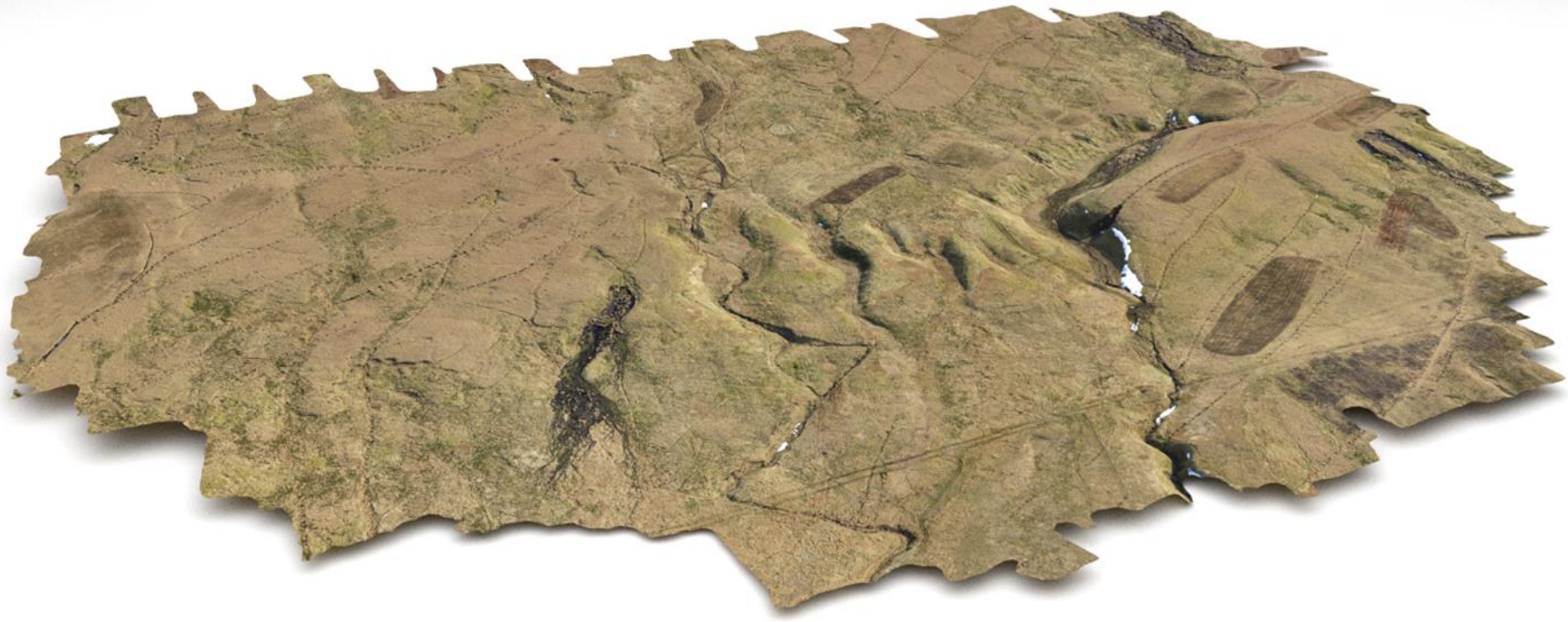
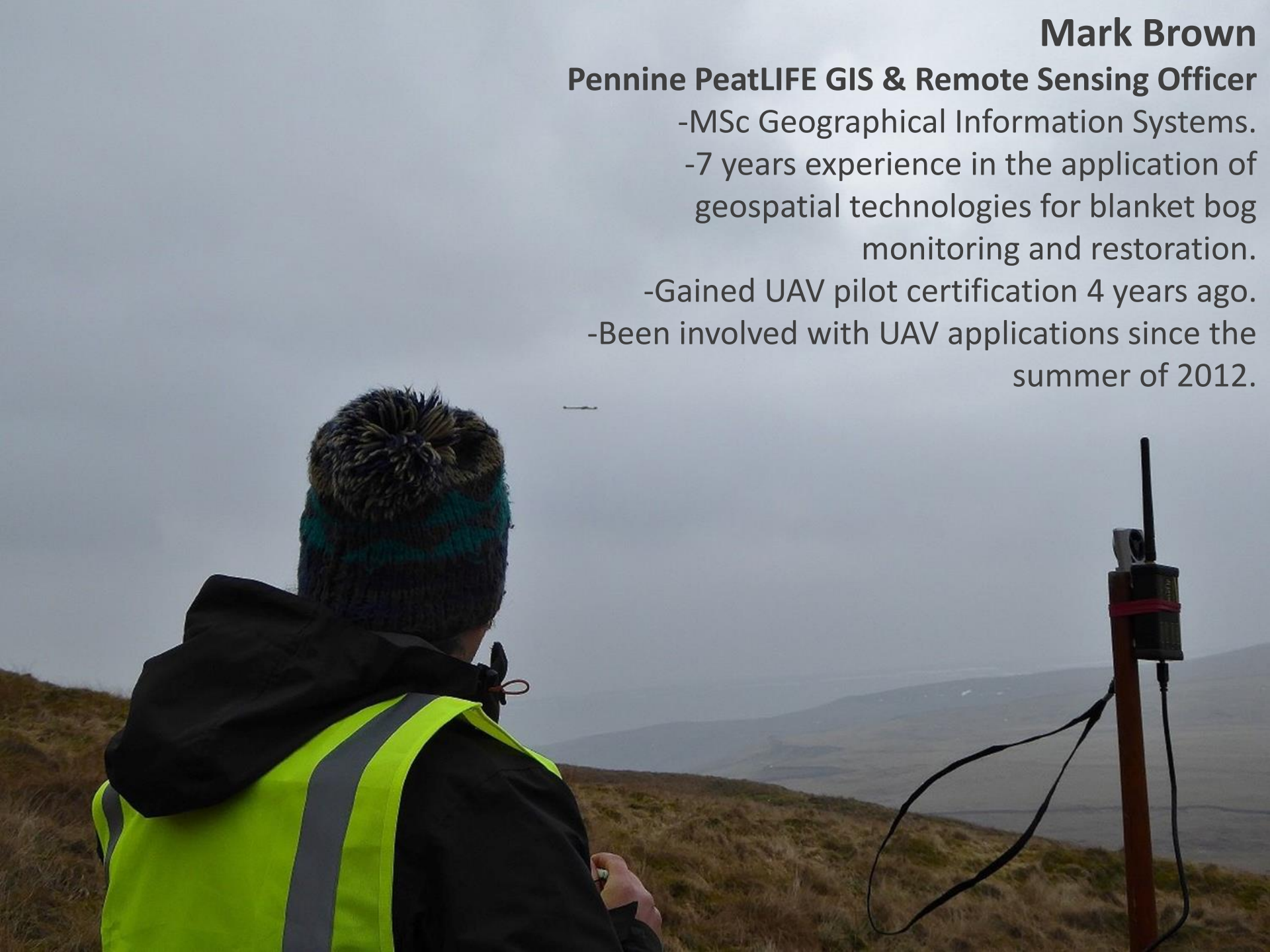


UAV Applications for blanket bog restoration and Monitoring

Mark Brown
GIS & Remote Sensing Officer
Pennine PeatLIFE

Yorkshire Wildlife Trust
www.ywt.org.uk



Mark Brown

Pennine PeatLIFE GIS & Remote Sensing Officer

-MSc Geographical Information Systems.

-7 years experience in the application of geospatial technologies for blanket bog monitoring and restoration.

-Gained UAV pilot certification 4 years ago.

-Been involved with UAV applications since the summer of 2012.

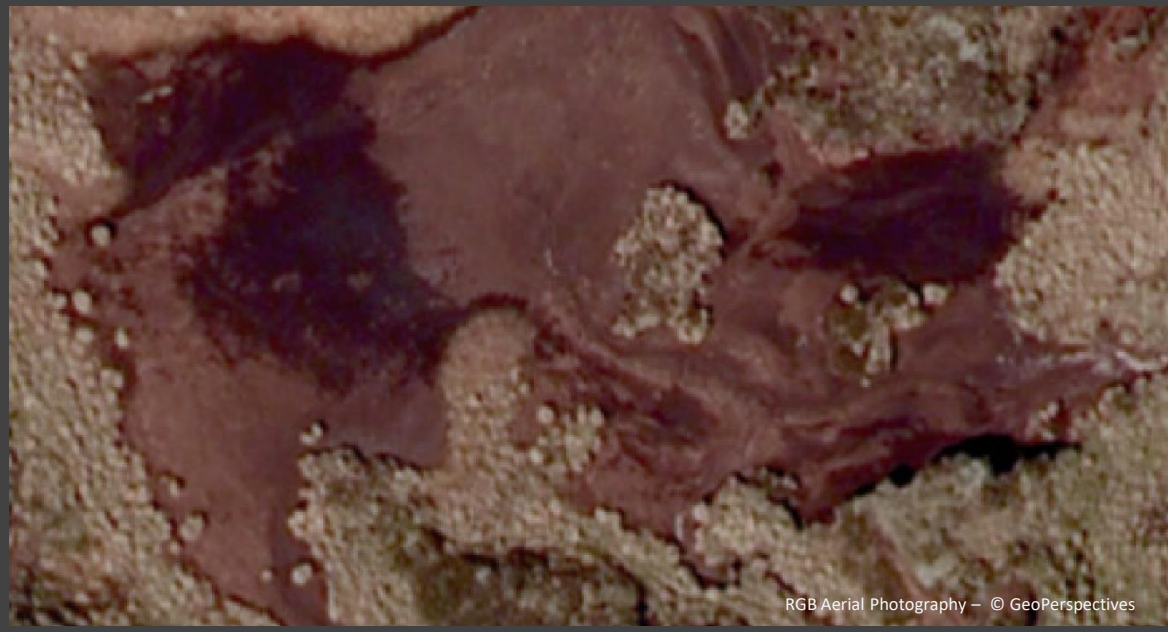
Presentation Overview

- Our background in UAVs
- Capturing data, image processing and digital products
- What we do with the data

How and why did we start using UAVs in our work?

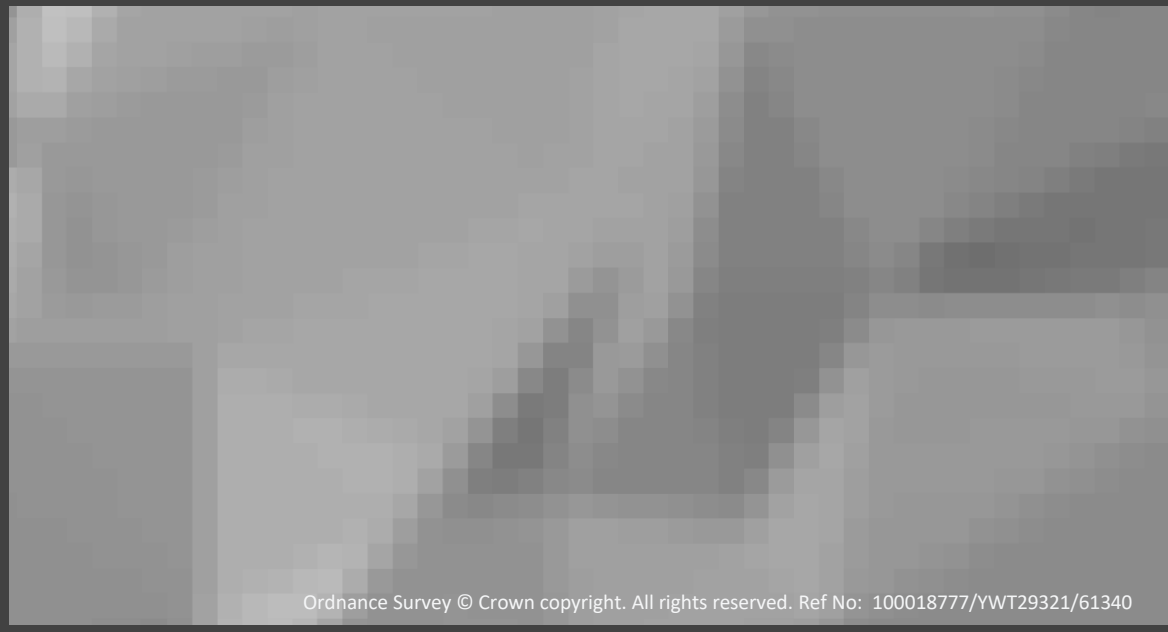
- We initially carried out a pilot project in collaboration with RAL Space (Part of the Science and Technologies Facilities Council (STFC)) back in the summer of 2012.
- This came about from our need for high resolution imagery and digital elevation models (DEMs) of peatland habitats

- Traditional commercial aerial imagery was years out of date and features were difficult to pick out in detail.
- At the time the off-the-shelf commercially available imagery was 25cm resolution.
- Costs to charter an aircraft to capture up-to-date imagery prohibitive and vastly outside of the budget of a not-for-profit organisation.

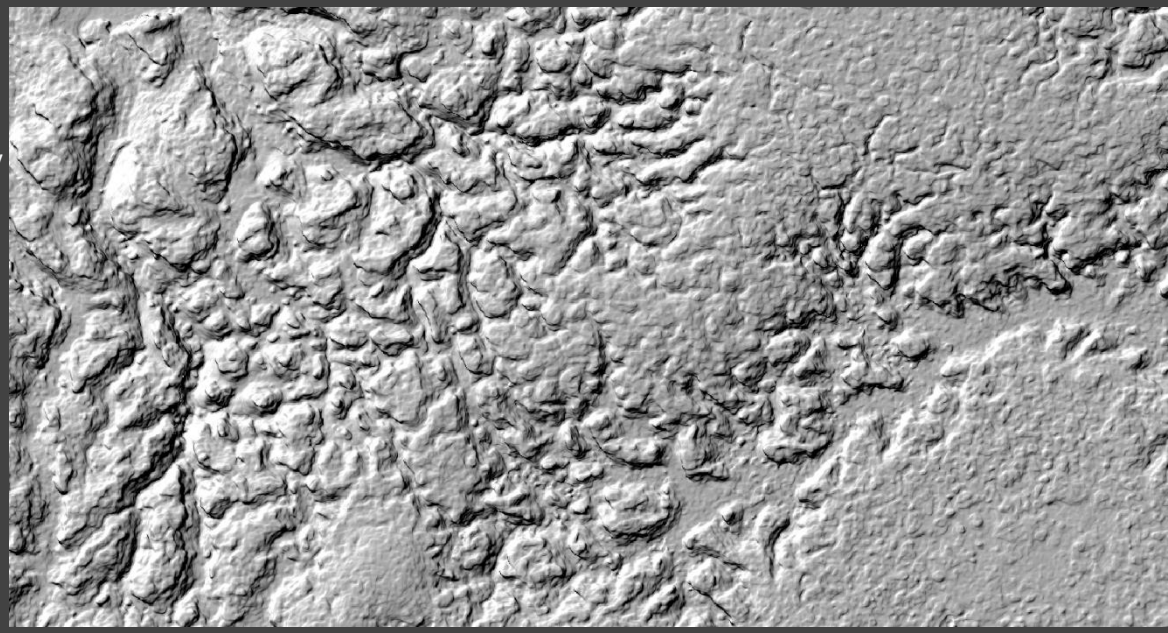


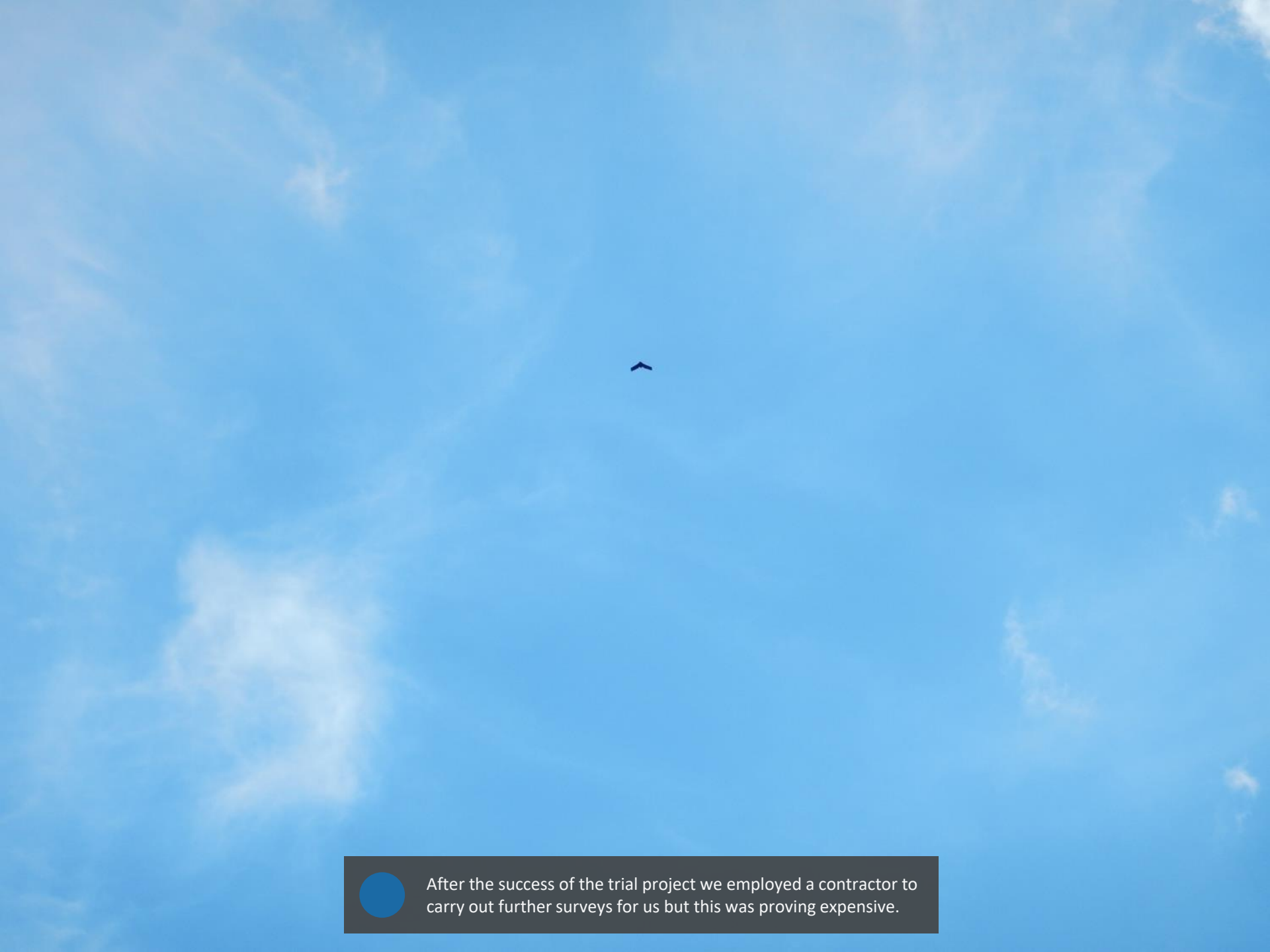
- Compare this to imagery captured using our UAV and processed at 3.5cm resolution.
- Vastly superior level of detail.
- Gives us remote sensing capabilities at a previously inaccessible scale

- LIDAR data available but very expensive at the time and limited coverage at higher resolutions.
- However even at 25cm resolution the data can still be of insufficient detail to detect key peat land features
- The cost to charter a plane or helicopter to carry out a LIDAR survey for just one of our sites was around the same cost as the new commercially available UAVs that were coming out back then.



