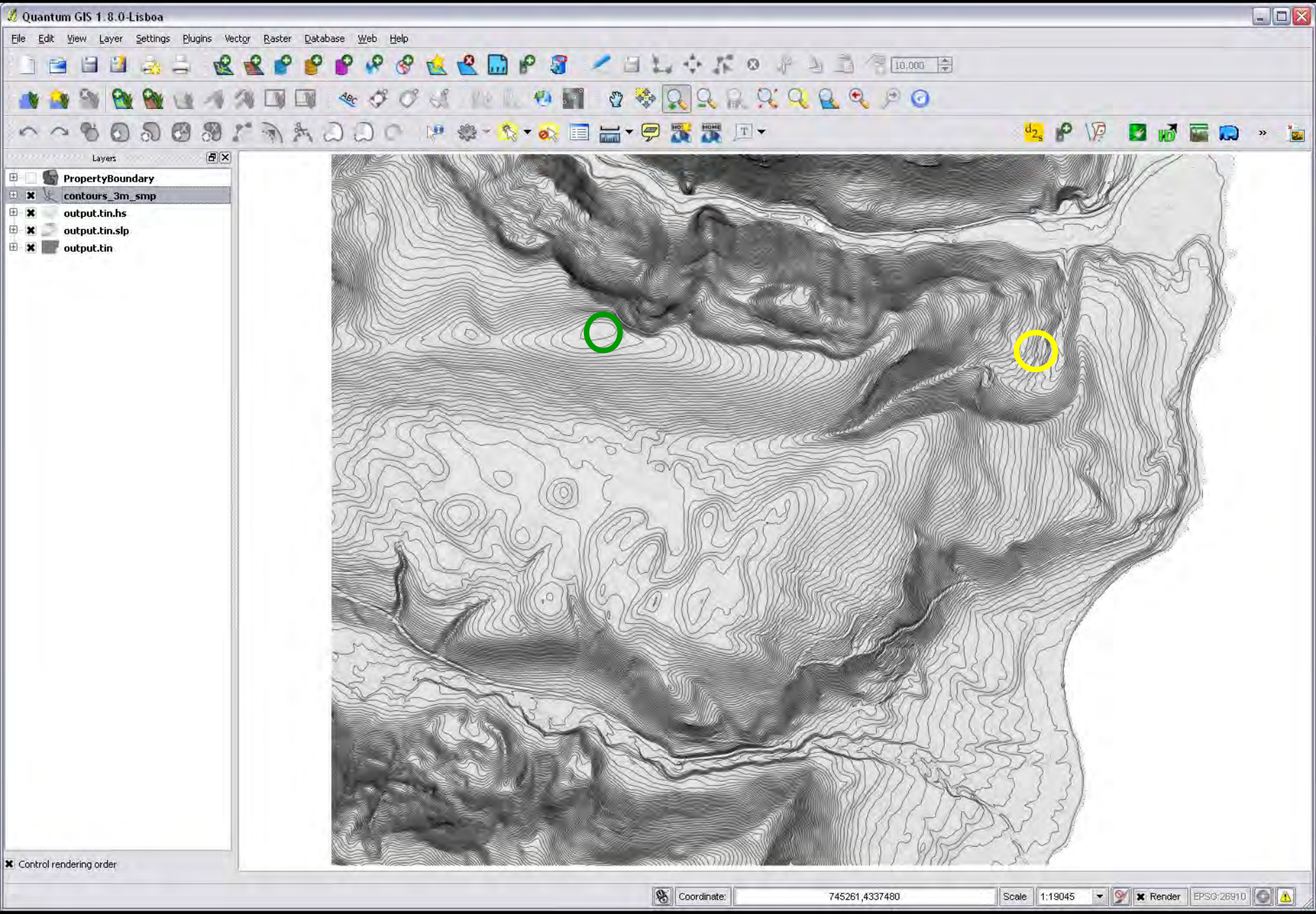
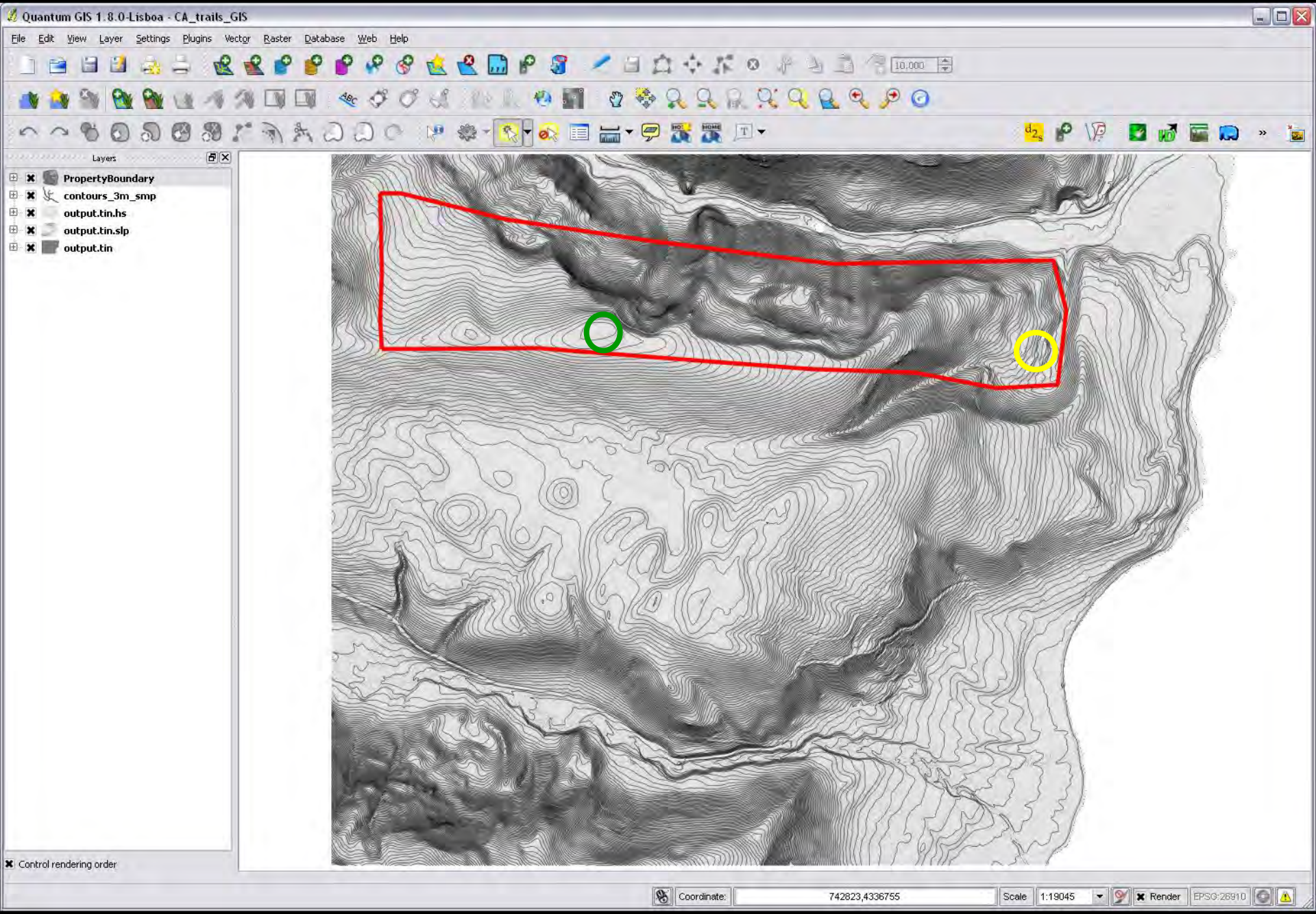


Contour Interval 3m



Contour Interval 3m

Step 1: Scouting
Main tasks: Learn the terrain and identify control points

Cliffs, view spots, rock out crops, wet areas, switchback locations.