- Compare the difference to a 5m resolution DEM and a 3.5cm resolution DEM that we generated from UAV Imagery covering the same area at the same scale
- What was essentially a blank canvas comes alive with the topography of the peat bog.
- This opened up a whole new world in which to carry out geospatial analysis of peat bog habitats.



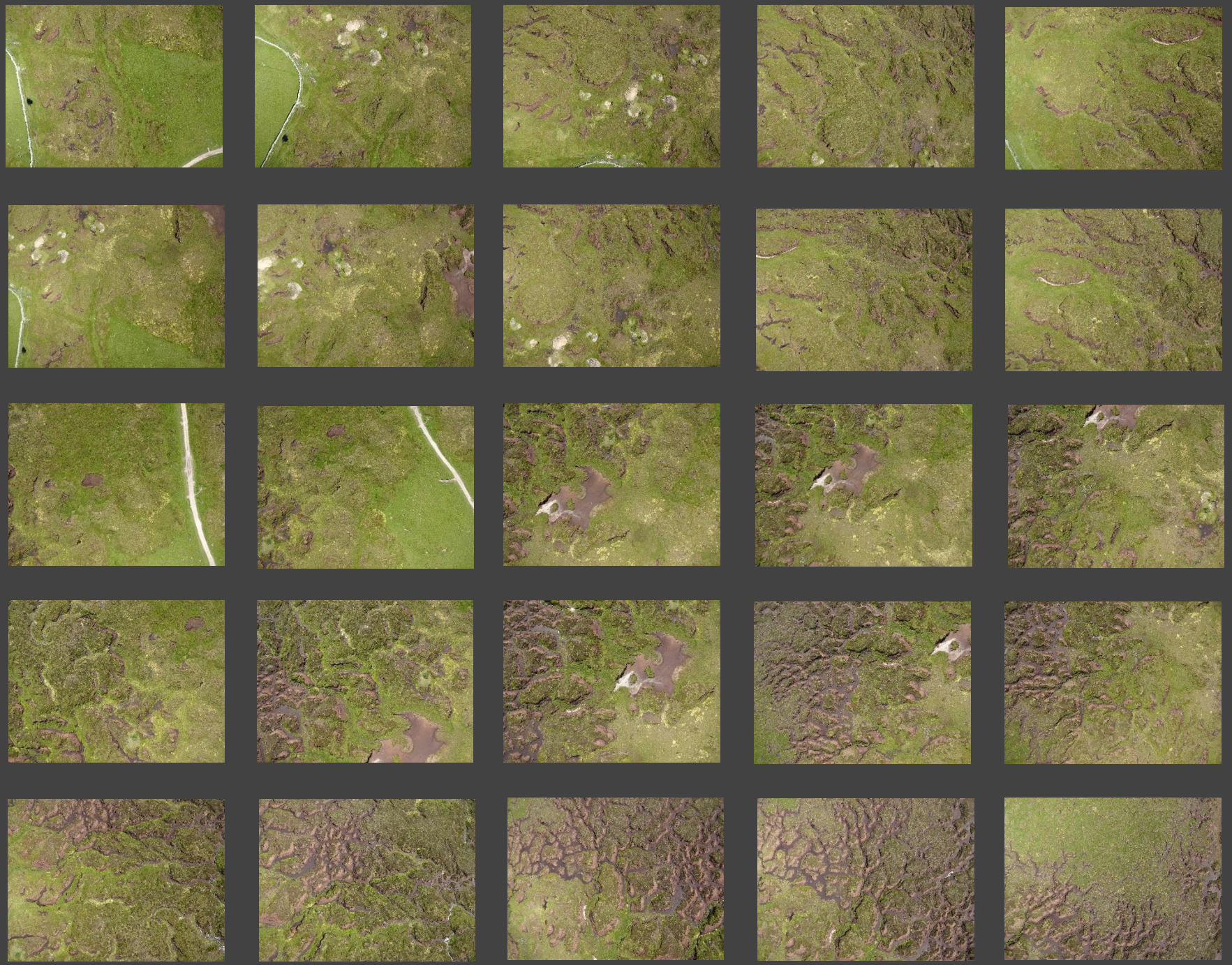

After the success of the trial project we employed a contractor to carry out further surveys for us but this was proving expensive.

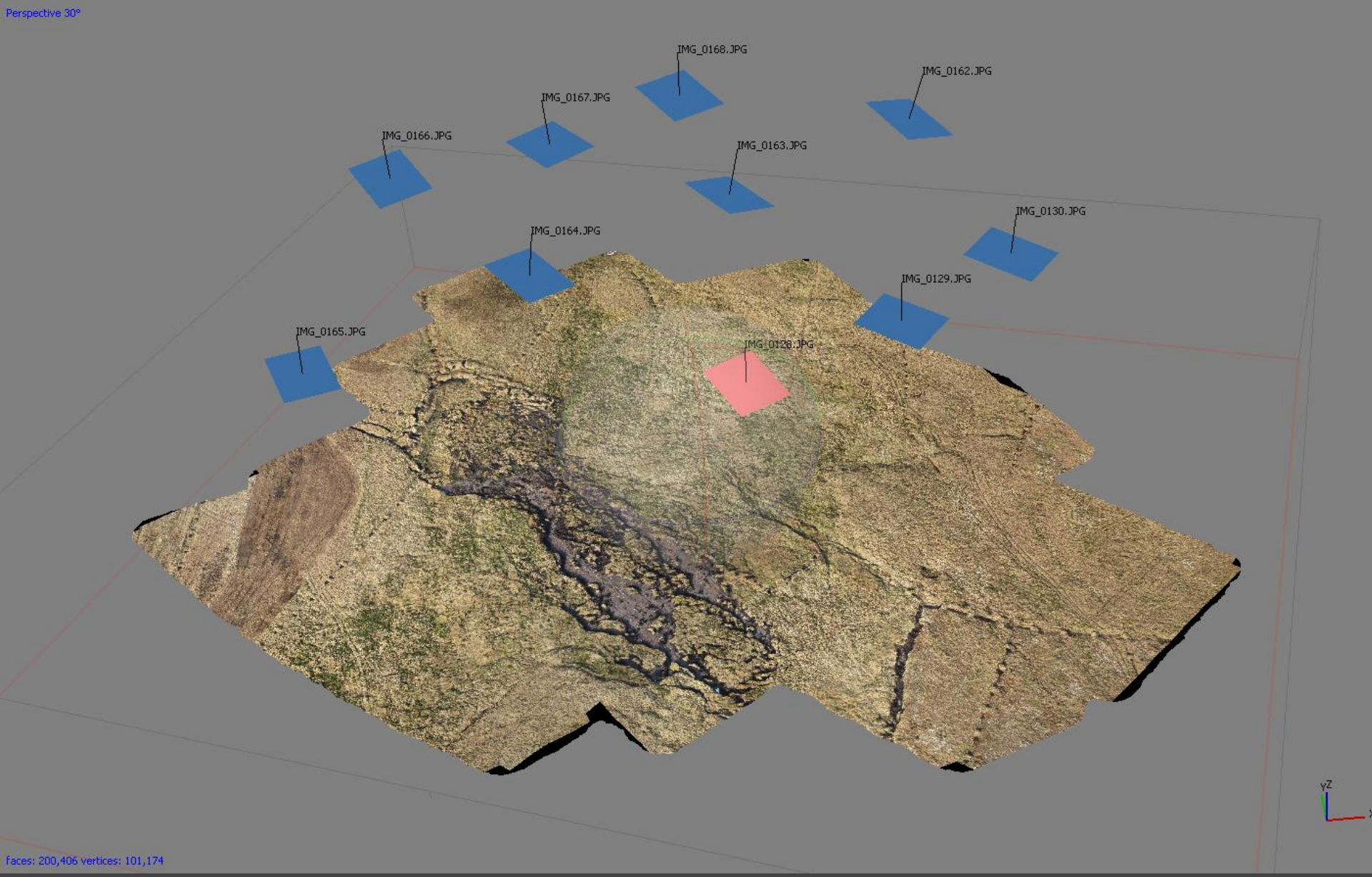
- Given the cost of commissioning a contractor to carry our surveys we decided to develop our own in-house capability and purchased our own UAV in the summer of 2014.

- Shortly after I was certified as a competent UAV pilot and we gained the necessary Permission for Aerial Work (PFAW) off the Civil Aviation Authority(CAA) in which to carry out commercial UAV work in UK airspace. We were the first Wildlife Trust to gain this permission.

Capturing data, image processing and digital products

- Flights are pre-programmed using flight control software. Live diagnostics of the UAV are provided during the flight.
- Due to CAA safety regulations we can't fly further than 500m away from the operator or at a height above 400ft. This equates to a maximum coverage of around 78.5ha per flight.
- A downward facing camera capture an image every few seconds. It is important that sufficient overlap between photographs is achieved in order for processing within photogrammetry software.





We use specialist software to perform photogrammetric processing of the digital imagery to generate 3D spatial data.

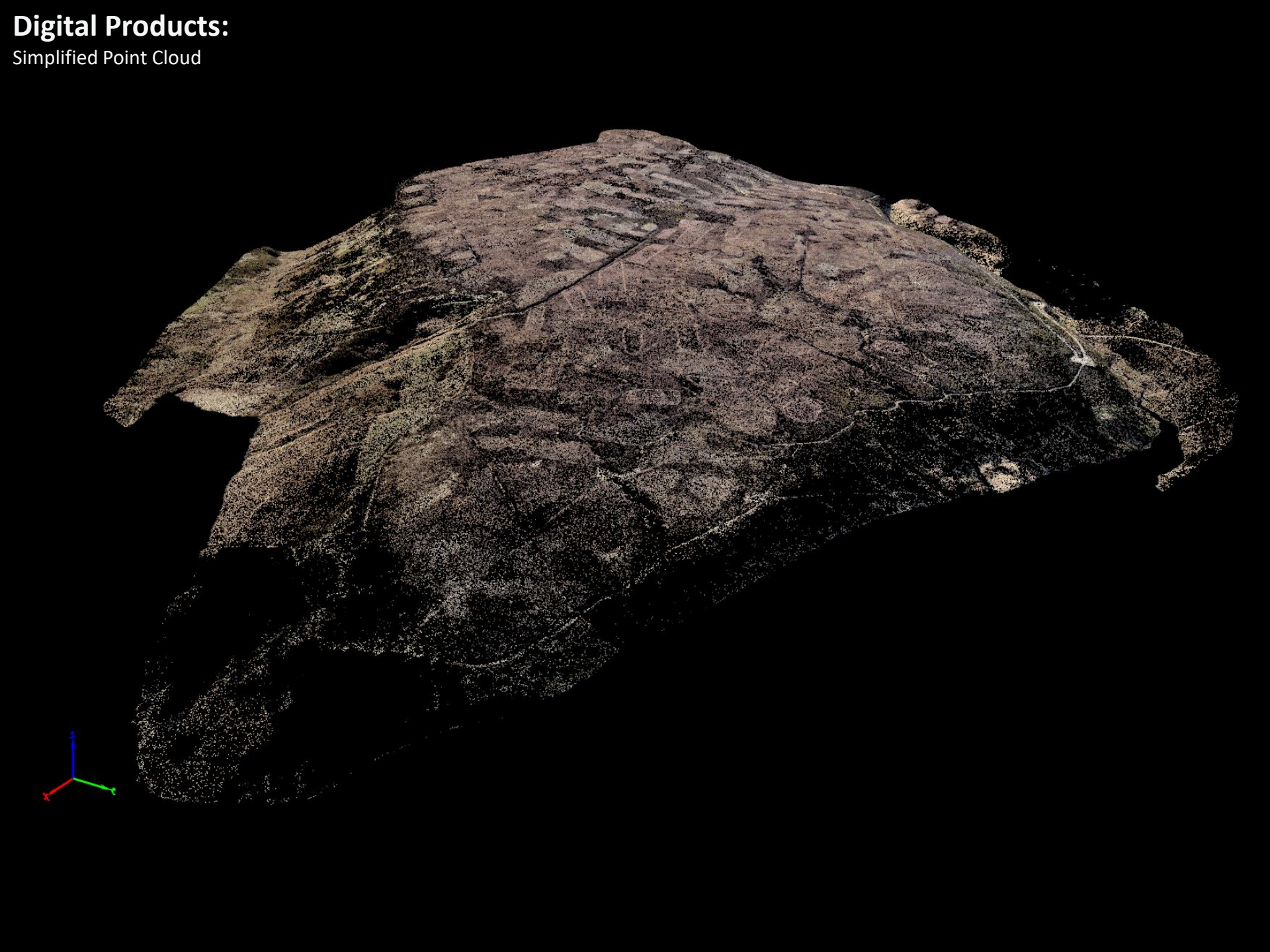
The software uses a range imaging technique from the field of **Computer vision** known as **Structure from Motion (SfM)**. Using this technique it is possible to estimate three-dimensional structures from a two-dimensional image sequence.

Digital products:

Ortho-imagery – RGB, NIR, Red Edge, Multispectral

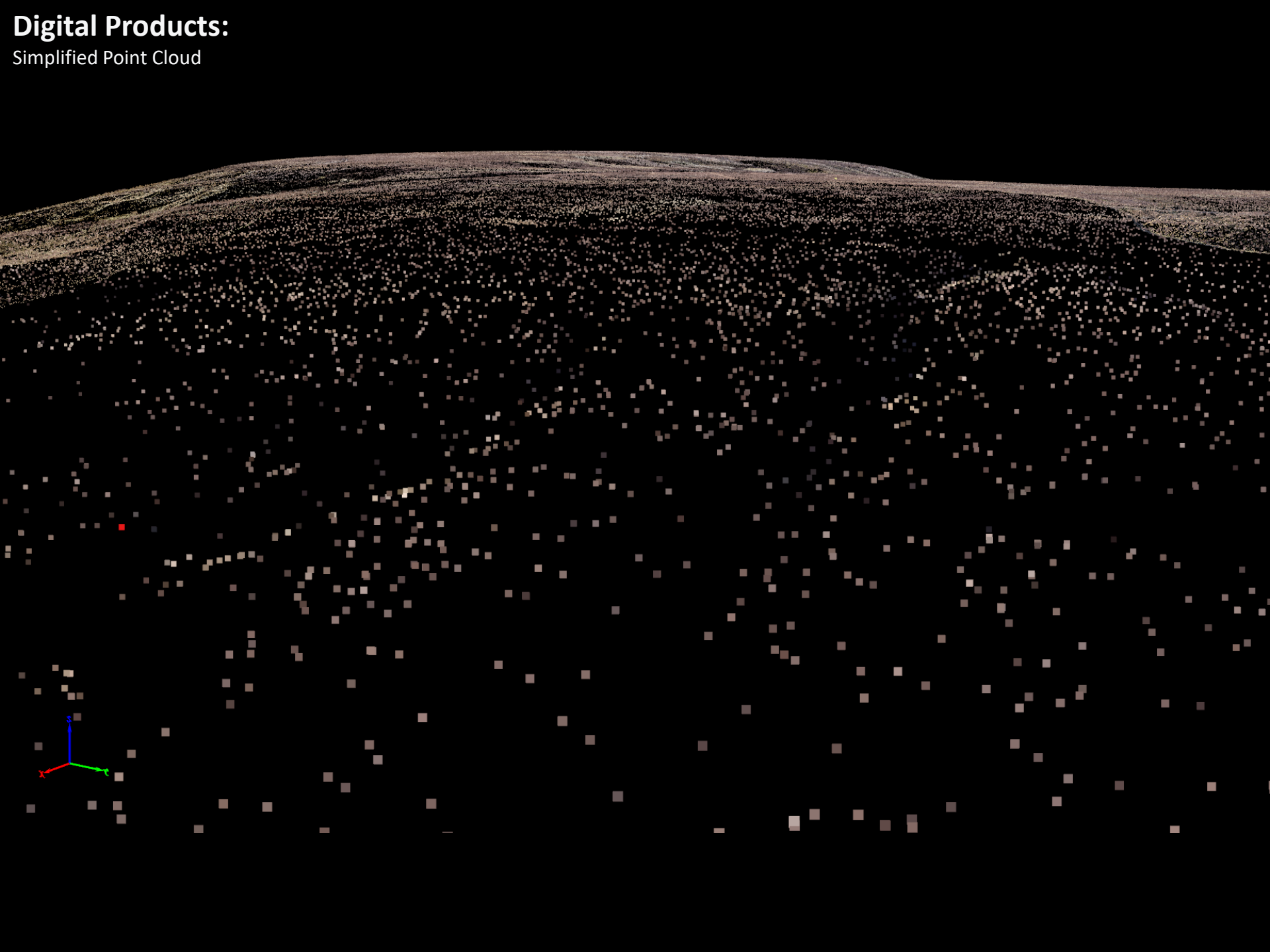
Digital Products:

Simplified Point Cloud



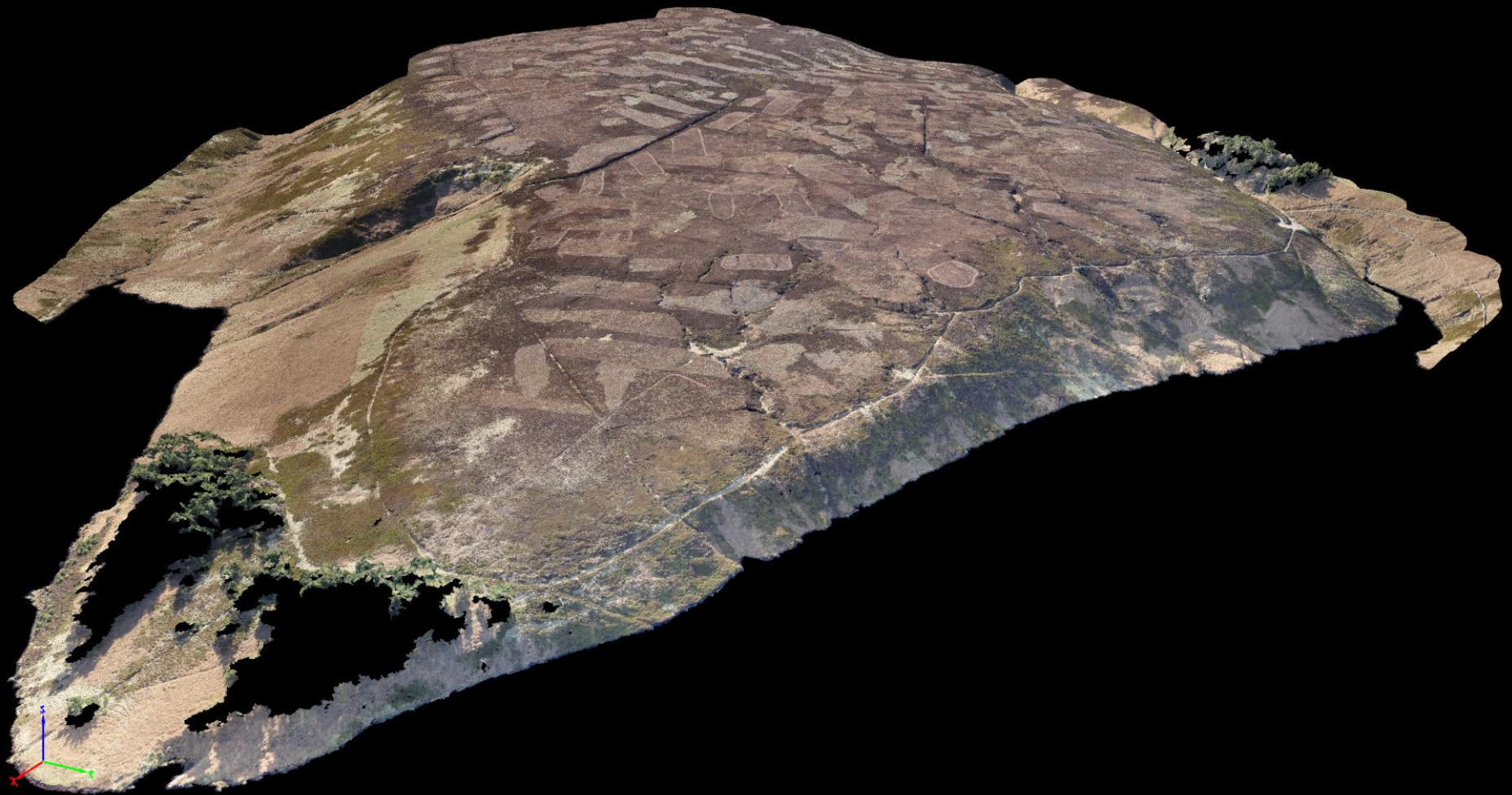
Digital Products:

Simplified Point Cloud

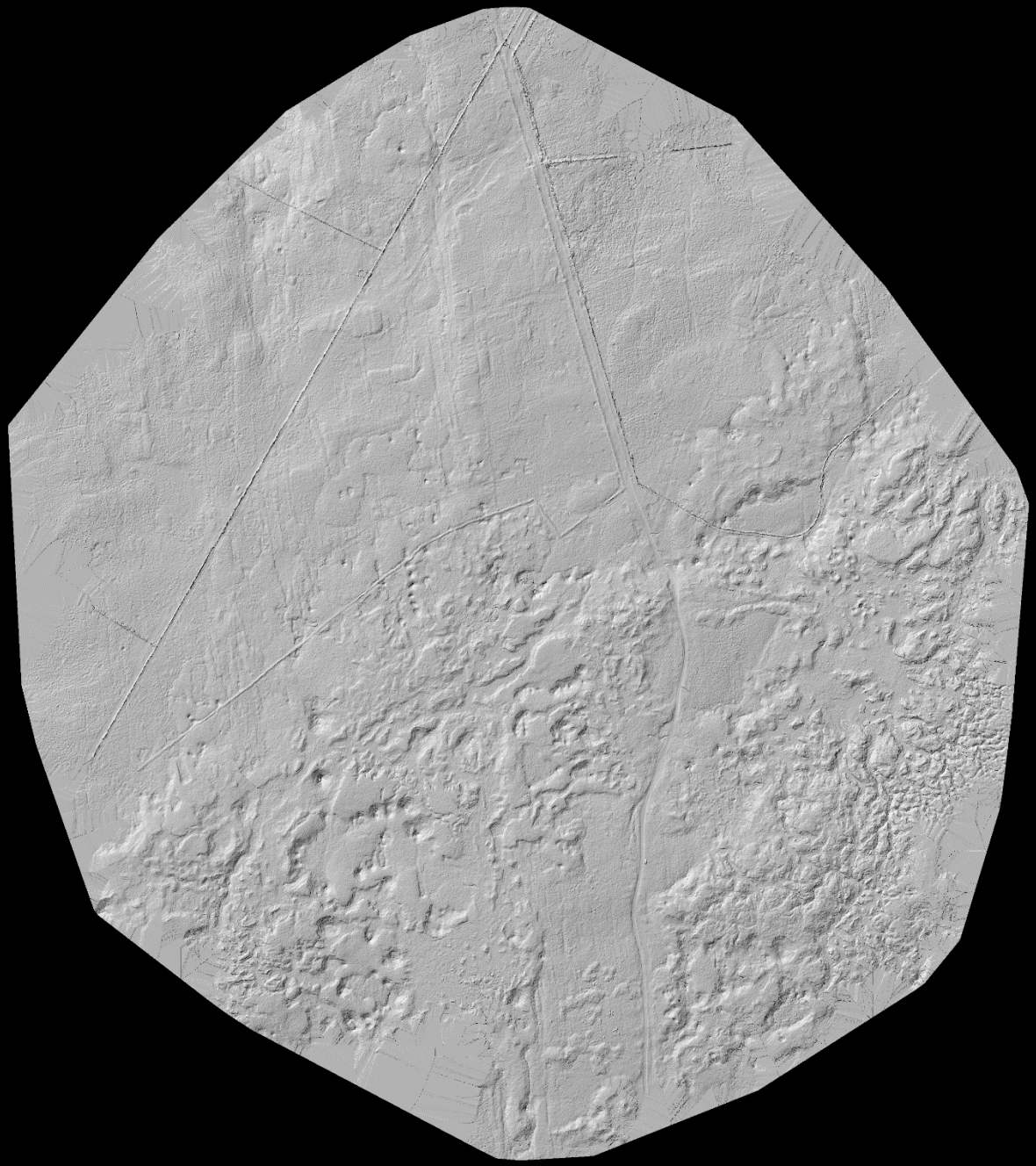


Digital Products:

Densified Point Cloud

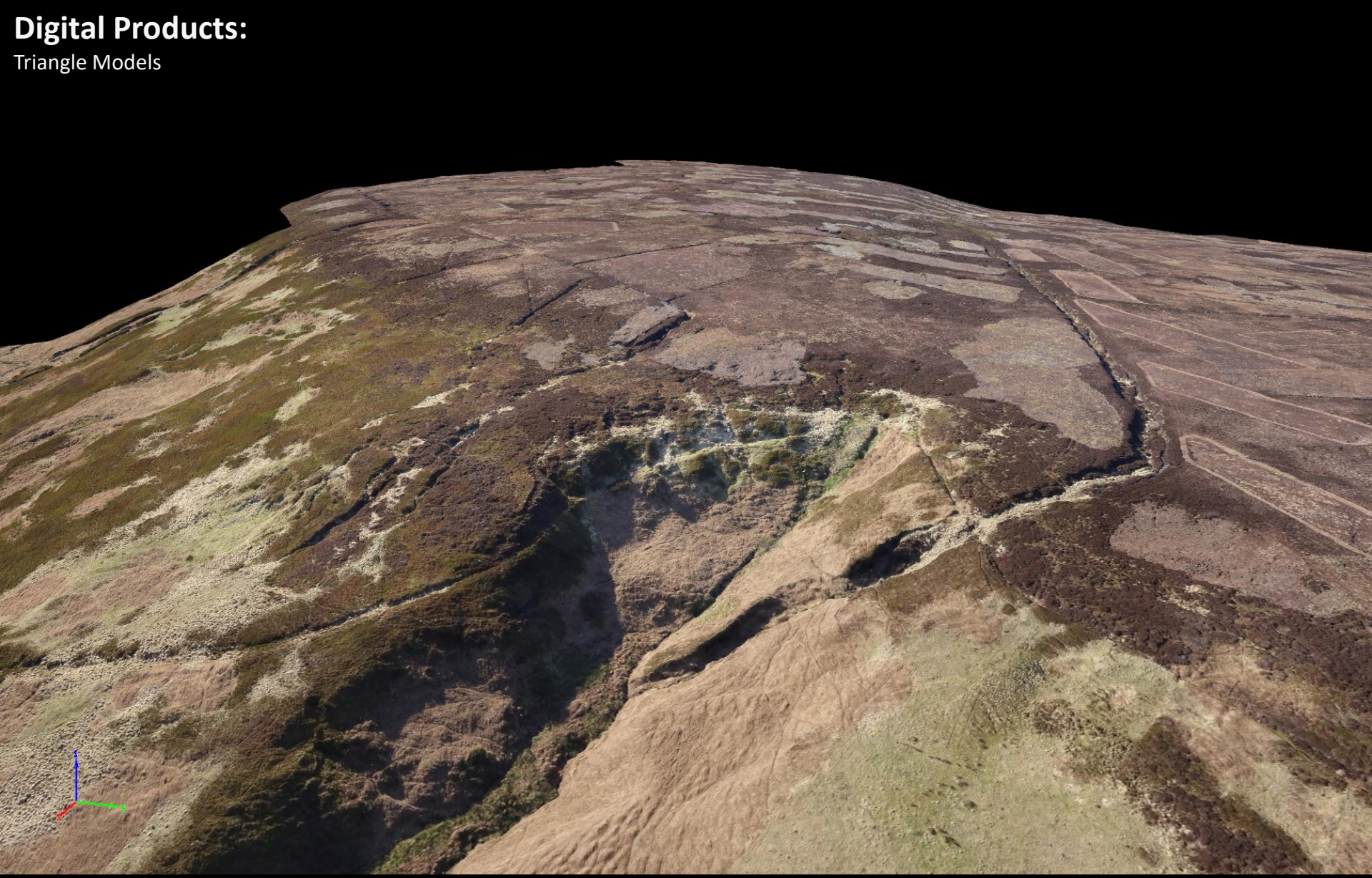


Digital Products: DSM



Digital Products:

Triangle Models



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Output Coordinate System: OSGB 1936 / British National Grid
Output Georeferenced: YES

Processing:
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Average Ground Sampling Distance (GSD) [cm/pixel]: 2.73592
Parameter Files Generated: YES
2. Point Cloud and Mesh Done: YES
Image Scale: multiscale, 1/2 (Half image size, Default)
Point Density: Optimal
3. DSM, Orthomosaic and Index Done: YES
Resolution [cm/pixel]: 3.5
Raster DSM Generated: YES
Grid DSM Generated: NO
Orthomosaic Generated: YES
Google Maps Tiles and KML Generated: NO

Images:
Enabled Images: 1264 out of 1264
Geolocated Images: 1264 out of 1264
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Coordinate System: WGS 84

Ground Control Points:
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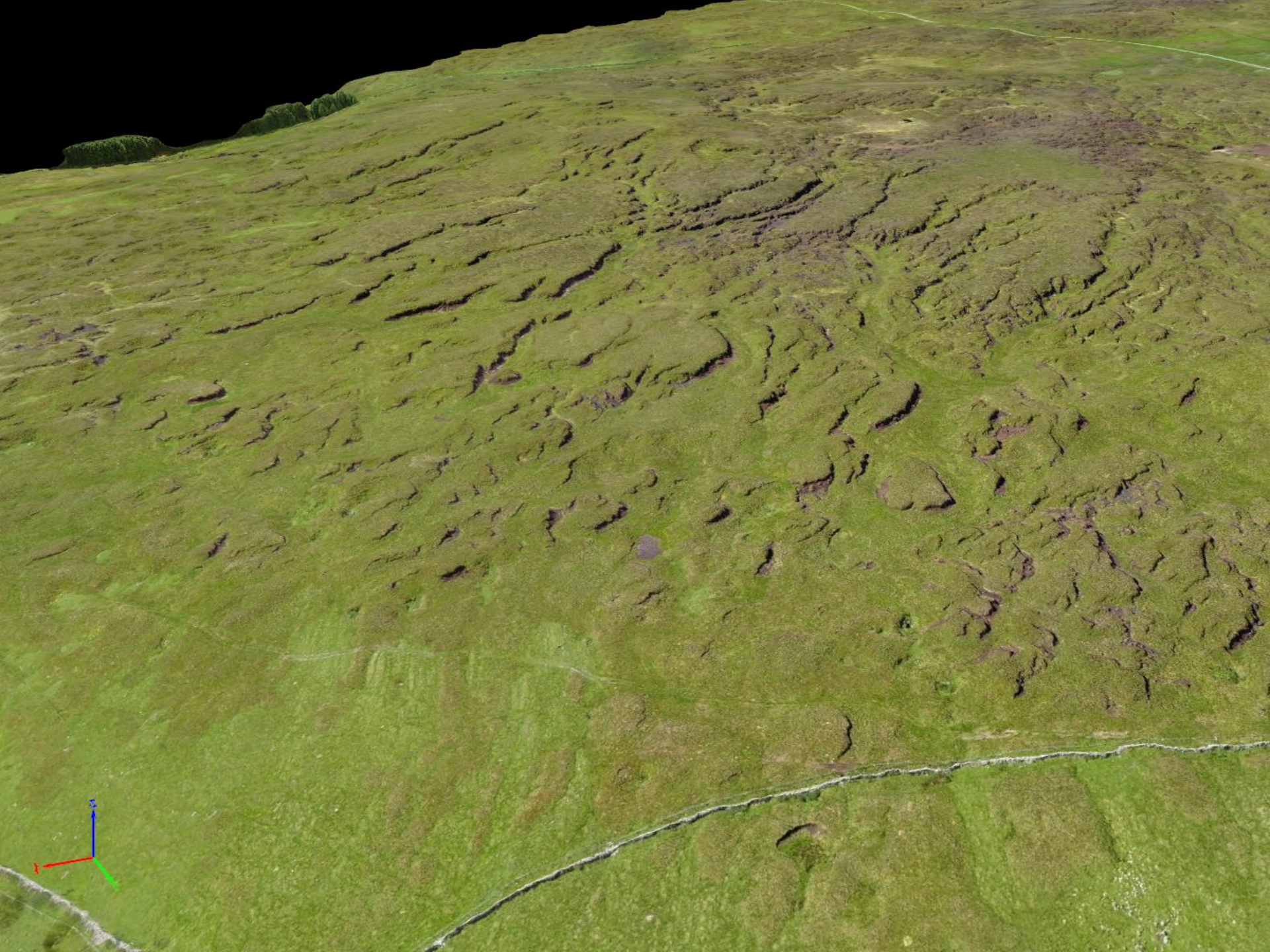
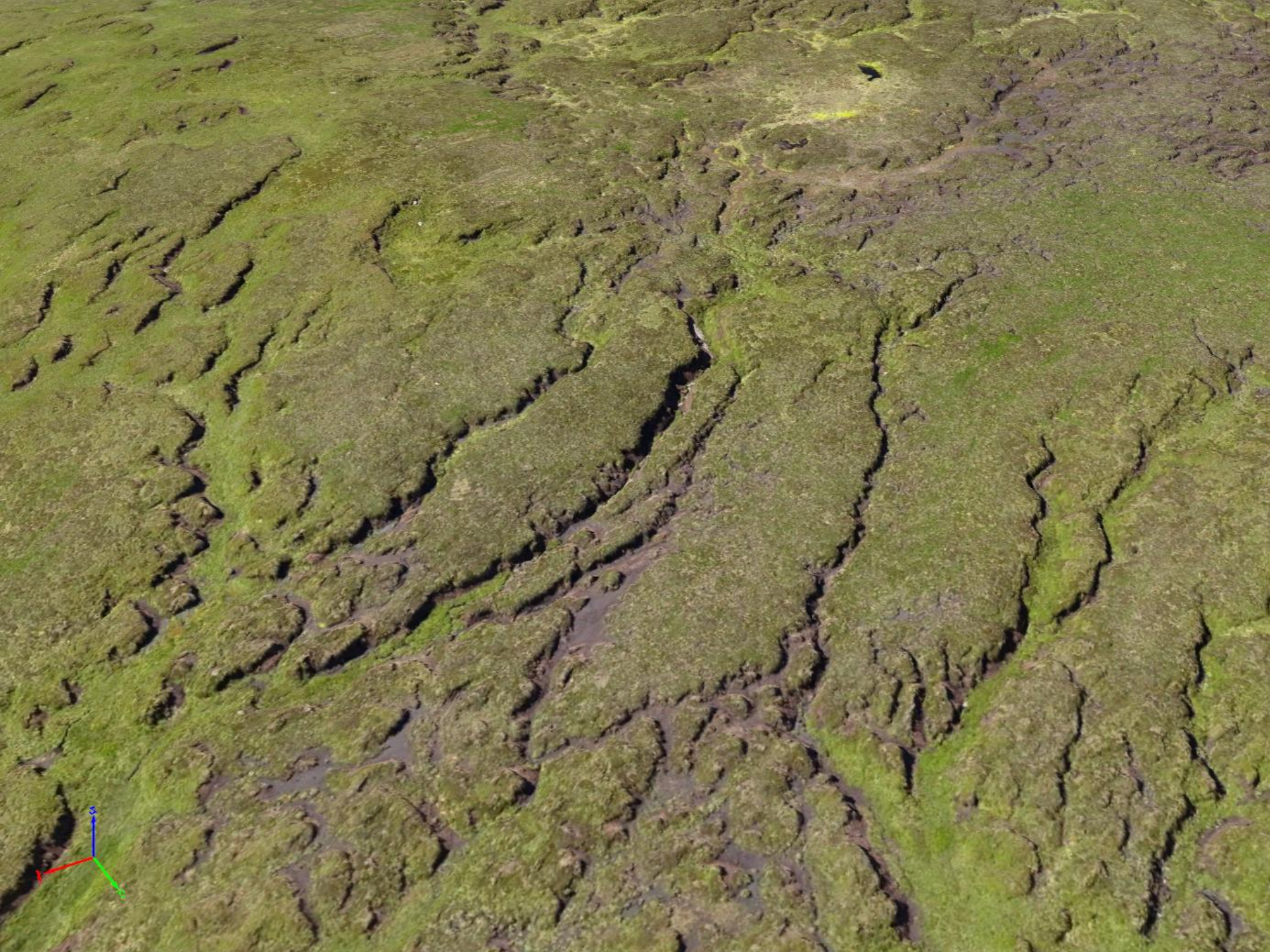
Datum: OSGB 1936
Coordinate System: OSGB 1936 / British National Grid





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Output Georeferenced: YES

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2. Point Cloud and Mesh Done: YES
Image Scale: multiscale, 1/2 (Half image size, Default)
Point Density: Optimal
3. DSM, Orthomosaic and Index Done: YES
Resolution [cm/pixel]: 3.5
Raster DSM Generated: YES
Grid DSM Generated: NO
Orthomosaic Generated: YES
Google Maps Tiles and KML Generated: NO

Images:
Enabled Images: 1919 out of 1919
Geolocated Images: 1919 out of 1919
Datum: World Geodetic System 1984
Coordinate System: WGS 84