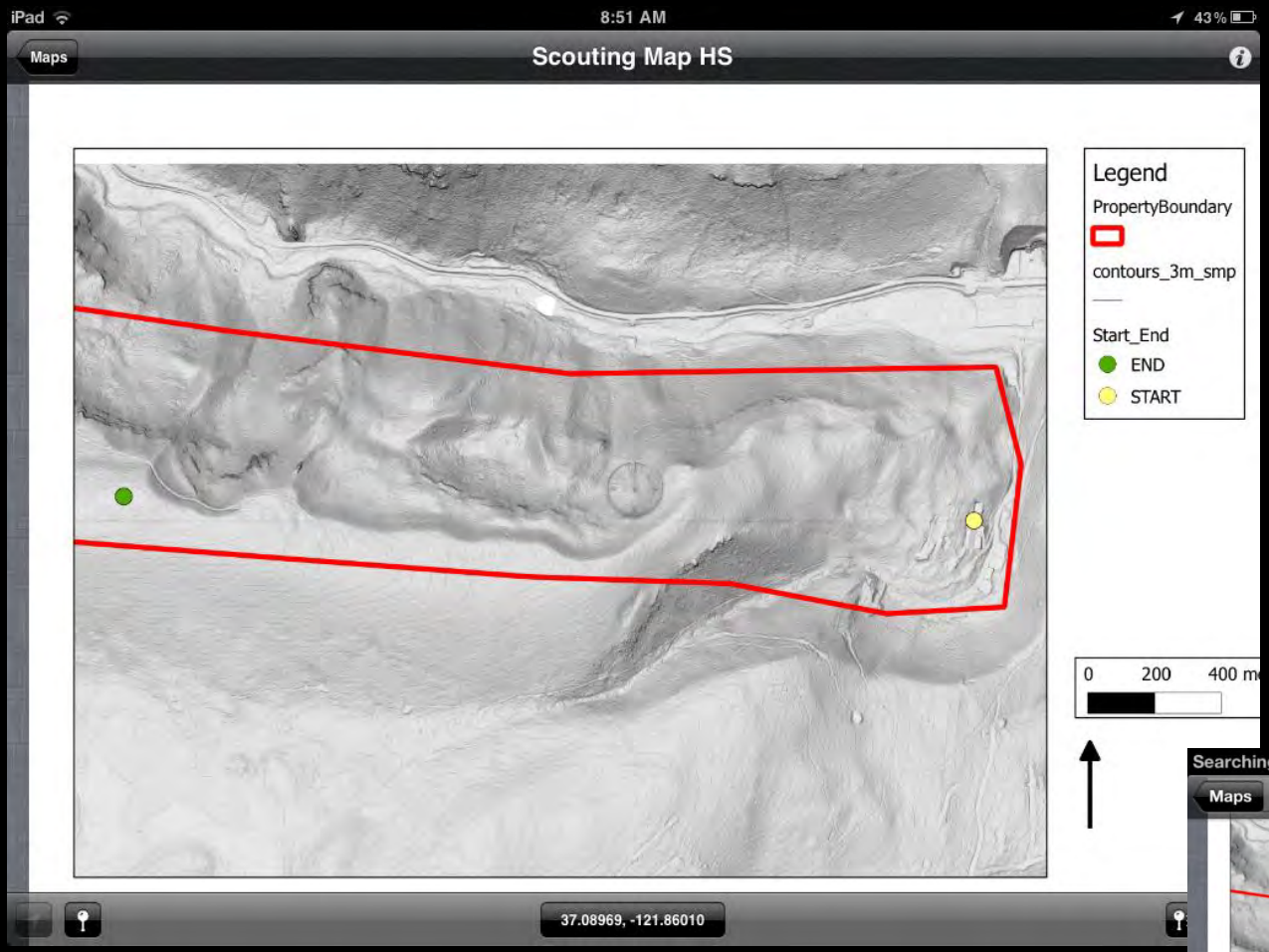
Still need to hike around to field verify and learn the terrain, but LiDAR can make our field work more efficient.

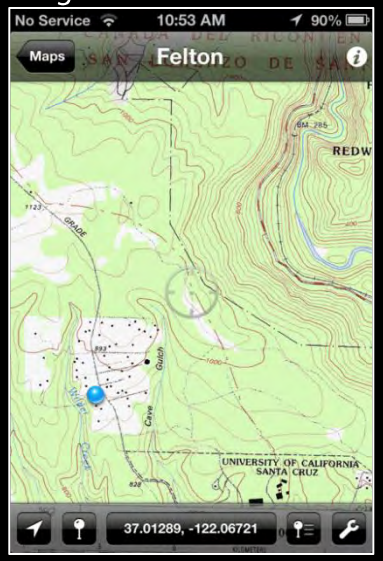
Ideally, an exported PDF map can be georeferenced. Then, loaded to smartphone using:

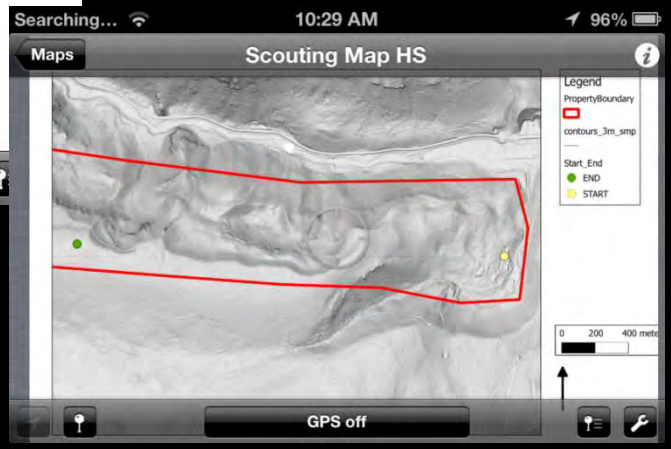
Avenza PDF Maps
Get the app, get the map.™

FREE

Tip: Make maps at high resolution (600 dpi) to allow sufficient zooming in PDF Maps App.







This can be done using ArcGIS
not currently possible with QGIS, but hopefully soon…

Searching...
10:46 AM
92%
Map
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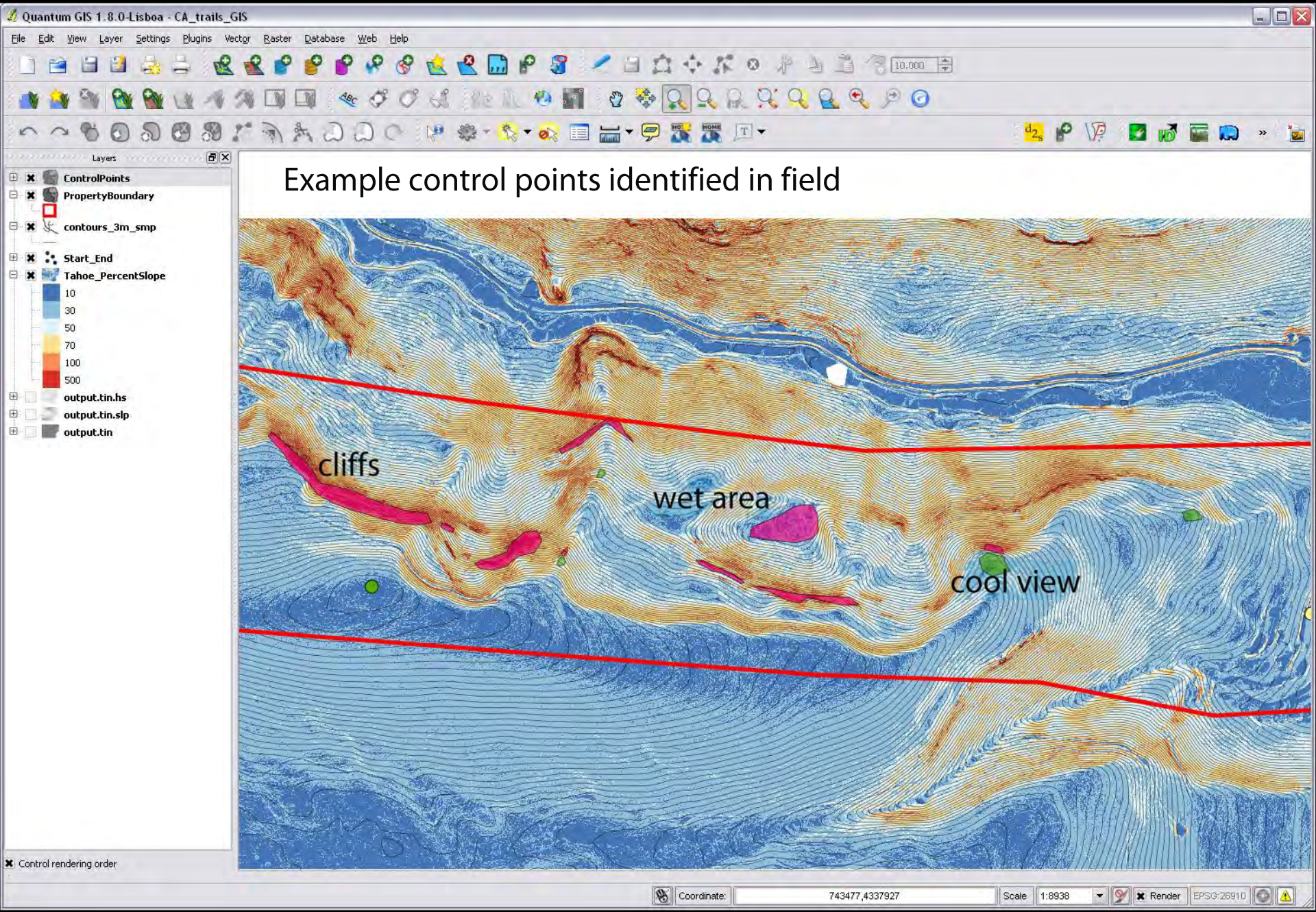