Ground Control Points:
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Datum: OSGB 1936
Coordinate System: OSGB 1936 / British National Grid

Project:
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Type: Standard
Workspace: C:/UAV_Processing
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Output Coordinate System: OSGB 1936 / British National Grid
Output Georeferenced: YES

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Parameter Files Generated: YES
2. Point Cloud and Mesh Done: YES
Image Scale: multiscale, 1/2 (Half image size, Default)
Point Density: Optimal
3. DSM, Orthomosaic and Index Done: YES
Resolution [cm/pixel]: 3.5
Raster DSM Generated: YES
Grid DSM Generated: NO
Orthomosaic Generated: YES
Google Maps Tiles and KML Generated: NO

Images:
Enabled Images: 839 out of 839
Geolocated Images: 839 out of 839
Datum: World Geodetic System 1984
Coordinate System: WGS 84

Ground Control Points:
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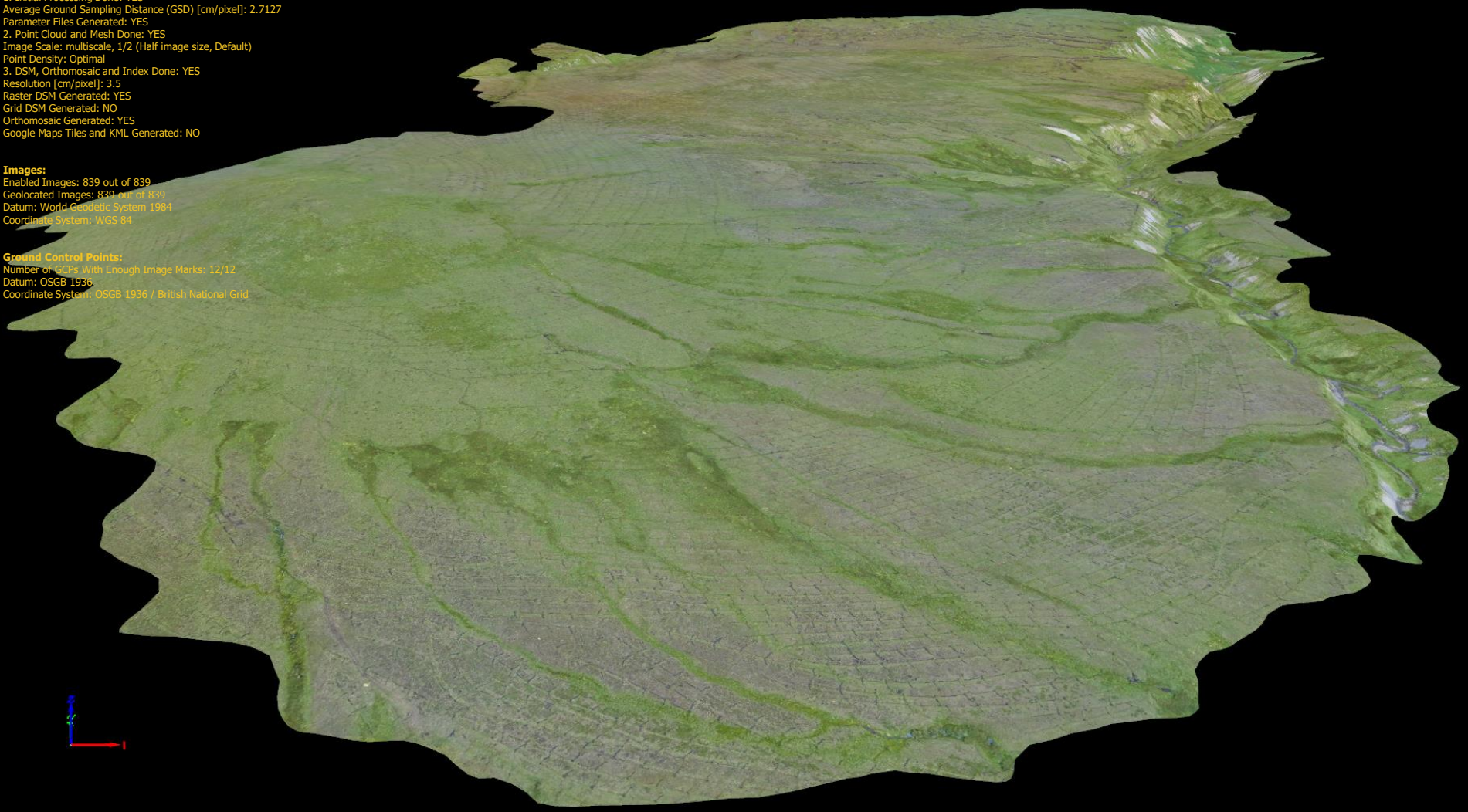
Datum: OSGB 1936
Coordinate System: OSGB 1936 / British National Grid



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Output Georeferenced:

Processing:
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Average Ground Sampling Distance (GSD) [cm/pixel]: -
Parameter Files Generated: NO
2. Point Cloud and Mesh Done: NO
Image Scale: -
Point Density: -
3. DSM, Orthomosaic and Index Done: NO
Resolution [cm/pixel]: -
Raster DSM Generated: NO
Grid DSM Generated: NO
Orthomosaic Generated: NO
Google Maps Tiles and KML Generated: NO

Images:
Enabled Images: 311 out of 311
Geolocated Images: 311 out of 311
Datum: World Geodetic System 1984
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Ground Control Points:
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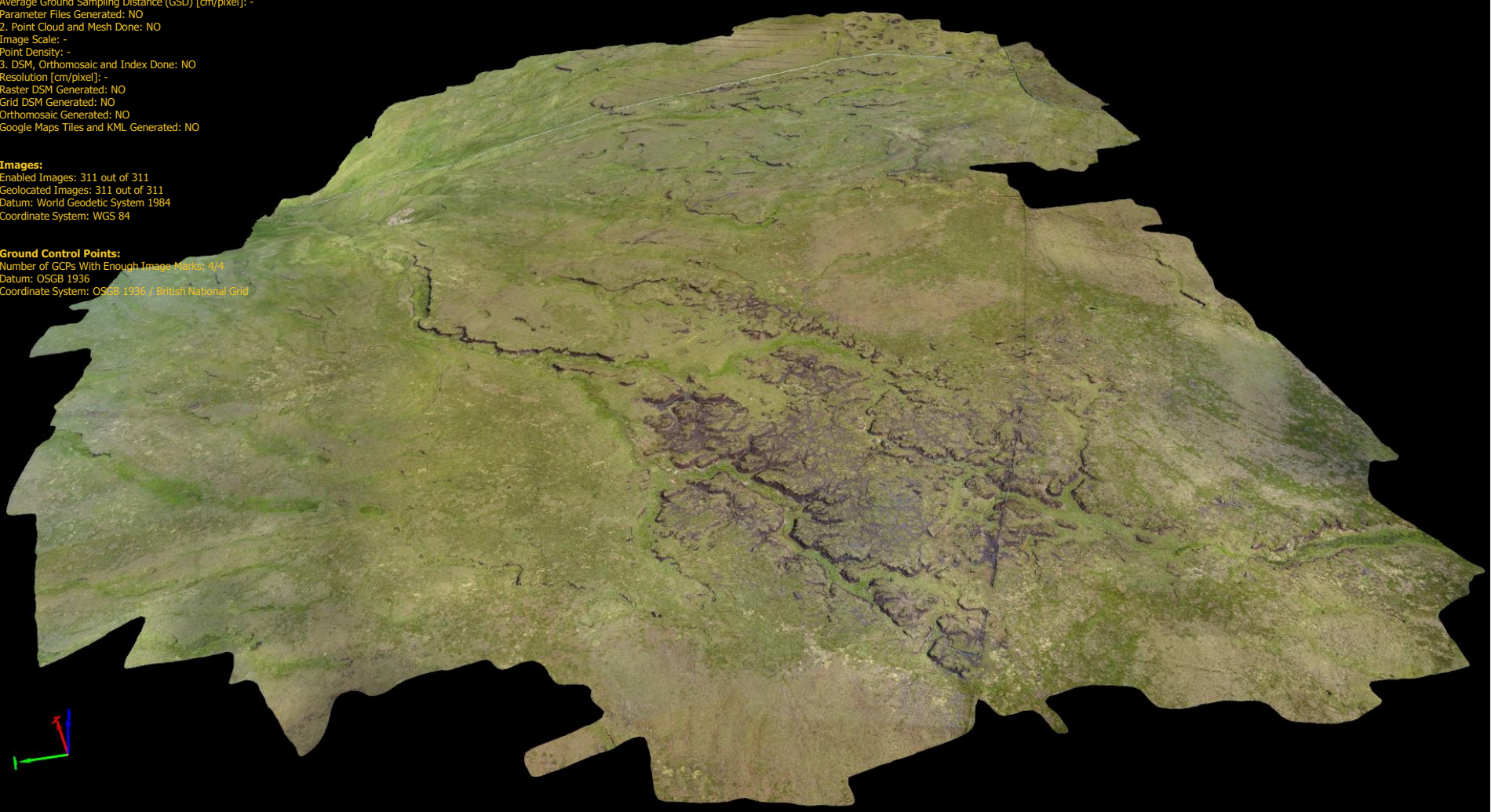
Datum: OSGB 1936
Coordinate System: OSGB 1936 / British National Grid



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Workspace: C:/UAV_Processing/
Output Datum: OSGB 1936
Output Coordinate System: OSGB 1936 / British National Grid
Output Georeferenced: YES

Processing:
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Parameter Files Generated: YES
2. Point Cloud and Mesh Done: YES
Image Scale: multiscale, 1/2 (Half image size, Default)
Point Density: Optimal
3. DSM, Orthomosaic and Index Done: YES
Resolution [cm/pixel]: 3
Raster DSM Generated: YES
Grid DSM Generated: NO
Orthomosaic Generated: YES
Google Maps Tiles and KML Generated: NO

Images:
Enabled Images: 668 out of 668
Geolocated Images: 668 out of 668
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Coordinate System: WGS 84

Ground Control Points:
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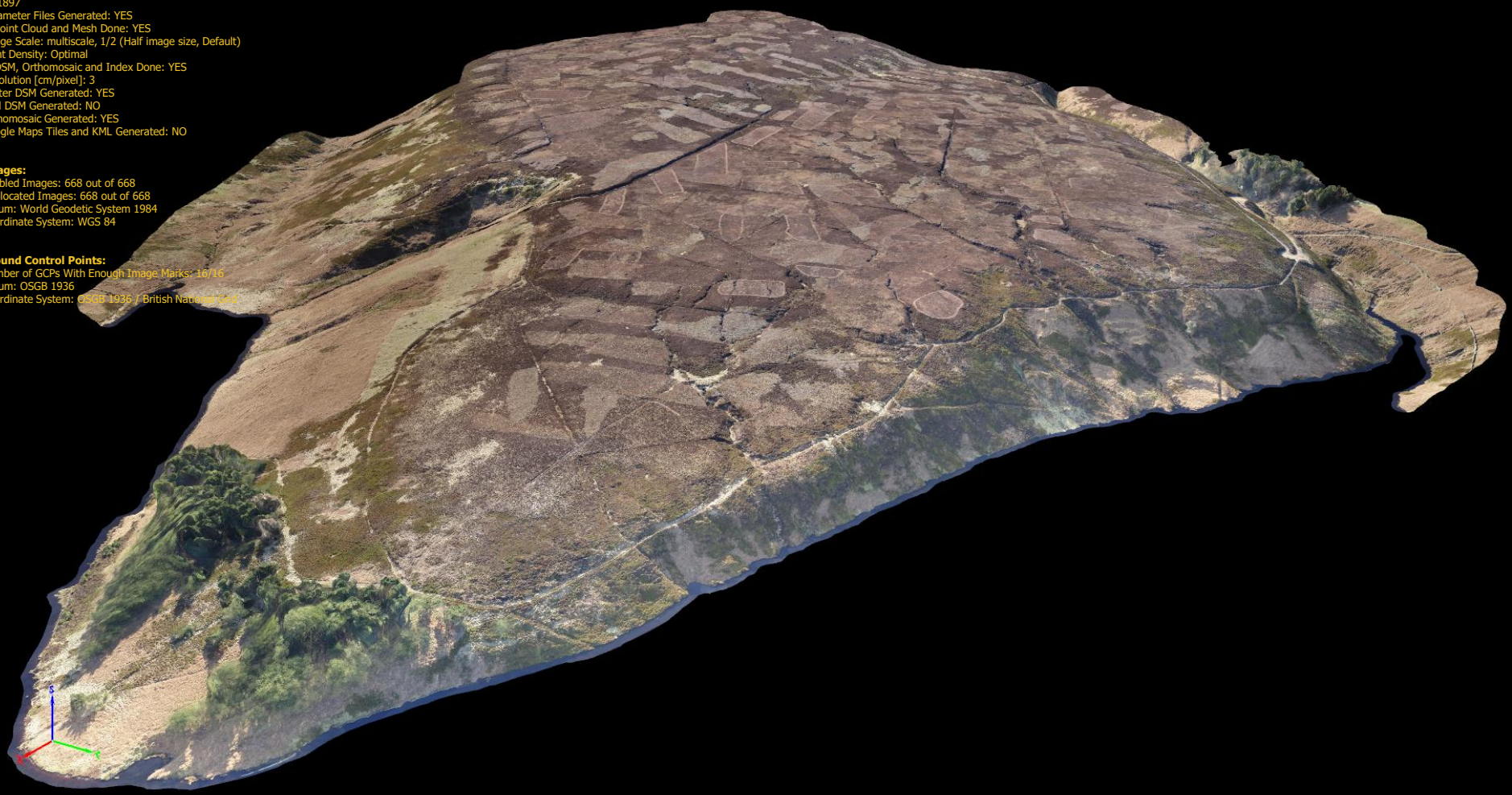
Datum: OSGB 1936
Coordinate System: OSGB 1936 / British National Grid



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Workspace: C:/UAV_Processing/
Output Datum: OSGB 1936
Output Coordinate System: OSGB 1936 / British National Grid
Output Georeferenced: YES

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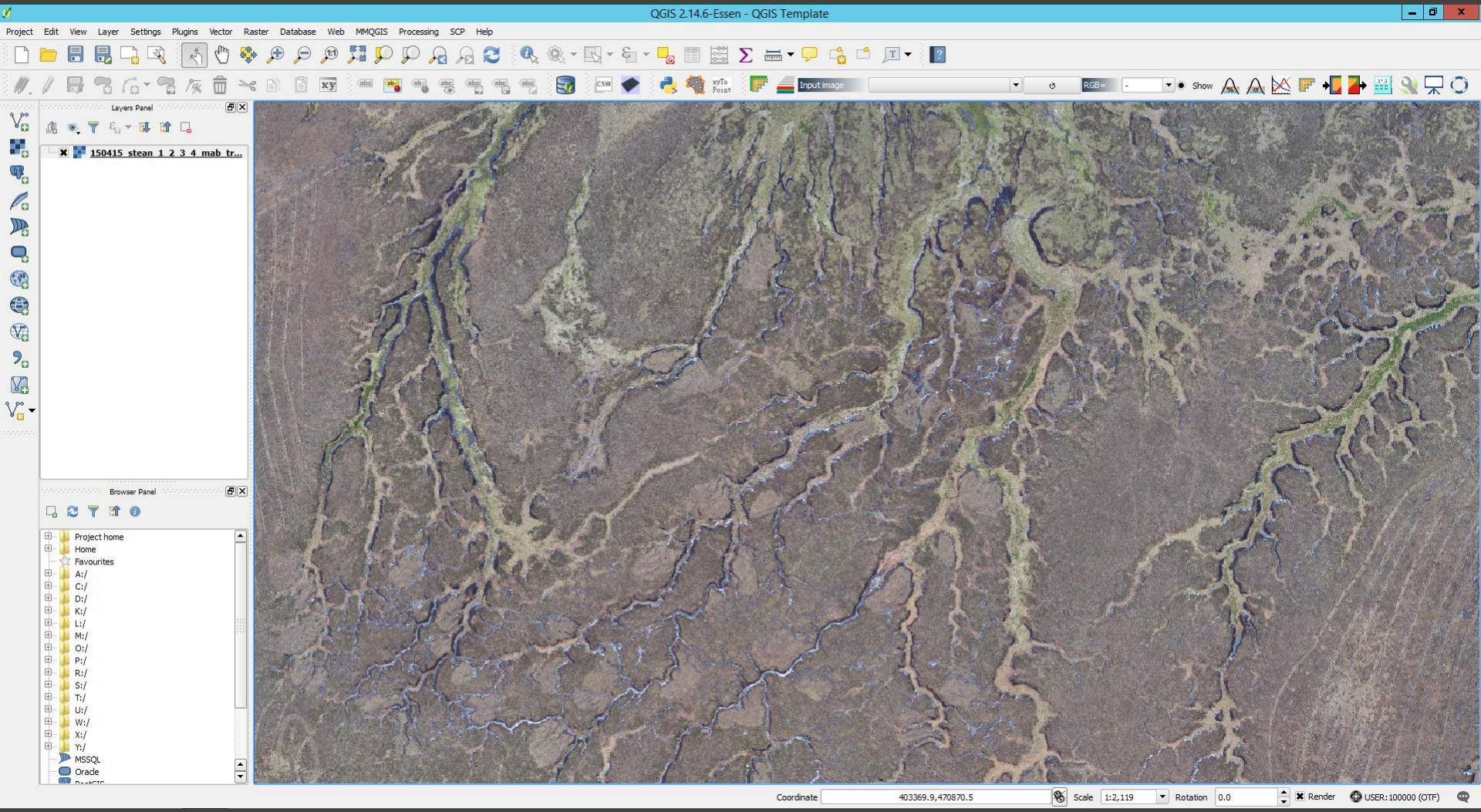
Parameter Files Generated: YES
2. Point Cloud and Mesh Done: YES
Image Scale: multiscale, 1/2 (Half image size, Default)
Point Density: Optimal
3. DSM, Orthomosaic and Index Done: YES
Resolution [cm/pixel]: 3
Raster DSM Generated: YES
Grid DSM Generated: NO
Orthomosaic Generated: YES
Google Maps Tiles and KML Generated: NO

Images:
Enabled Images: 1128 out of 1128
Georeferenced Images: 1128 out of 1128
Datum: World Geodetic System 1984
Coordinate System: WGS 84

Ground Control Points:
Number of GCPs With Enough Image Marks: 9/11
Datum: OSGB 1936
Coordinate System: OSGB 1936 / British National Grid

What we do with the data



- Enhanced visualisation and mapping in GIS software
- Traditionally we used MapInfo Professional but we have recently transferred to QGIS. Also ESRI ArcGIS.
- I’m very much a proponent of Open Source solutions because why spend thousands and thousands on software and training when with some technical knowhow most GIS and Remote Sensing capabilities are freely available.