Contour Interval 3m

Step 2: Identify potential corridors (30m wide)

Contour Interval =	2 m
Grade	Distance between contours
1%	200 m
2%	100 m
3%	67 m
4%	50 m
5%	40 m
6%	33 m
7%	29 m
8%	25 m
9%	22 m
10%	20 m
11%	18 m
12%	17 m
13%	15 m
14%	14 m
15%	13 m

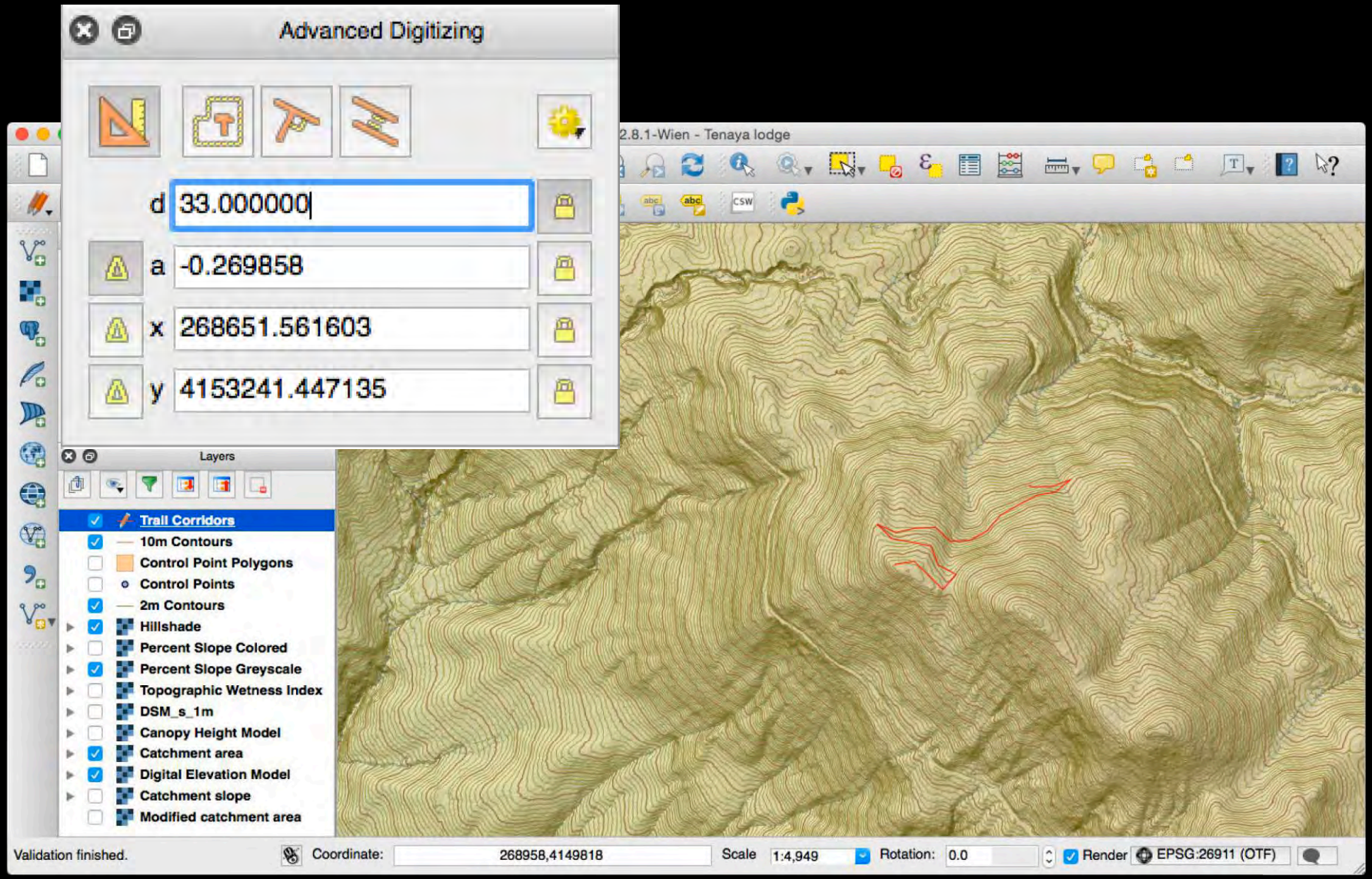
Grade = rise/run

Target maximum average grade = 6%

rise = 2m contour interval

2m/33m = 0.06

Target for corridor layout is 33m or more between contours.


Advanced Digitizing
d 33.000000
a -0.269858
x 268651.561603
y 4153241.447135
2.8.1-Wien - Tenaya lodge
Layers
Trail Corridors
10m Contours
Control Point Polygons
Control Points
2m Contours
Hillshade
Percent Slope Colored
Percent Slope Greyscale
Topographic Wetness Index
DSM_s_1m
Canopy Height Model
Catchment area
Digital Elevation Model
Catchment slope
Modified catchment area
Validation finished.
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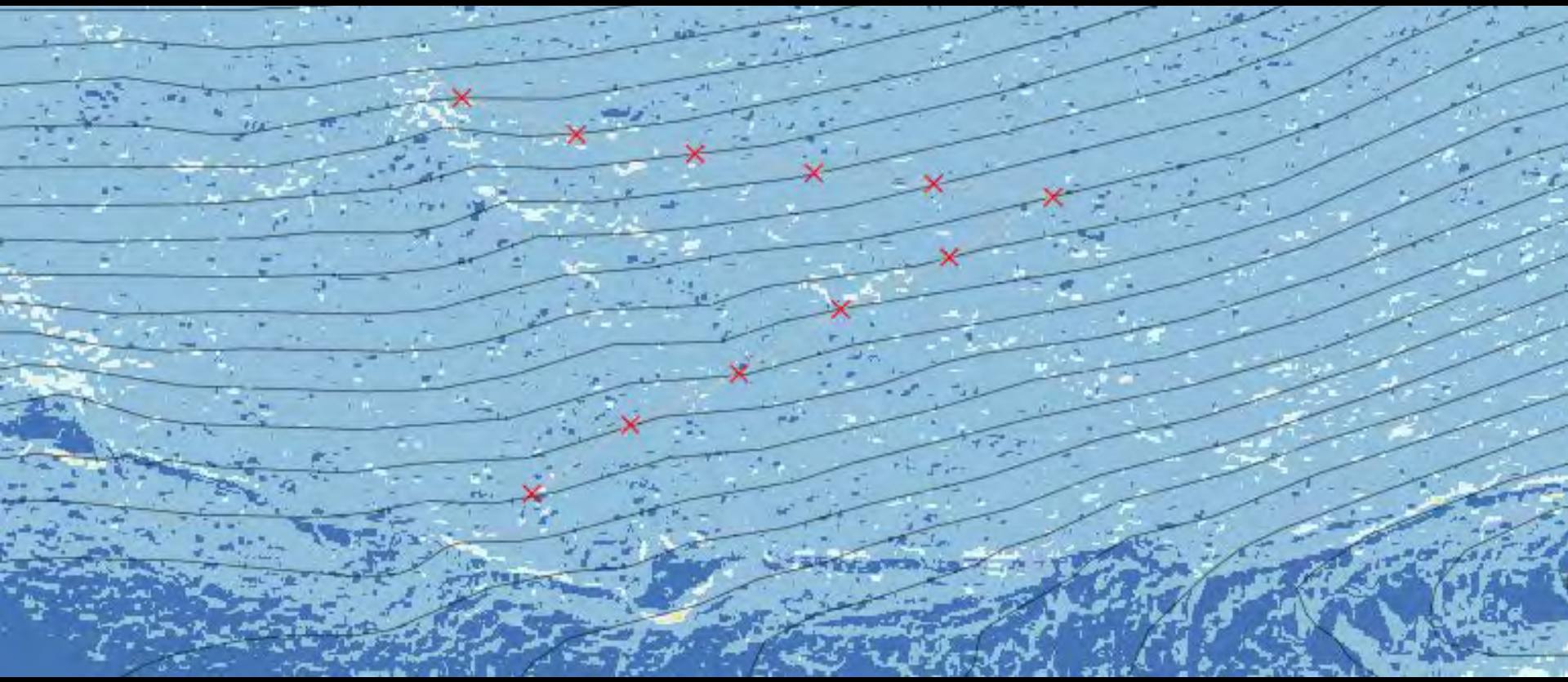
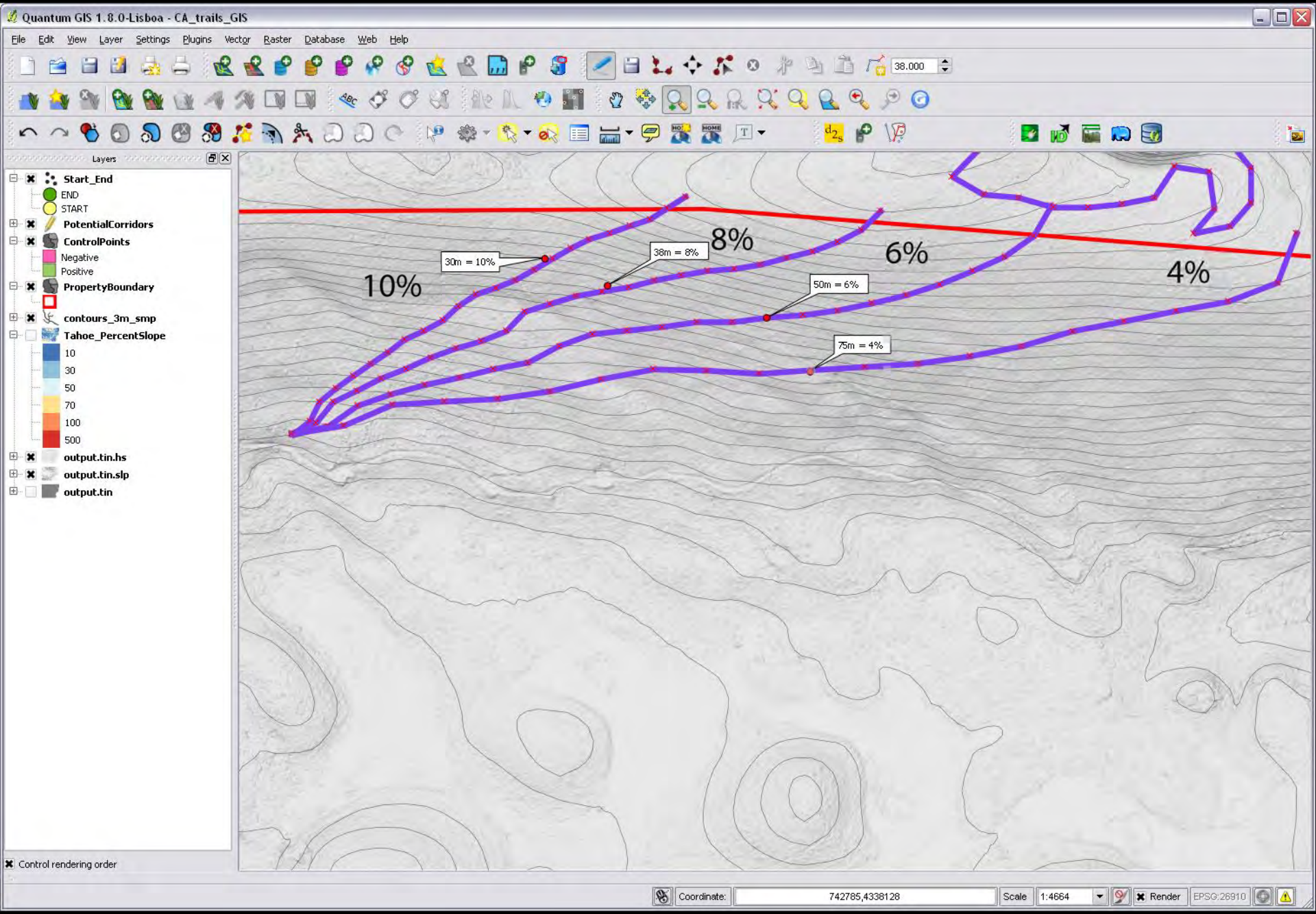
EPSG:26911 (OTF)

Target maximum average grade = 6%

Grade maintained by using a set polyline segment length, and snapping to contours