Monitoring of Restoration Work – Grip blocking

Google Earth Pro (Free since early 2015) Imagery showing extensive grips at Stean Moor in Nidderdale AONB.

Google Earth Pro imagery overlaid with up-to-date ortho generated from imagery captured using UAV.

Shows results of grip blocking.

Good for remote monitoring of Restoration works

Monitoring of restoration work
– Re-profiling

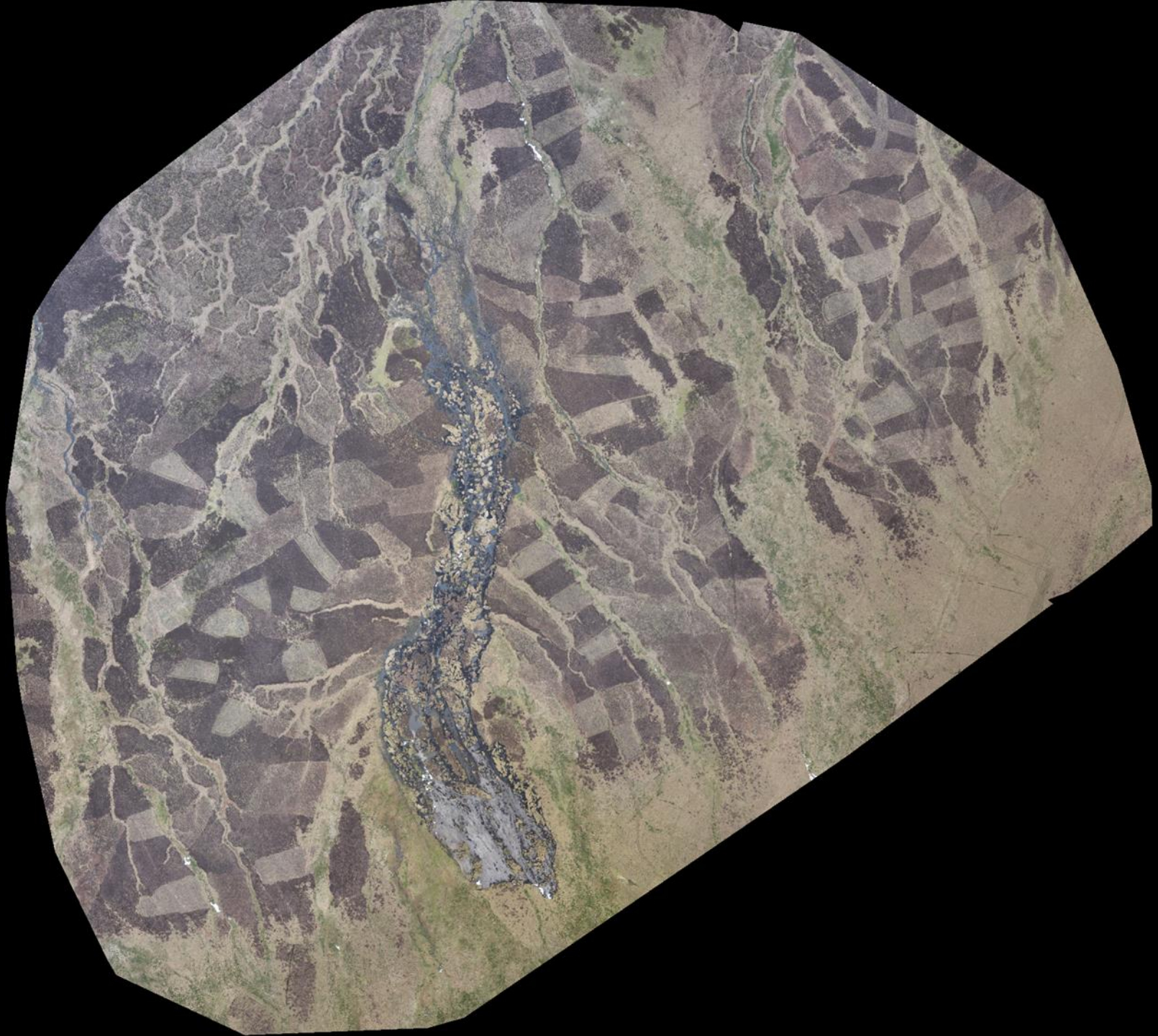
UAV imagery captured pre-restoration works

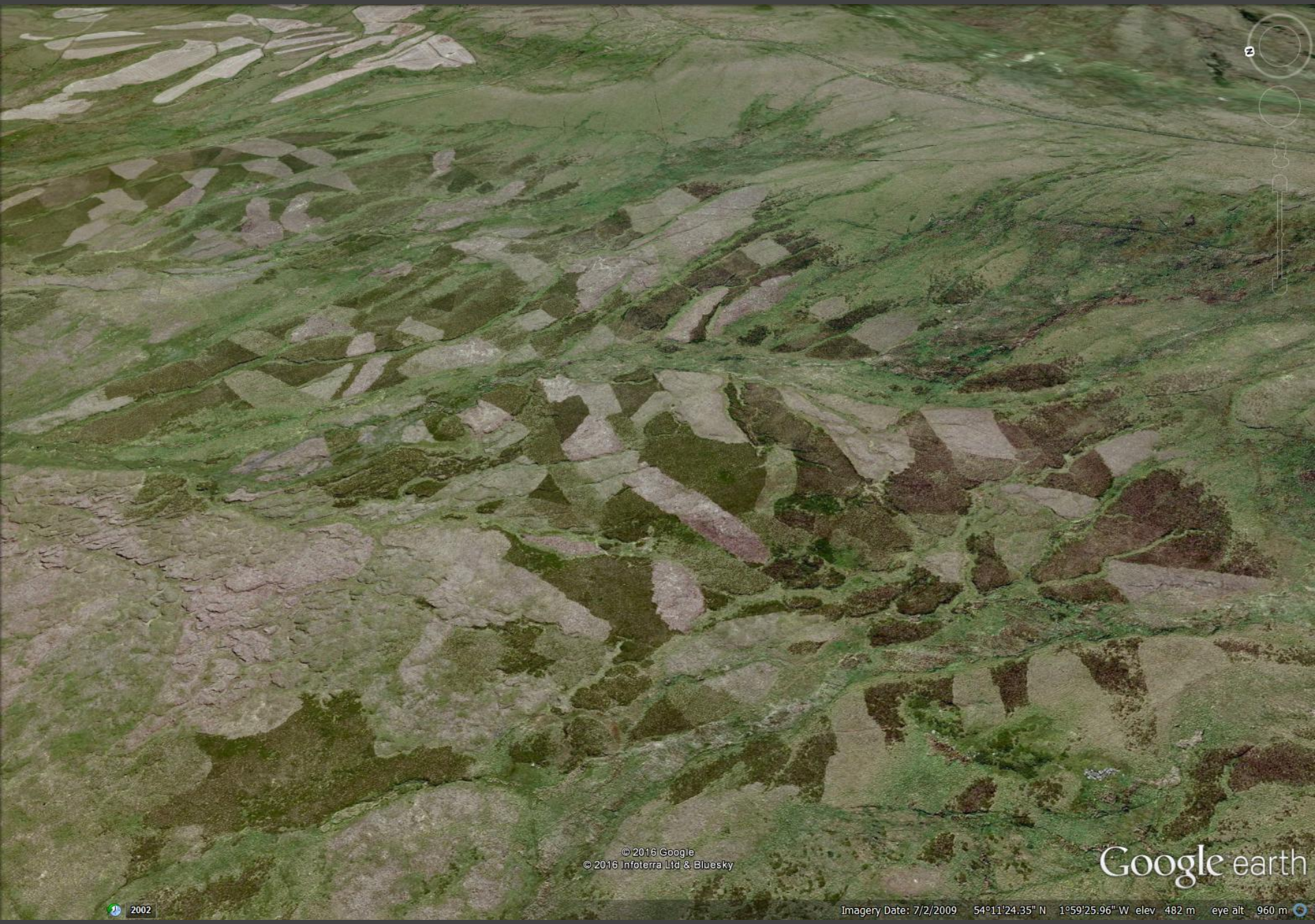
UAV imagery captured post-reprofiling and brashing of hagged area.

We’re currently developing routines in order to quantify these changes.

Rapid reaction and assessment - Peat slide after extreme storm event

On Sunday 20th July, 2014 an enormous cloudburst occurred over Great Whernside and the upper reaches of Conistone Moor creating huge floods down Mossdale, Thorpengill, Gill House, Dry Valley, Dowber Gill, Caseker Gill, Coverdale and How Stean. As a result of the cloud burst several peat slides occurred.




© 2016 Google
© 2016 Infoterra Ltd & Bluesky
Google earth
2002
Imagery Date: 7/2/2009 54°11'24.35" N 1°59'25.96" W elev 482 m eye alt 960 m

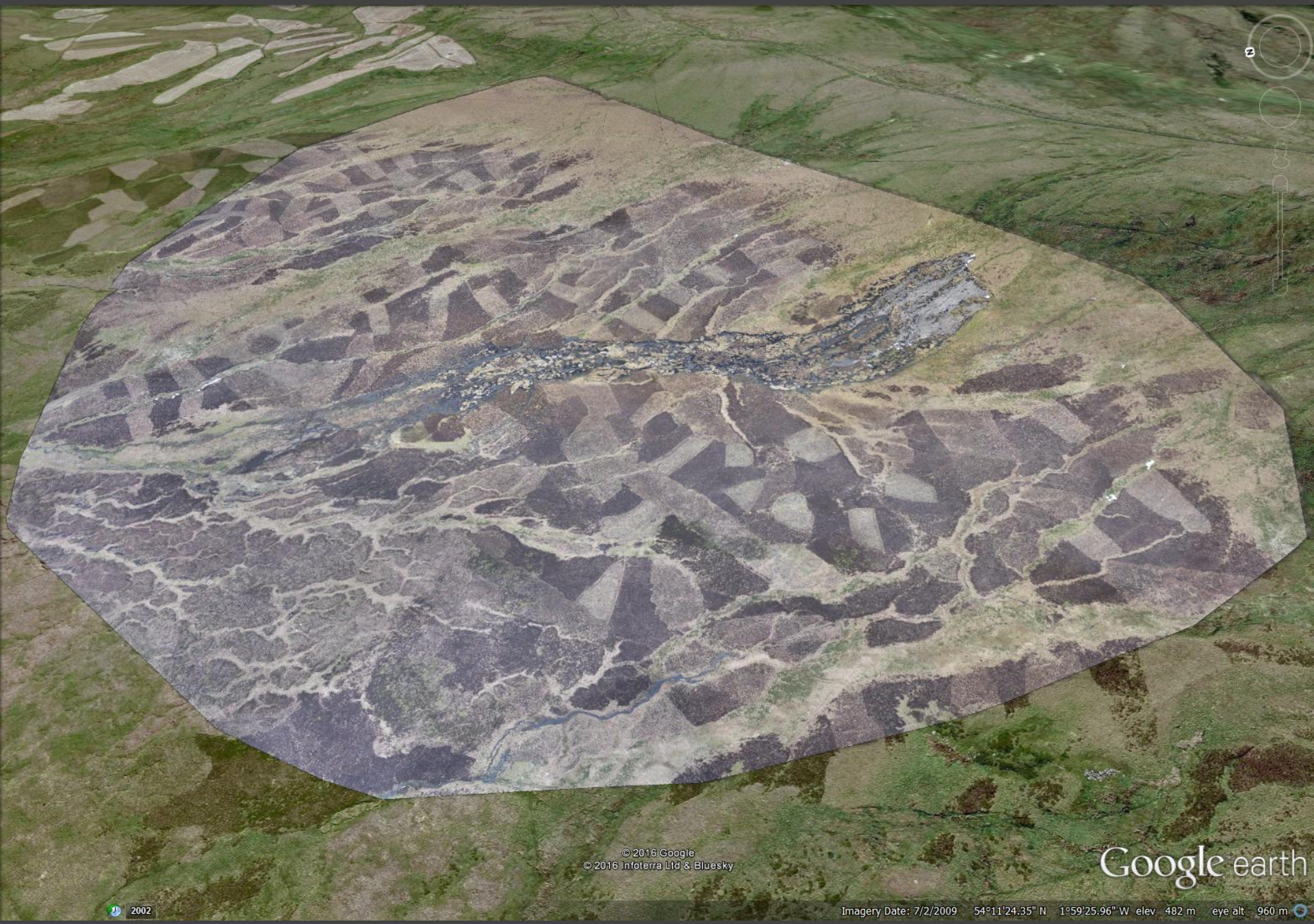

© 2016 Google
© 2016 Infoterra Ltd & Bluesky
Google earth
2002
Imagery Date: 7/2/2009 54°11'24.35" N 1°59'25.96" W elev 482 m eye alt 960 m

Image Classification – traditional pixel based methods

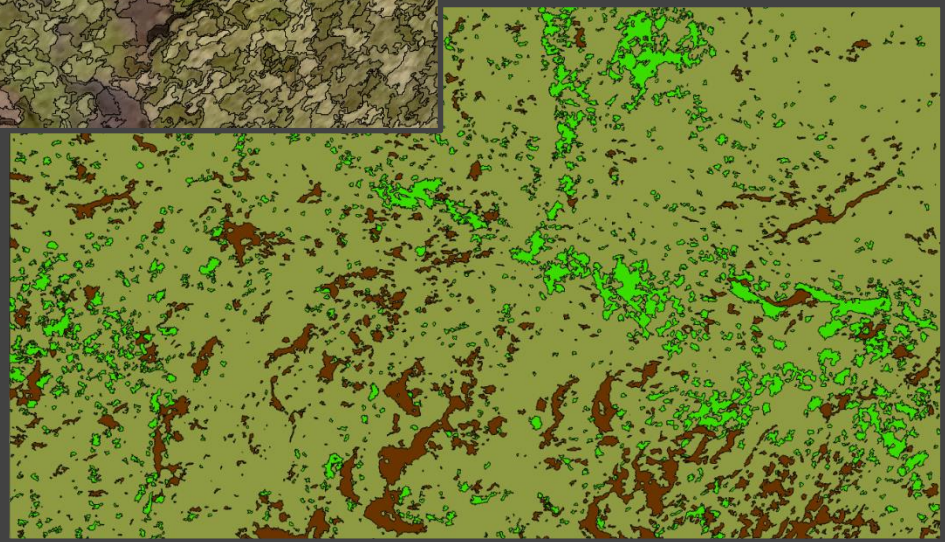
- Interested in automating the mapping of bare peat areas as a means for quantification for restoration work.
- The imagery shows the results of a classification using a traditional pixel based approach. This is where individual pixels are classified according to their spectral properties.
- I have been developing a range of methodologies using open source methods for optical image classification.

- Why? We're interested in performing image analysis without the need of expensive licensing and software.
- Lots of options out there including the Semi-automatic image classification plug in for QGIS, GRASS, SAGA, and Orfeo Toolbox.
- Also libraries available for popular programming languages such as RSGISLib for Python and RSToolbox for R.

Image Classification – Object based image analysis (OBIA)

- This imagery shows image classification using an Open Source OBIA solution.
- There are limitations in differentiating between different vegetation types with similar spectral properties using traditional classification methods.
- By using OBIA analysis we can also take into account patterns and textures within the imagery.

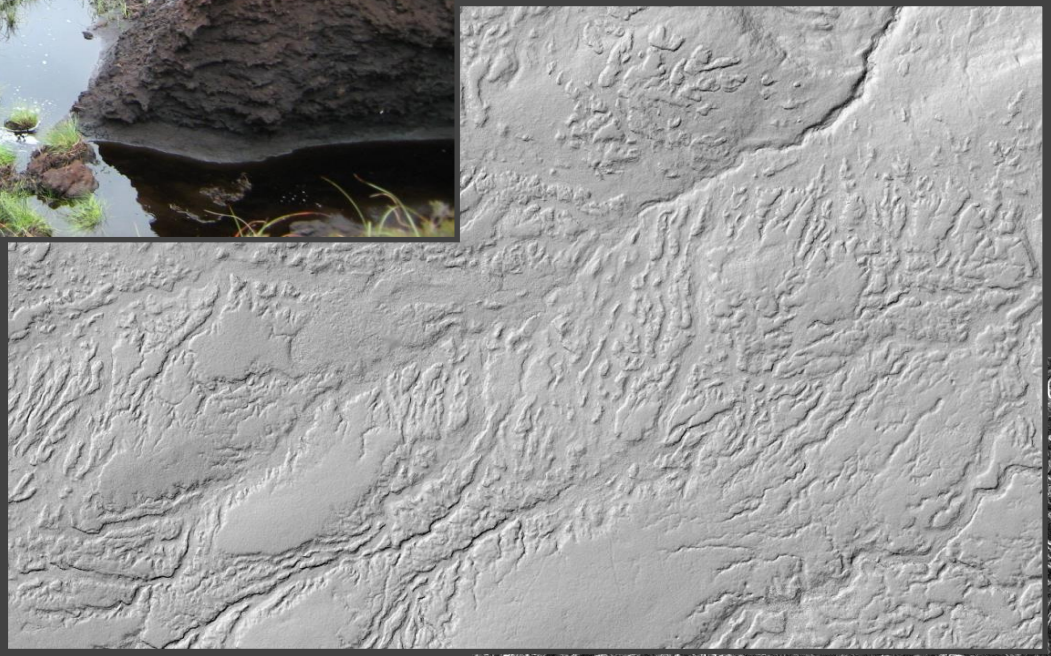
OBIA groups pixels together according to similar spectral properties during a segmentation process.

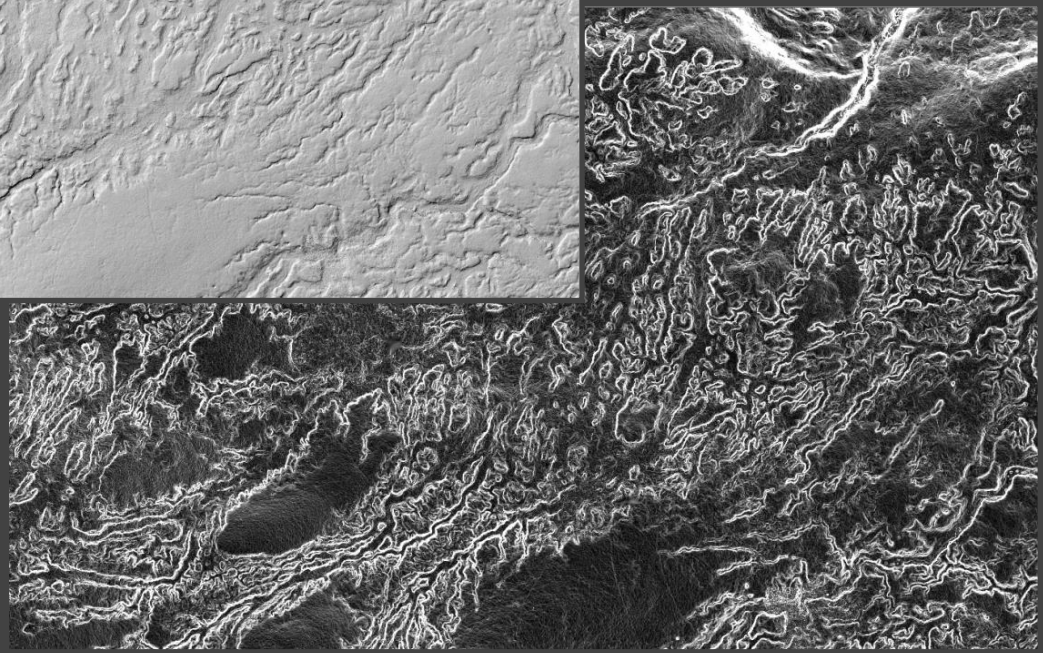


- In the classification here I was looking into classifying areas of bare peat and clusters of sphagnum.
- Further surveys after restoration should show a reduction in the area of bare peat and an increase in sphagnum mosses across the moor.
- We're building on this with additional Multi-spectral sensors for the UAV to aid in differentiating between vegetation types.

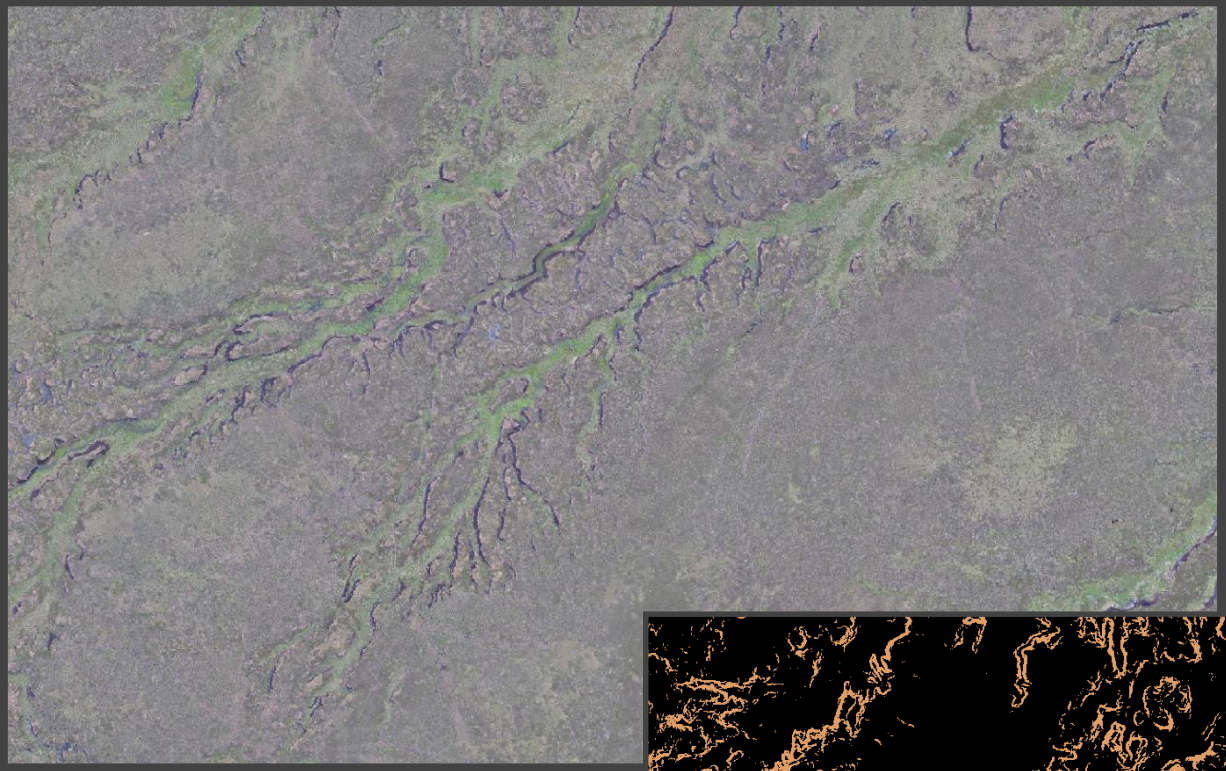
Surface Analysis - Roughness

- High resolution DSMs allow us to analyse the surface of peat bogs at a previously inaccessible scale.
- We can identify areas of erosion by modelling exaggerated changes in surface topography.
- In the example shown I've ran a standard deviation filter across a DSM.



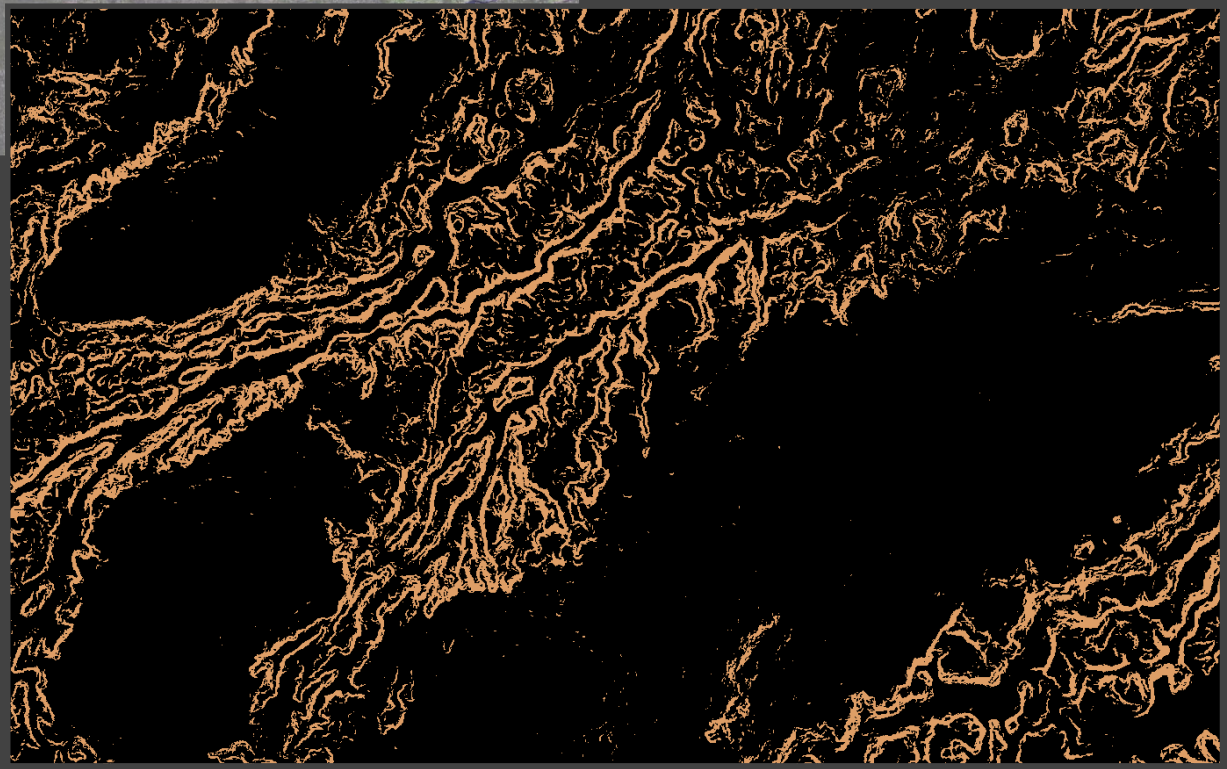


- This identifies those pixels with the greatest variation in elevation across a search neighbourhood.
- Those areas with the greatest variation equate to those with a steeper slope whereas those with lowest variation equate to flatter areas.
- As you can see we can use this to detect the steep gullies sides as shown in the photograph above.



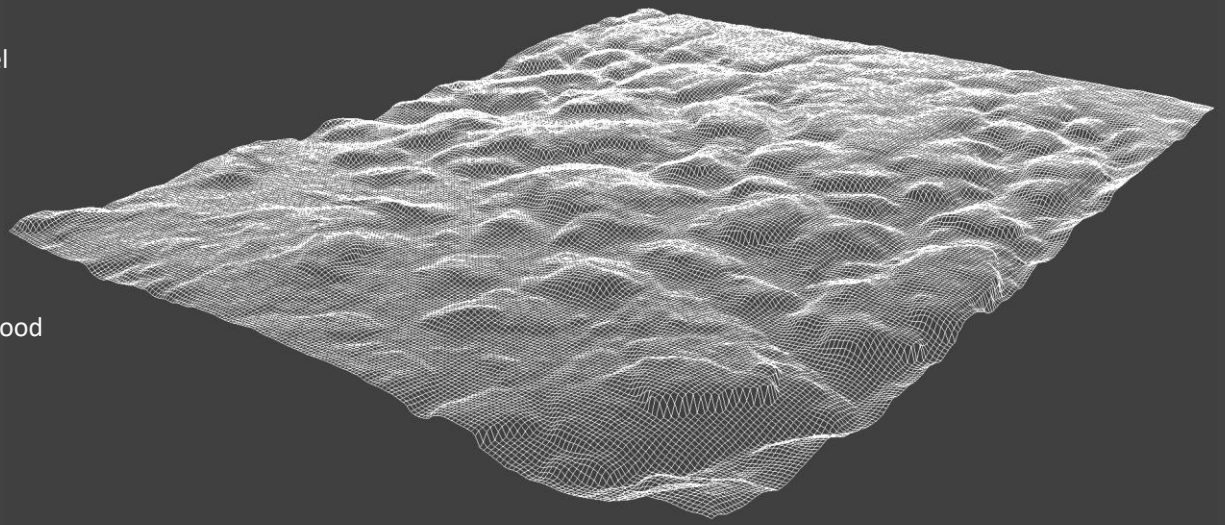
Surface Analysis - Roughness

- We can then apply a threshold to extract the steeper gully sides.
- There are several different methodologies to achieve this.



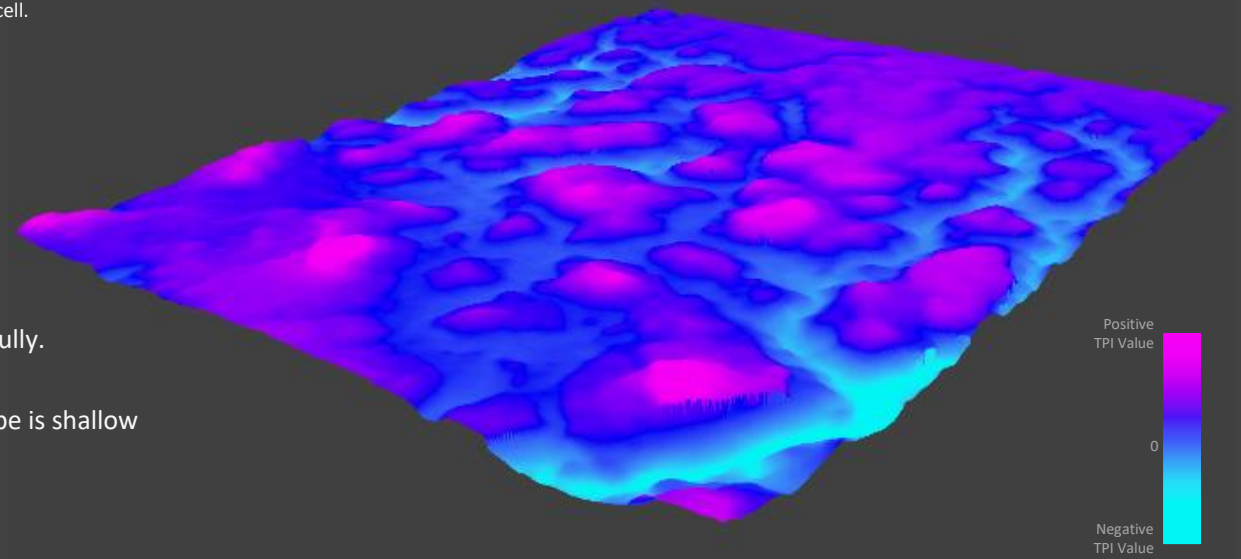
Surface Analysis – Topographic Position Index

- This algorithm was originally developed to model topography on a landscape scale.
- We have been experimenting with various topographic indexes at a much finer scale.
- The Topographic Position Index (TPI) compares the elevation of each cell in a DEM to the mean elevation of a specified neighbourhood around that cell.



$$\lambda = \ln\left(\frac{\alpha}{\tan \beta}\right)$$

where λ is the topographic index, α is the upslope contributing area per unit length of contour, and β is the topographic slope of the cell.



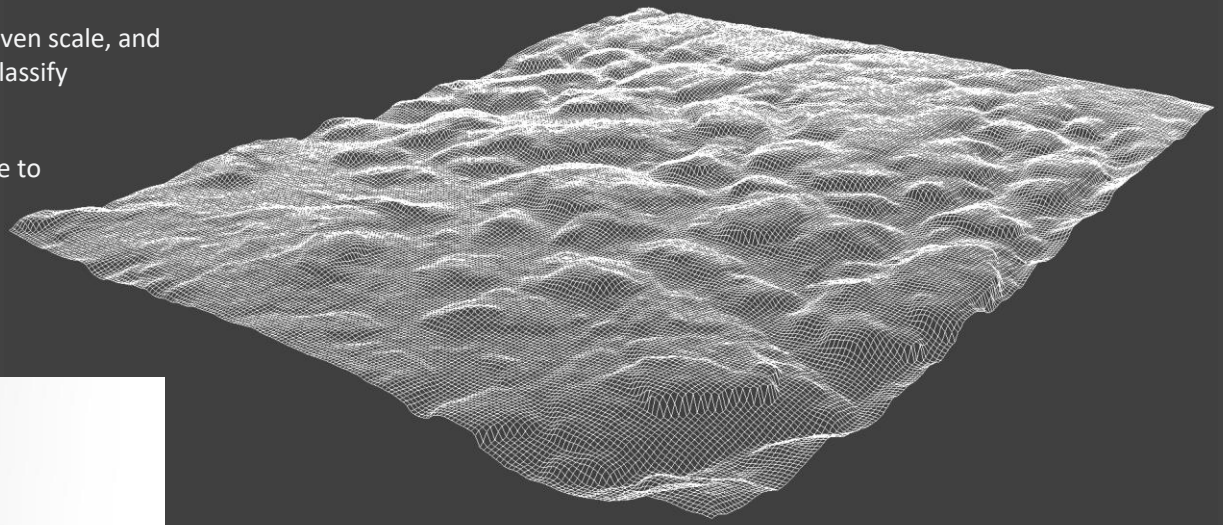
- Positive values indicate a ridge or crest.
- Negative values indicate the lower reaches of a gully.
- Values around 0 will indicate a flat area if the slope is shallow or mid-slope areas if there is a significant slope.

Surface Analysis – Slope Position Classification

By thresholding the continuous TPI values at a given scale, and checking the slope for values near zero we can classify the peat bog into discrete slope position classes.

TPI values near 0 mean that the elevation is close to the mean elevation of the neighbourhood cells.

This could happen if that cell is in a flat area or if it is mid-slope somewhere.



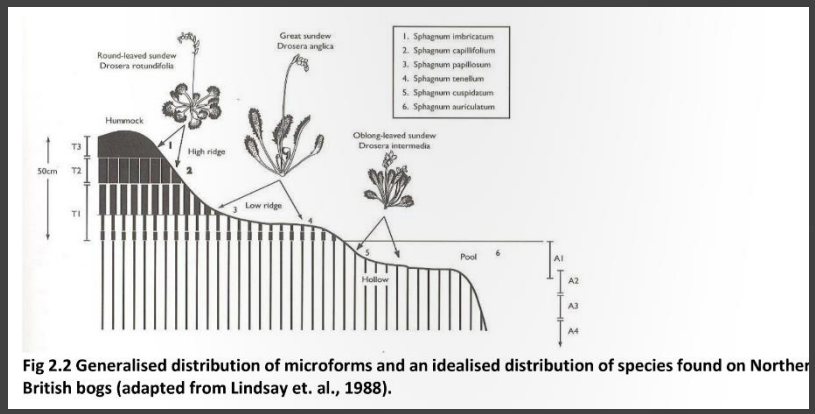
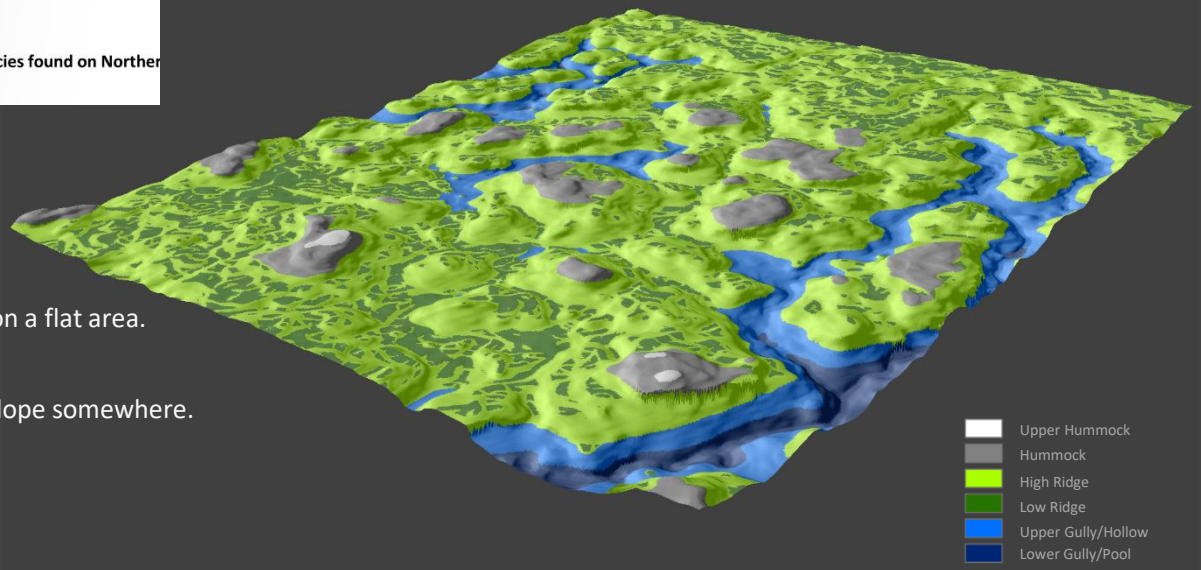


Fig 2.2 Generalised distribution of microforms and an idealised distribution of species found on Norther British bogs (adapted from Lindsay et. al., 1988).

An easy way to distinguish between these 2 possibilities is to check the slope at that point.

If the slope is near 0, then the point is probably on a flat area.

A high slope value implies that the point is mid-slope somewhere.



Hydrological Analysis

A very important part of our work involves blocking grips and gullies to restore the hydrological integrity of the peatland.