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Start_End
END
START
PotentialCorridors
ControlPoints
Negative
Positive
PropertyBoundary
contours_3m_smp
Tahoe_PercentSlope
10
30
50
70
100
500
output.tin.hs
output.tin.slp
output.tin
Control rendering order
30m = 10%
38m = 8%
50m = 6%
75m = 4%
10%
8%
6%
4%
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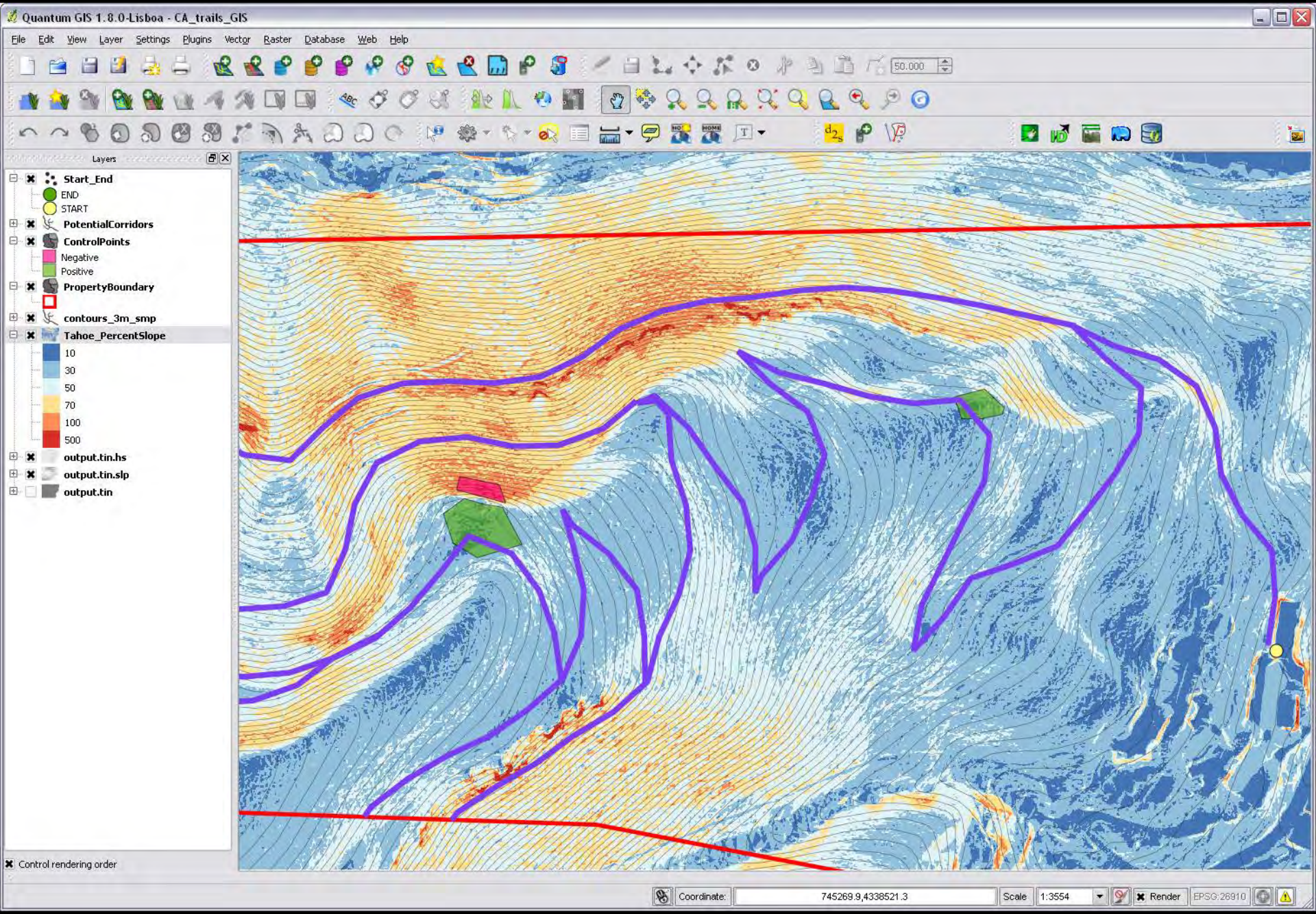
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ControlPoints
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Tahoe_PercentSlope
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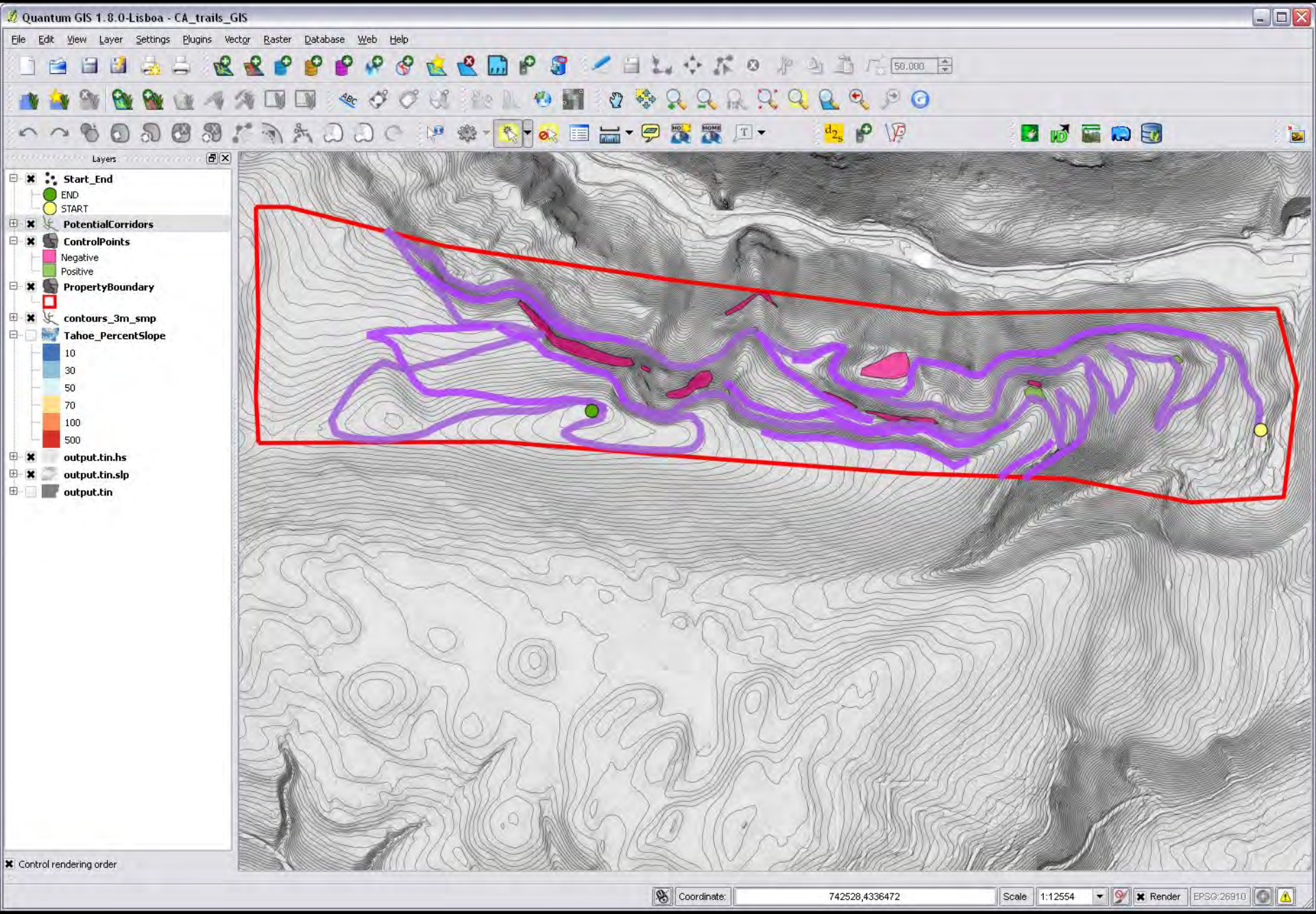
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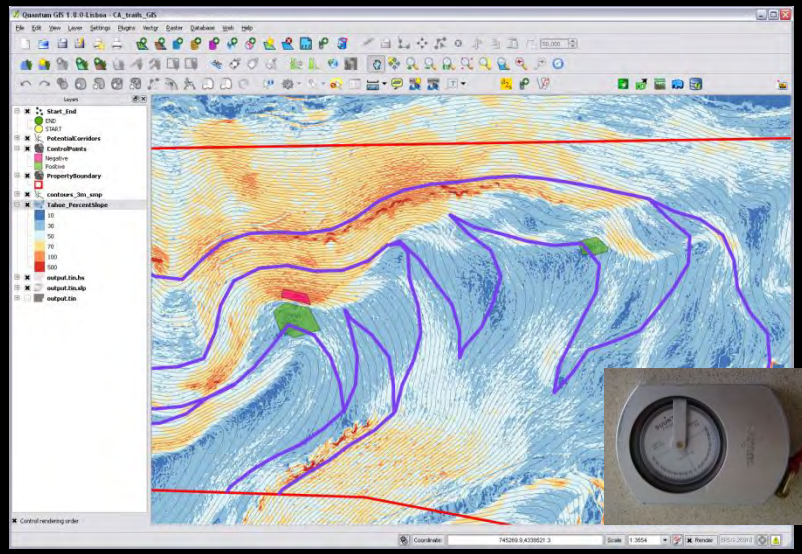
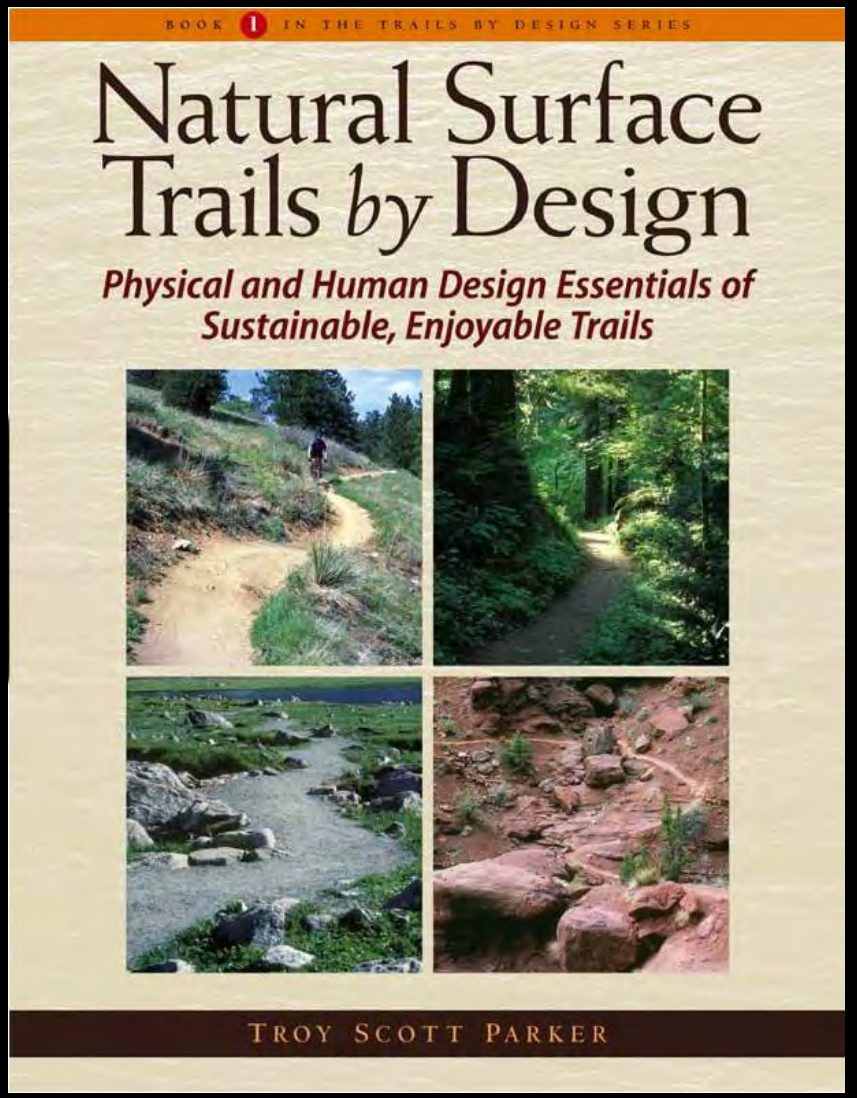
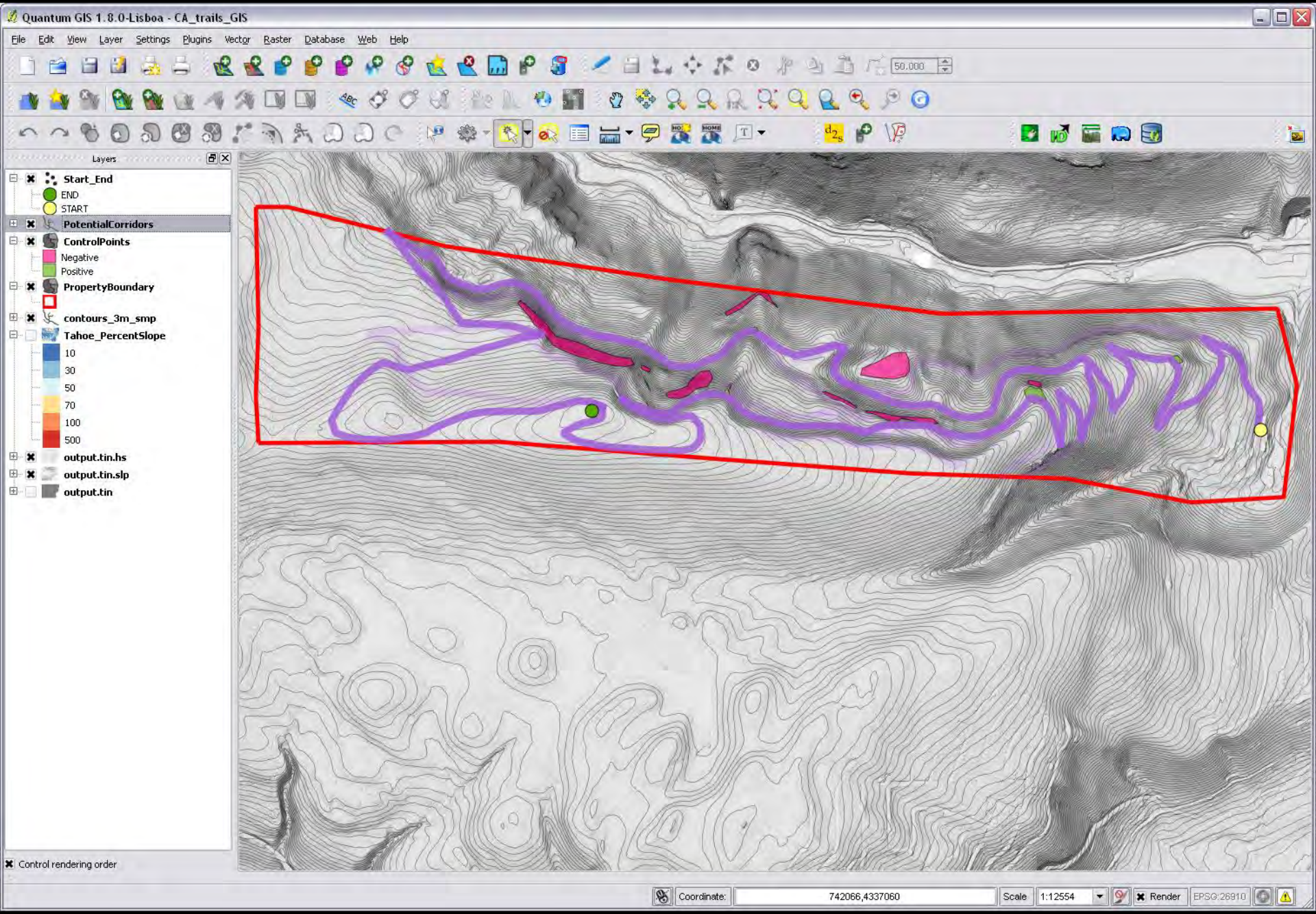
Next steps...