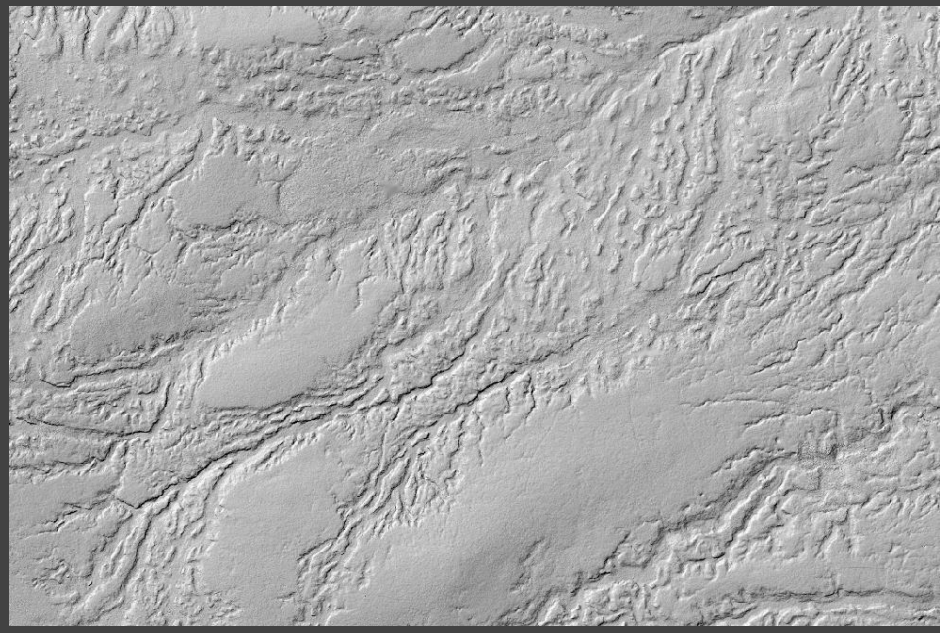
In areas of dendritic gullying it is very confusing both on the ground and from aerial photographs to assess in which direction water is flowing.

By performing hydrological analysis we can identify where water is flowing and therefore make some sense of these systems.

We can then use this data to inform us where to install dams as well as the total lengths of gullies on a restoration site.

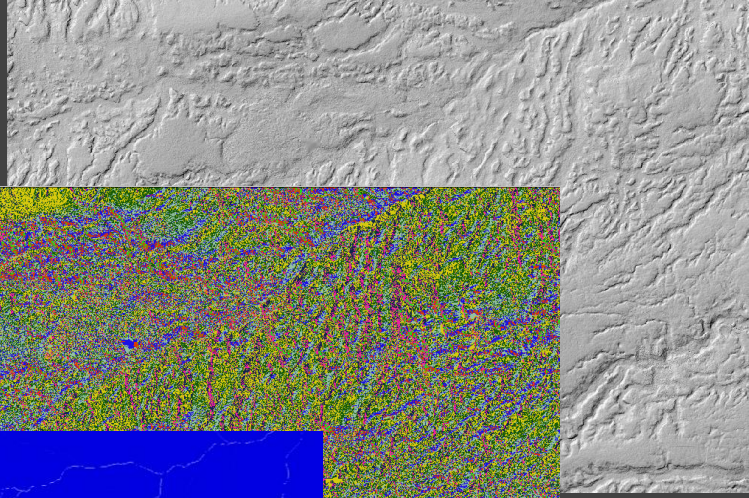
What would be a painful few days to map gullies by hand can be fully automated in this way.

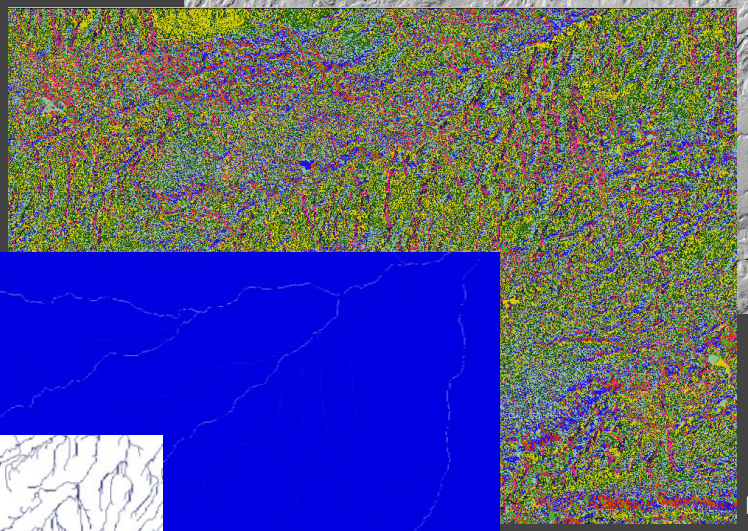
Further to this we can identify sub-basins within a catchment area. We are using this to divide the peat bog up into distinct hydrological areas in which contractors carry out there work.



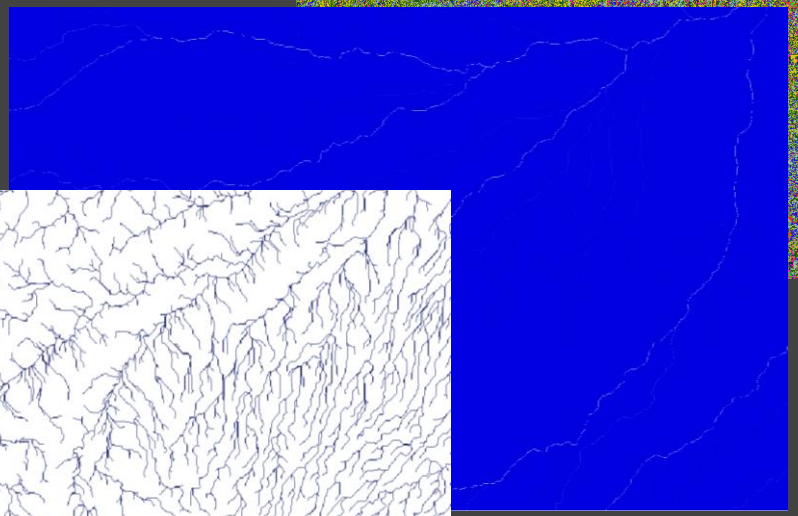
Hydrological Analysis – Stream networks

Stages in processing a stream network.

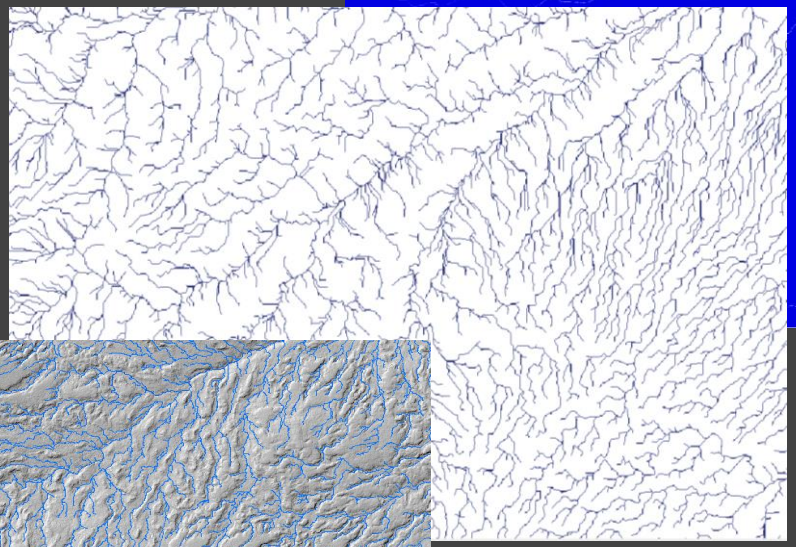




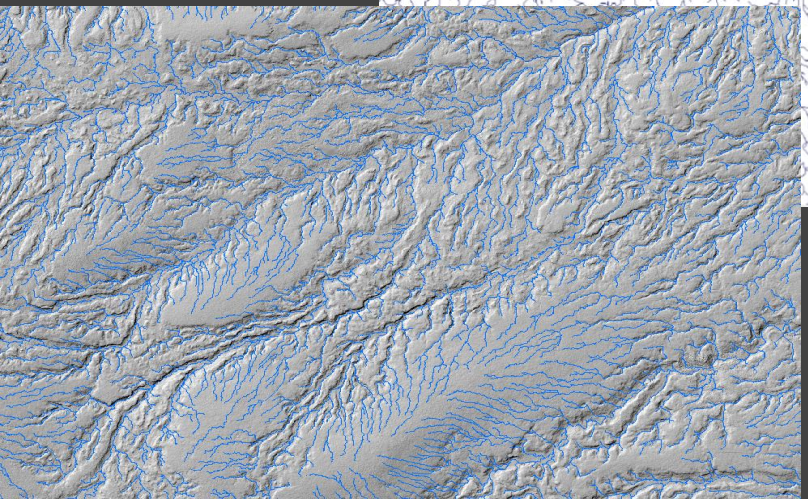
Flow Direction



Flow accumulation



Conditional Assessment



Stream Network

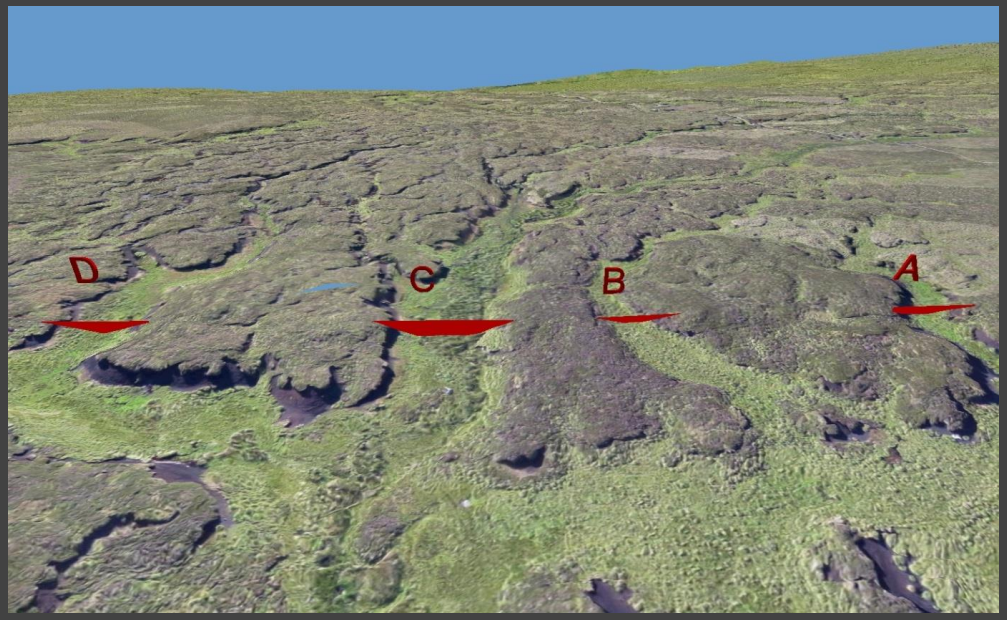
Hydrological Analysis – Modelling of catchment areas

Cross sectional profiles

We can extract the dimensions of gullies from the high resolution DSMs generated from UAV data. This was something we couldn't do previously.

We need to know the width and depths of gullies in order to Decide which type of restoration work needs carrying out.

For wider gullies we will carry out re-profiling of the gully sides to prevent further erosion. We will install dams in gullies below a certain width.

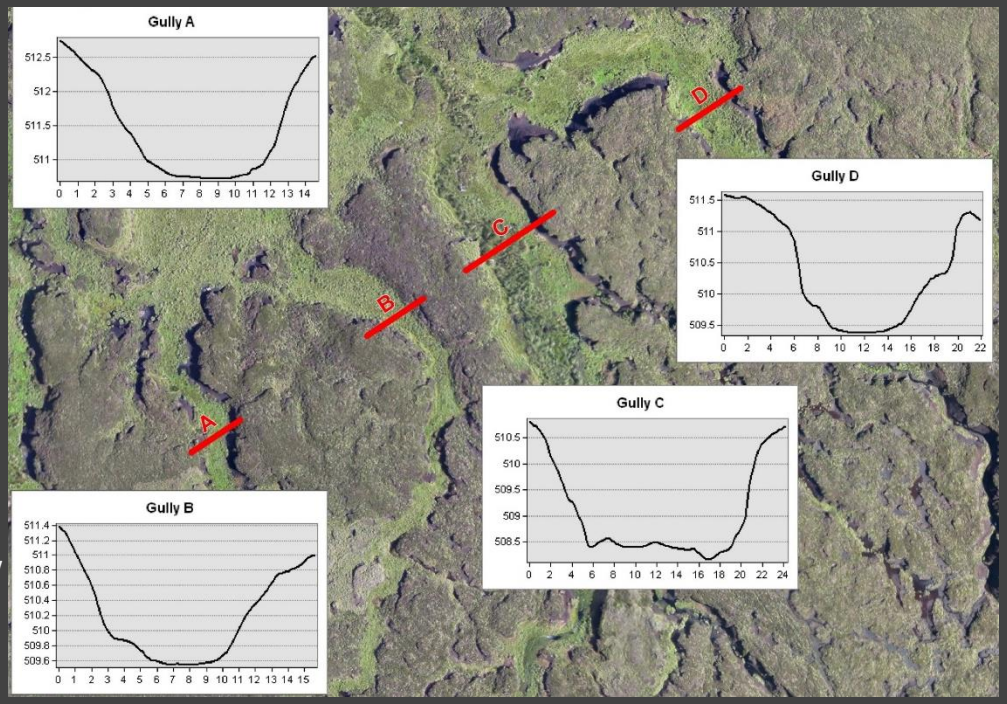


We can generate accurate cross-sectional profiles in GIS software.

This can save time in the field where someone might have to walk across an entire site measuring dimensions.

By knowing the exact location of where we're going to install a dam alongside the gully dimensions we can calculate the width and height of the dam required to carry out gully blocking.

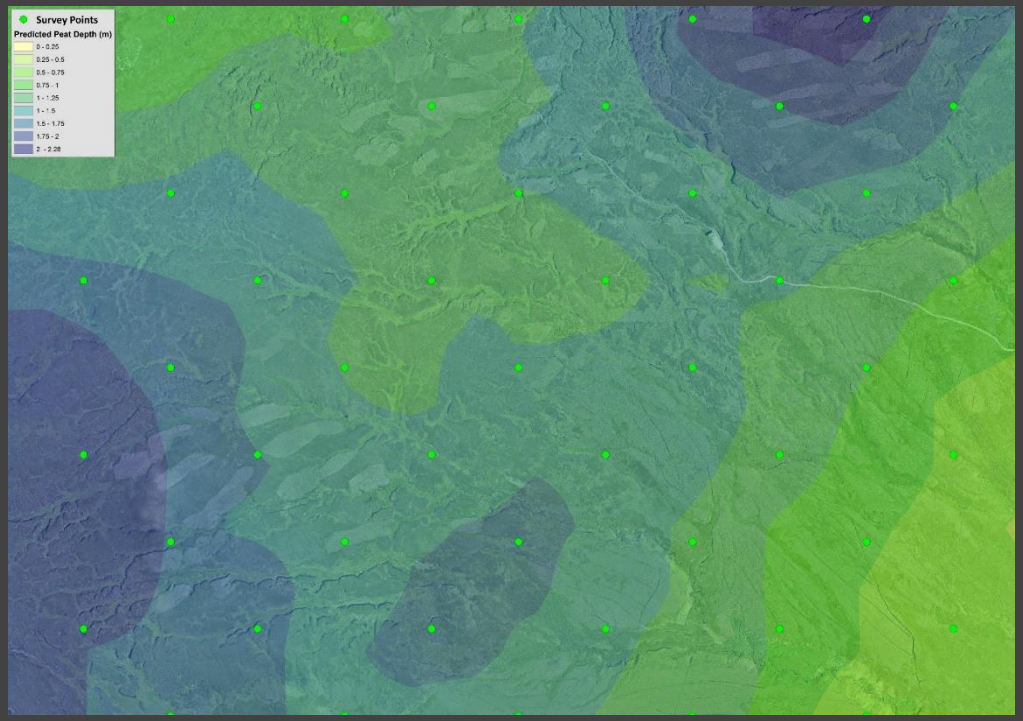
We can then use this to give a much more accurate estimate of how much wood might be required to build wooden dams across a site.



Geostatistical Interpolation and modelling of subsurface peat reserves

We have collected tens of thousands of peat depth records over the course of our project.

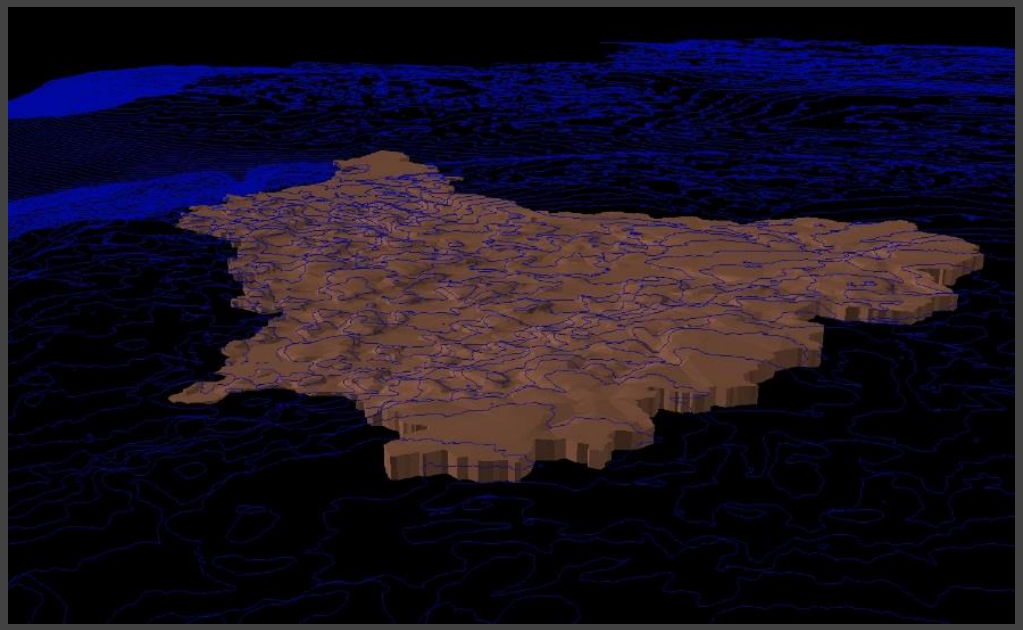
Using geostatistical interpolation methods such as kriging we can estimate the depth of peat across our restoration sites.