BOOK 1 IN THE TRAILS BY DESIGN SERIES
Natural Surface Trails by Design
Physical and Human Design Essentials of Sustainable, Enjoyable Trails
TROY SCOTT PARKER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Render
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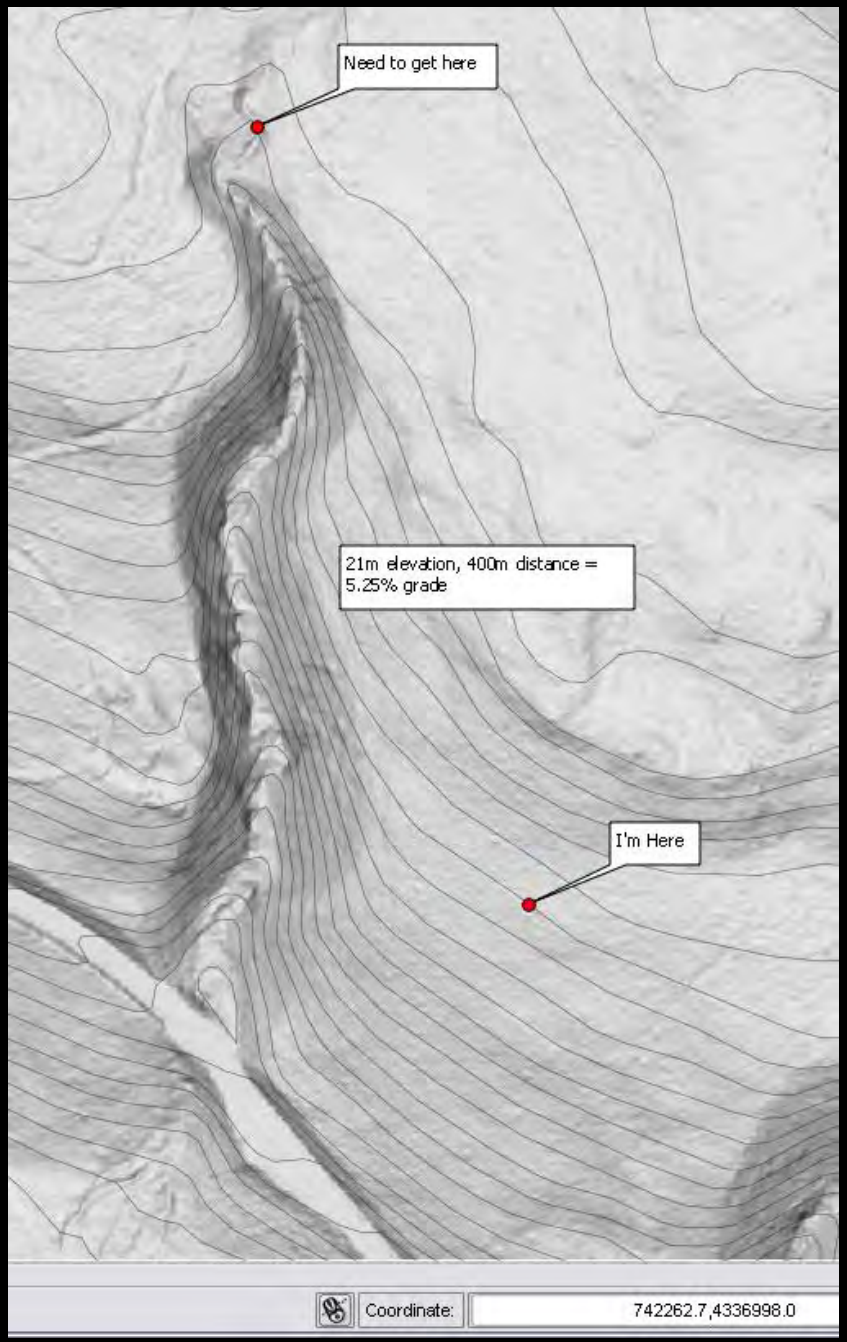
Step 3: Corridor flagging
Main task: Identify review corridor