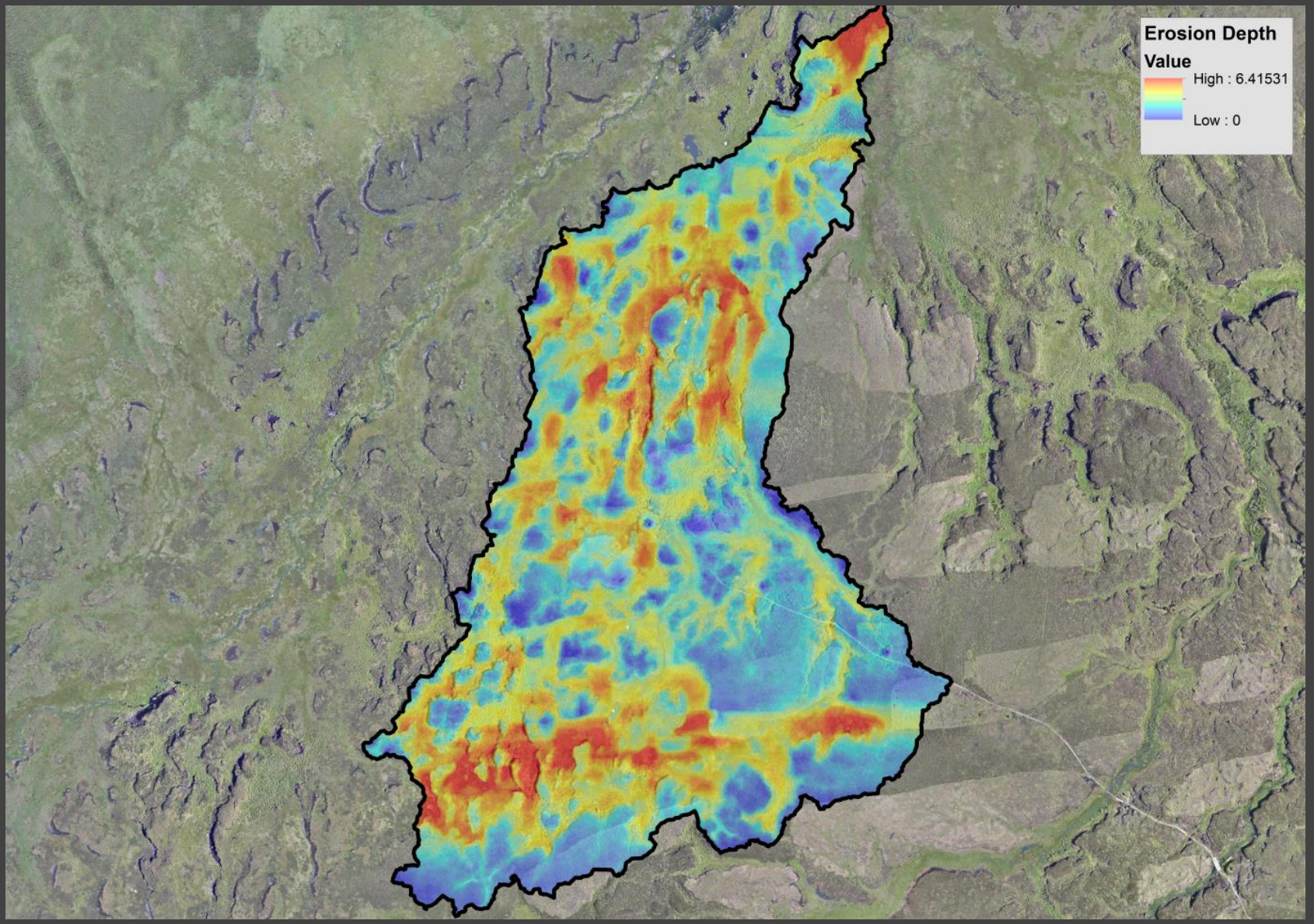
By combining peat depth models with high resolution DSMs we can create more accurate sub-surface peat models than we could previously.

We can use this data to estimate the volume of peat beneath the surface as well to build 3D models of the sub-surface peat reserves.

This data could then be used to give an estimate of carbon stored in the bog.



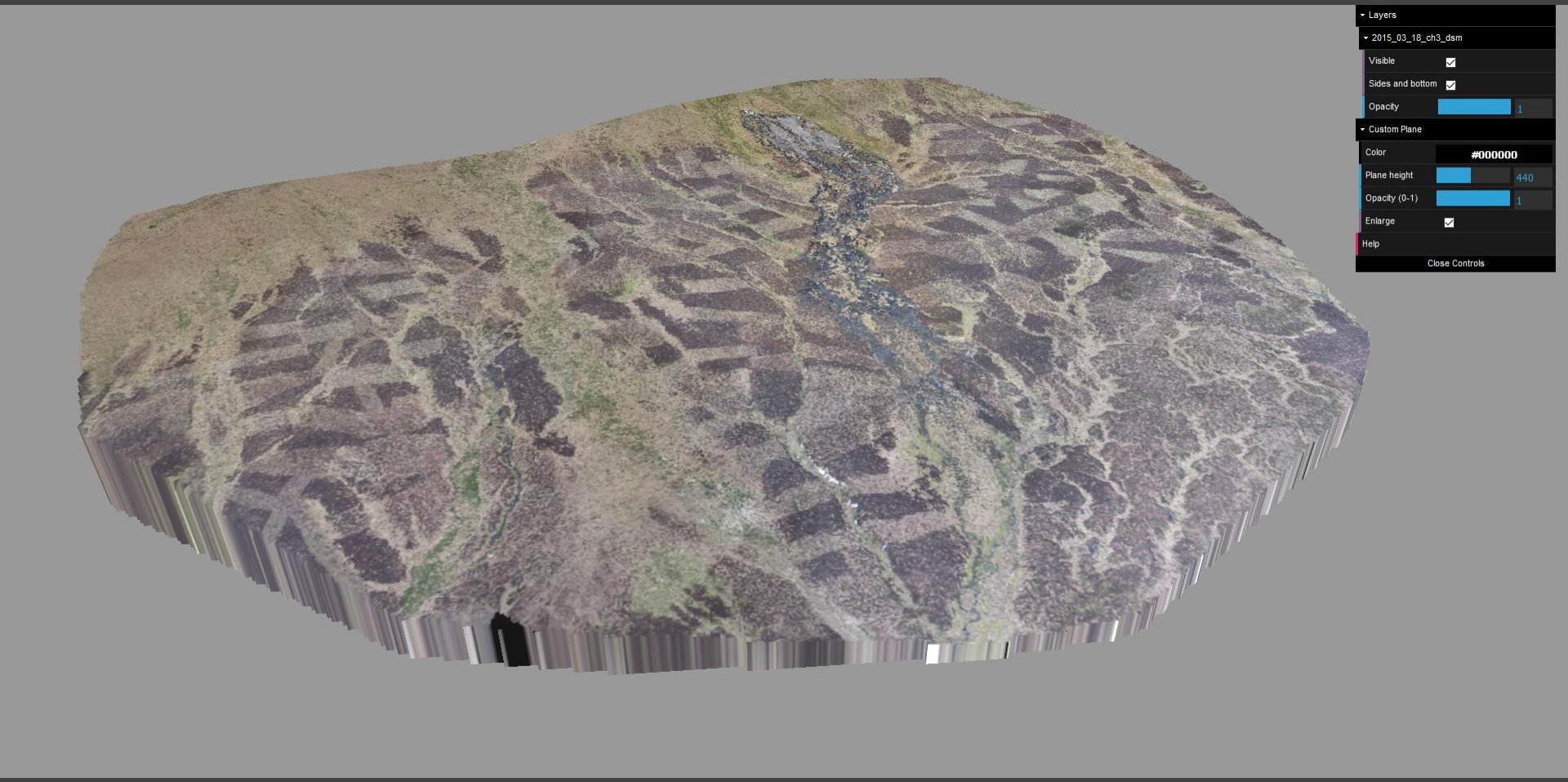
Erosion Depth Model



By making assumptions about the original surface of the bog we can use the UAV data to model erosion depth.

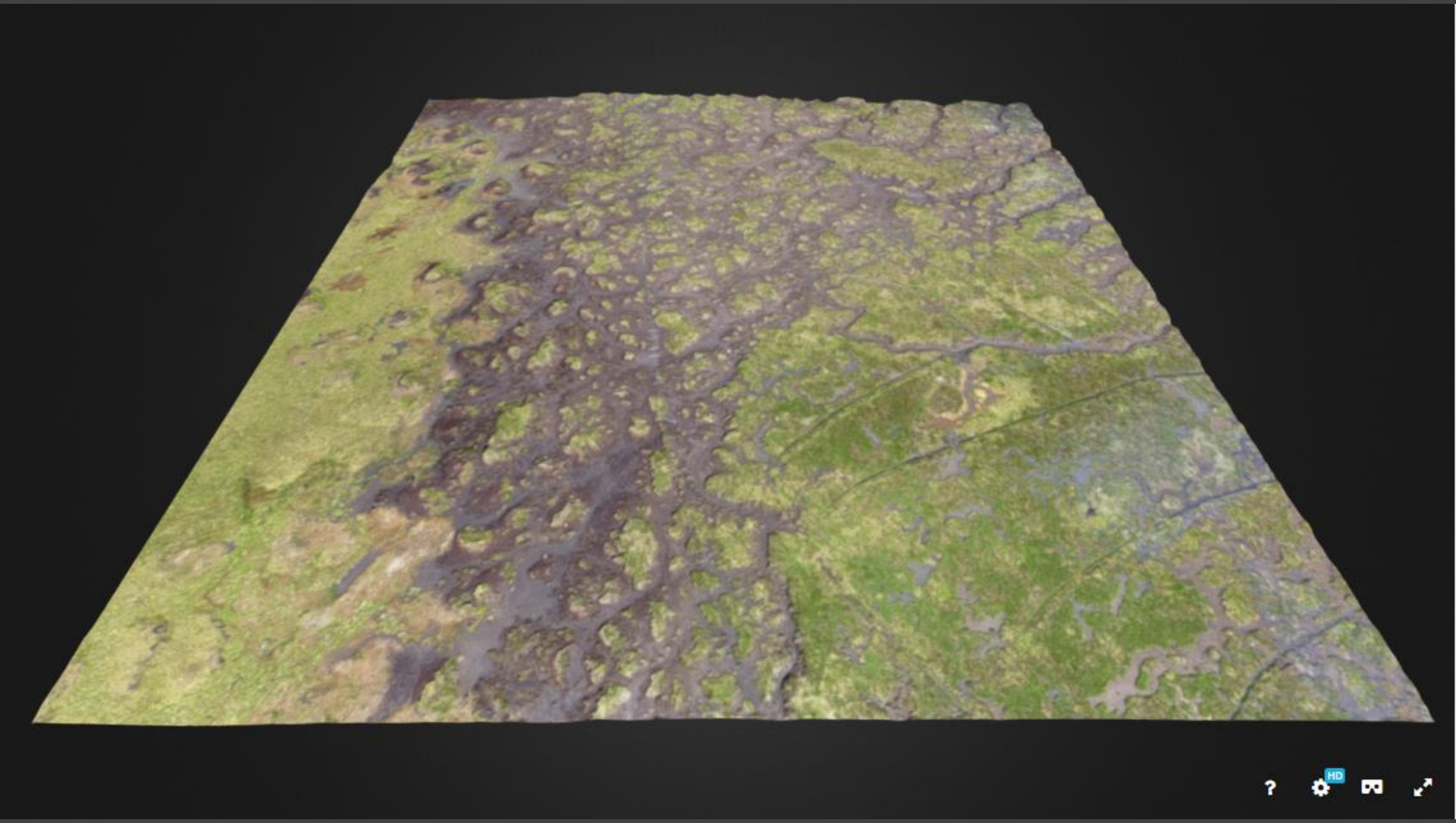
We do this by subtracting the DSM from the estimated surface to give a model to which the depth of erosion has taken place across the bog.

Sharing data



- Not everyone has the capability to view UAV data within a GIS or Remote Sensing software package.
- Something I am interested in is ways to share the data from the surveys that we have carried out.
- Of particular interest are ways to display our data in a web browser. This means we can then share our data with landowners, gamekeepers or whoever might be interested in the data. There are several ways to go about this.
- One way is to build your own website from scratch. There are a number of javascript libraries that enable viewing of 3D data in your web browser. However this requires good knowledge of html/css/javascript.
- Here I have built a website using the three.js library to visualise the peat slide that I showed you earlier.

Sharing data



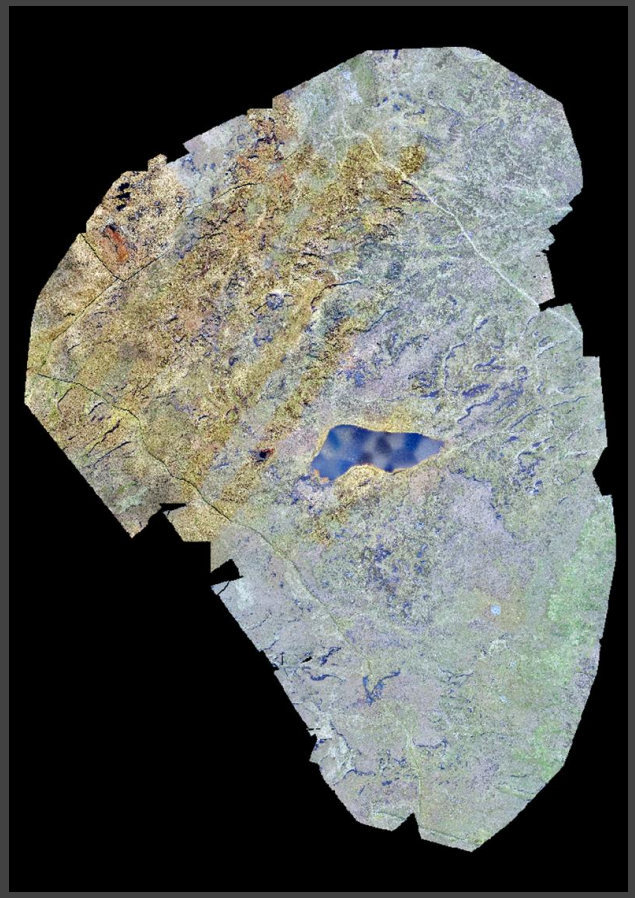
- Another way to make your 3D data viewable in a web browser might be to use a paid for subscription service.
- Sketchfab was originally used so that computer games designers could share 3D models that they have created.
- It has become popular with people generating 3D models using structure from motion.

Sharing data

- Dronelab.io is a relatively new paid for service. Click here!
- Using this you can share your orthophotos online.
- This service has inbuilt measuring tools and they are expanding the service with lots of new ideas.

Issues

- Peat bogs aren't exactly the optimal environment for UAV operations, i.e low cloud, fog, rain, strong winds.
- Changing weather conditions can impact on the final product.
- Surveying is very opportunistic in nature. Weather forecasts are just that.



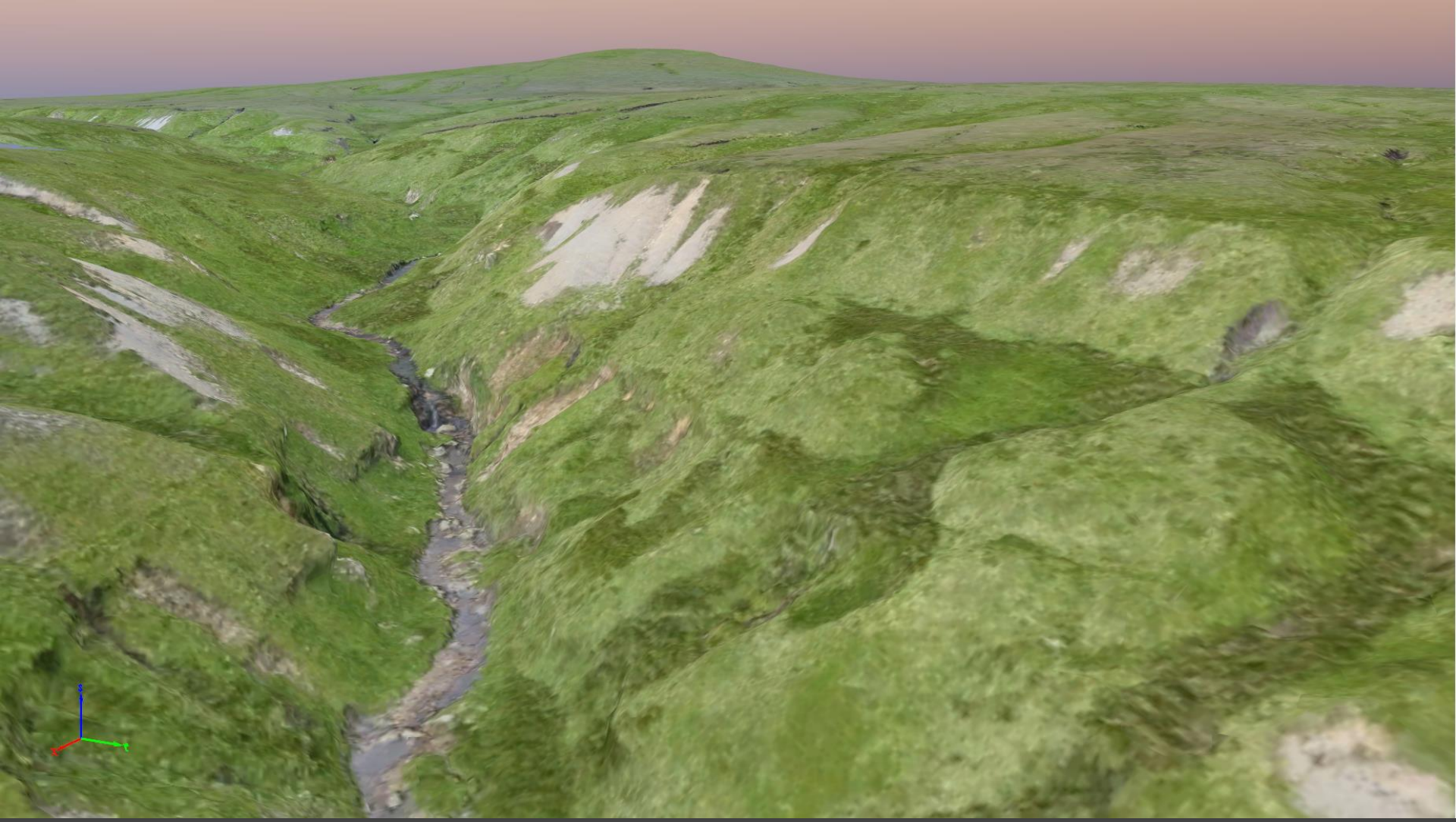
- Processing is extremely intensive on your computer. Data processing can be slow depending on computer specifications.
- Standard office computers don't quite cut it. Optimal processing with high end gaming computers.
- File sizes are big. For example data processing from one flight only. 18.7 GB. Orthophoto 1.82 GB. DSM 1.76 GB. You need to make sure that you have the IT Infrastructure in place to handle this.

Yorkshire Wildlife Trust Twin Mapper UAS

- RGB and Multi-spectral capabilities
- 24.4 mp RGB Camera
- 5 band multi-spectral sensor, R, G, B, NIR, Red Edge

Yorkshire Wildlife Trust

www.ywt.org.uk



Questions?

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