Once you have identified the ideal corridor, now it is time to get out your flagging.

Now working towards corridor 10m wide

(My favorite is Texas Brand GloPink)

Flagging in thick, steep, forested canyons (like most of Santa Cruz).
Still should use your clinometer, especially if you are not using high precision GPS (like an iPhone) or your LiDAR data isn't super accurate.



Flagging in thick, steep, forested canyons (like most of Santa Cruz).
Still should use your clinometer, especially if you are not using high precision GPS (like an iPhone) or your LiDAR data isn't super accurate.

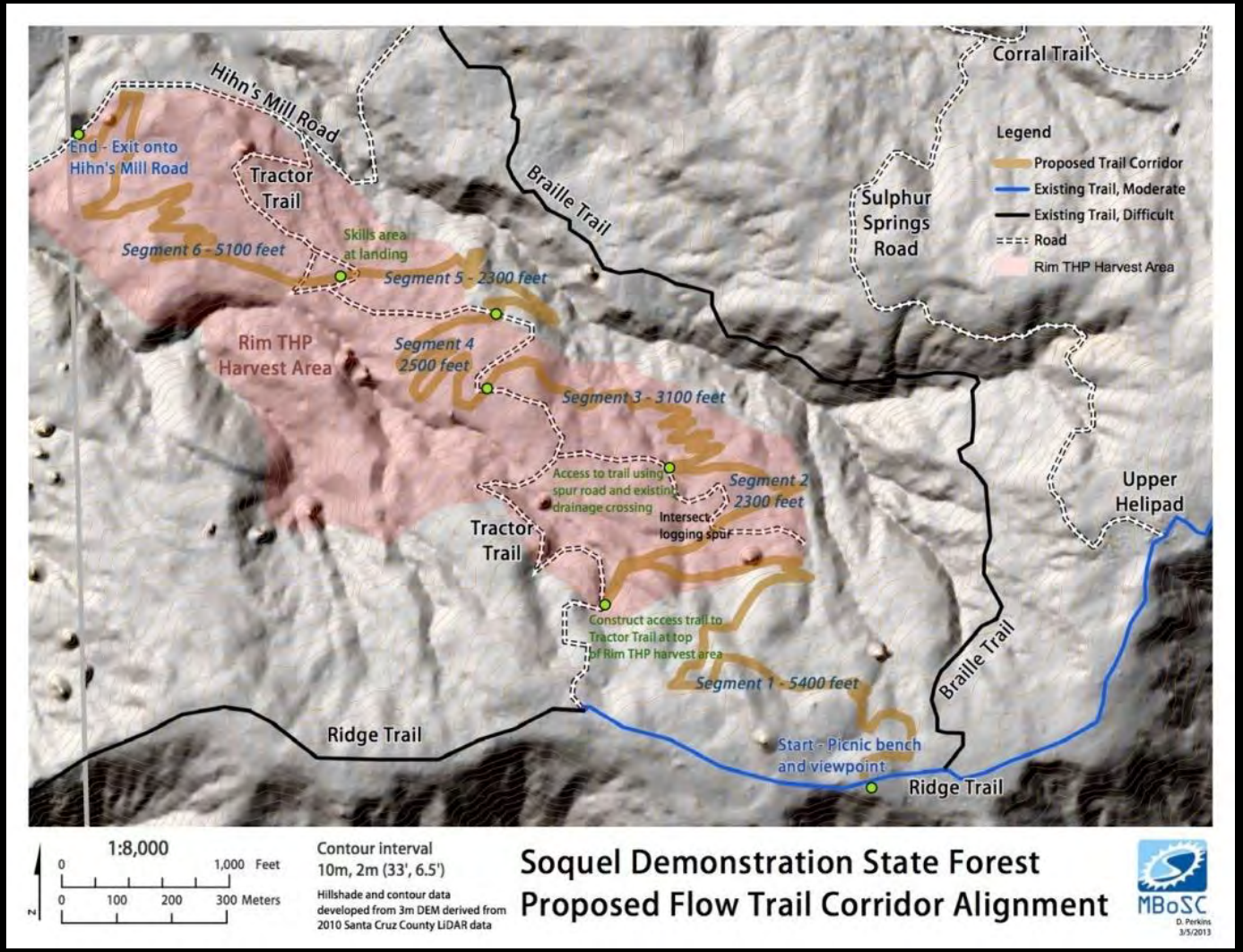
Flagging in heavy brush

Maybe leave the clinometer at home if…

Montaña de Oro State Park, San Luis Obispo County

Step 4: Reviews and approvals

A good map and terrain data usually can help this process as well!



Step 5: Fine flagging (1m wide)

Conclusion

Very useful LiDAR data and analysis tools are available for free in many locations in the state, and coverage is expanding quickly.

LiDAR data provides a rich topographic dataset that allows a trail designer to work more efficiently and make better decisions.

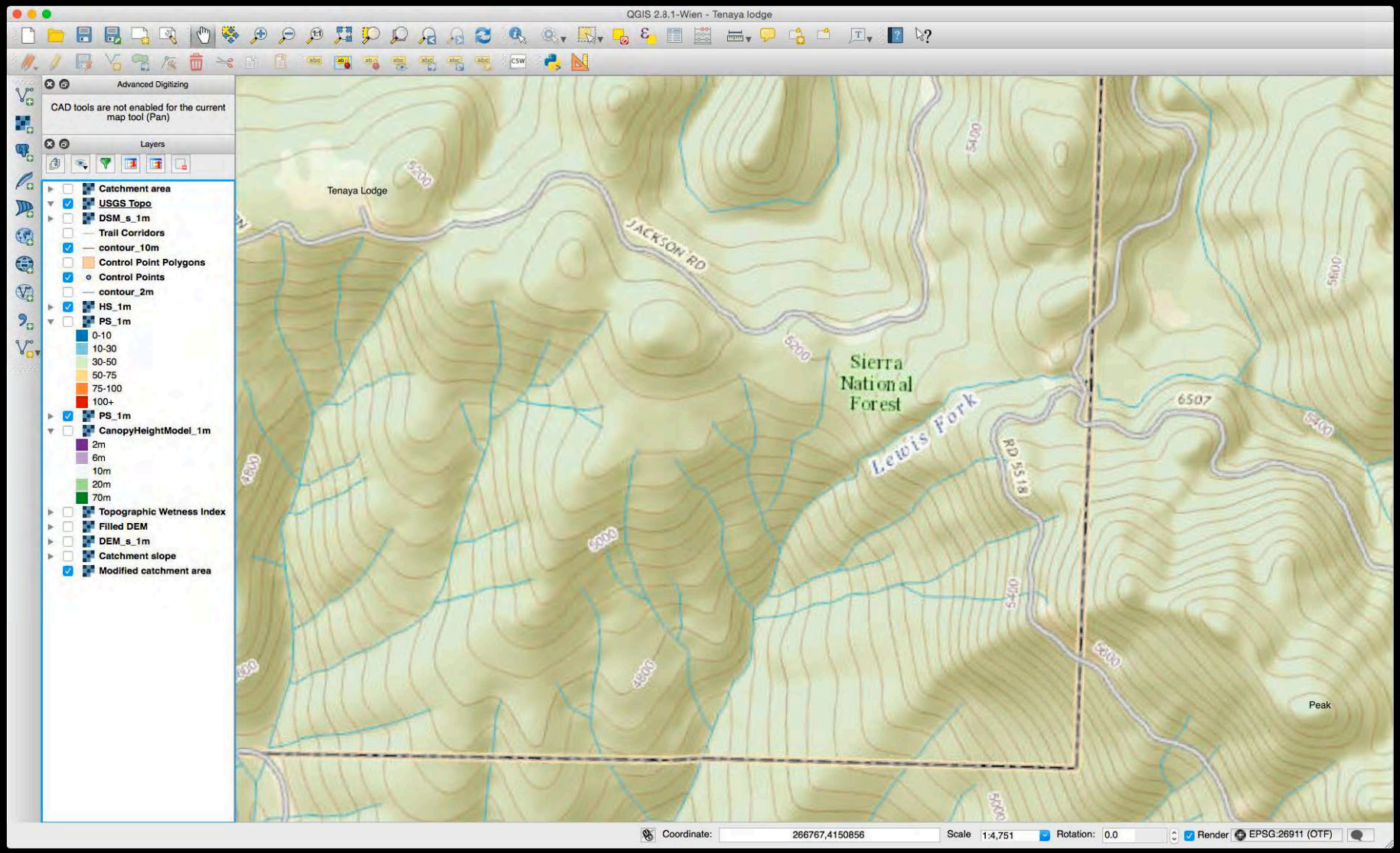
Greg and I wishing we had LiDAR data at Montaña de Oro State Park

NOT A SUBSTITUTE FOR SPENDING TIME ON THE GROUND!

Thanks! Questions?

Drew Perkins

Contact Info:
trails@mbosc.org


QGIS 2.8.1-Wien - Tenaya lodge
Advanced Digitizing
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Layers
Catchment area
USGS Topo
DSM_s_1m
Trail Corridors
contour_10m
Control Point Polygons
Control Points
contour_2m
HS_1m
PS_1m
0-10
10-30
30-50
50-75
75-100
100+
PS_1m
CanopyHeightModel_1m
2m
6m
10m
20m
70m
Topographic Wetness Index
Filled DEM
DEM_s_1m
Catchment slope
Modified catchment area
Tenaya Lodge
JACKSON RD
Sierra National Forest
Lewis Fork
RD 5518
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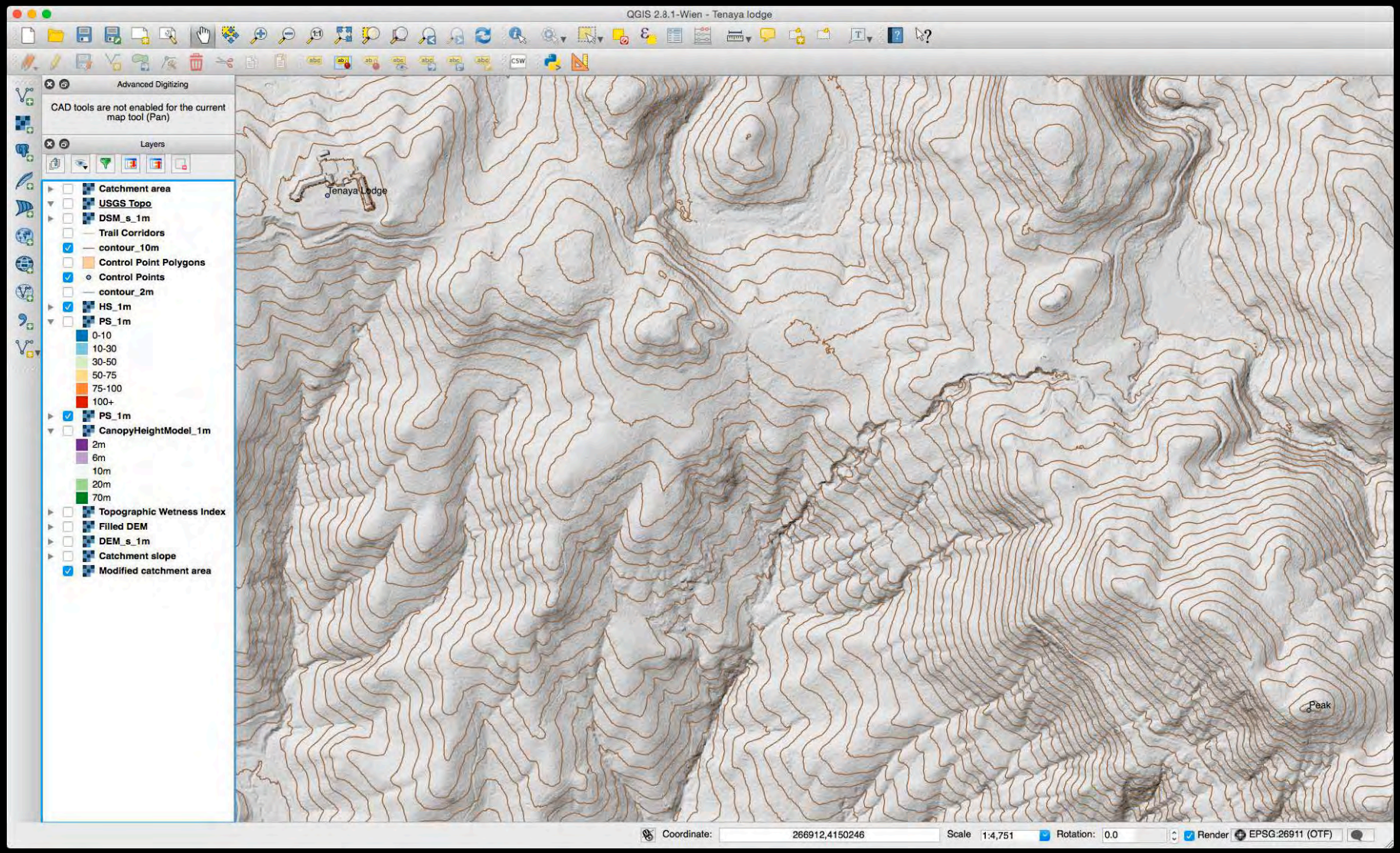
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USGS Topo
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Trail Corridors
contour_10m
Control Point Polygons
Control Points
contour_2m
HS_1m
PS_1m
0-10
10-30
30-50
50-75
75-100
100+
PS_1m
CanopyHeightModel_1m
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6m
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