March 2026

MHA Digital Awards Presentation

Derbyshire County-wide Landslide Susceptibility Assessment

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- Examples in Derbyshire
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The Problem

Landslides are a major source of infrastructure damage across Derbyshire, particularly for roads managed by Derbyshire County Council (DCC).

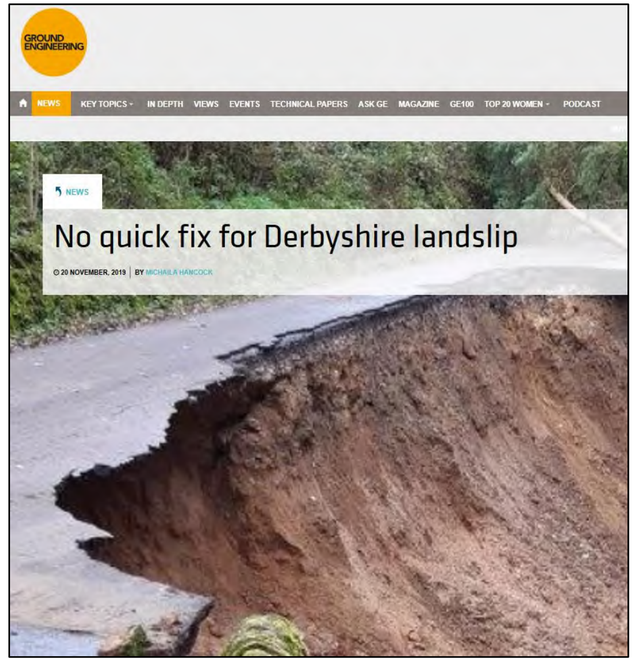
<u>Why? Old glacial landscape, historical landslides and Head, locally highly plastic soils, layered bedrock, steep slopes, wet weather.</u>


NEWS

Landslide-damaged Derbyshire roads to reopen by end of year

28 OCTOBER, 2020 | BY NIA KAIASTIE

Derbyshire County Council has earmarked more than £40M for road maintenance and improvements over the next 18 months, including repairs to two roads closed due to landslides.


GROUND ENGINEERING

NEWS KEY TOPICS IN DEPTH VIEWS EVENTS TECHNICAL PAPERS ASK GE MAGAZINE GE100 TOP 20 WOMEN PODCAST

NEWS

No quick fix for Derbyshire landslip

20 NOVEMBER, 2019 | BY MICHAELA HANCOCK


Derbyshire TIMES News you can trust since 1855

Environment

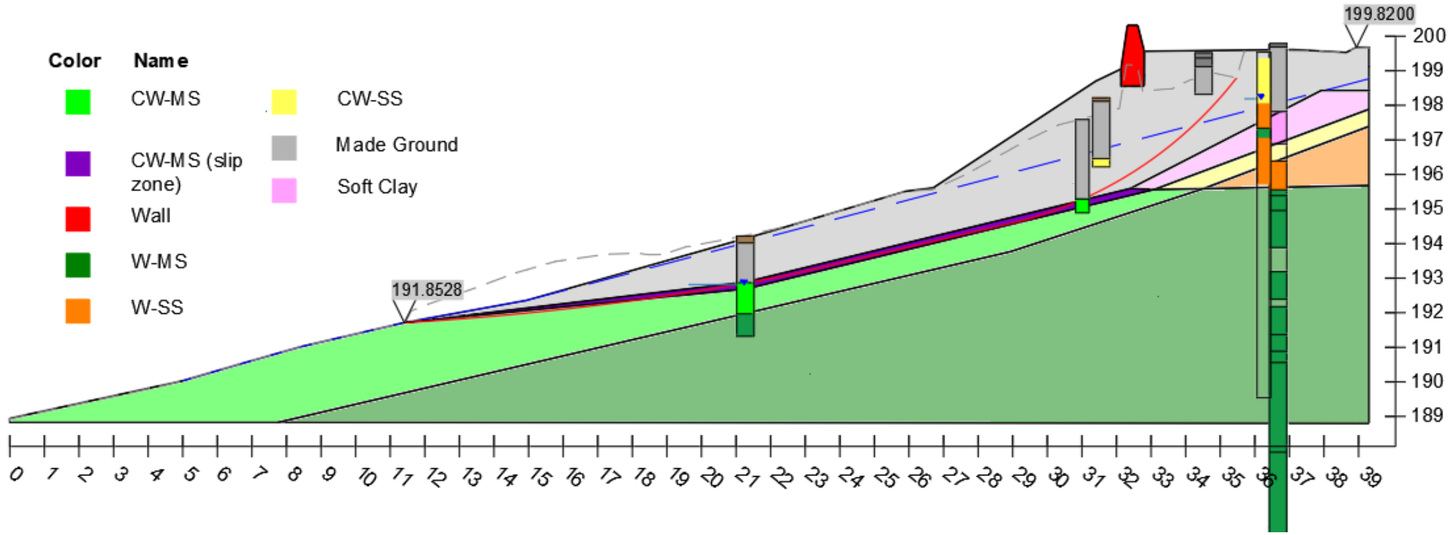
The Derbyshire roads closed by landslips - and why they keep happening on our highways

By Tim Paget
Specialist Journalist

Published 2nd Mar 2022, 14:45 GMT


Hell Bank, above Beeley, was closed by highways chiefs after being hit by two huge landslips. Image: Derbyshire County Council.

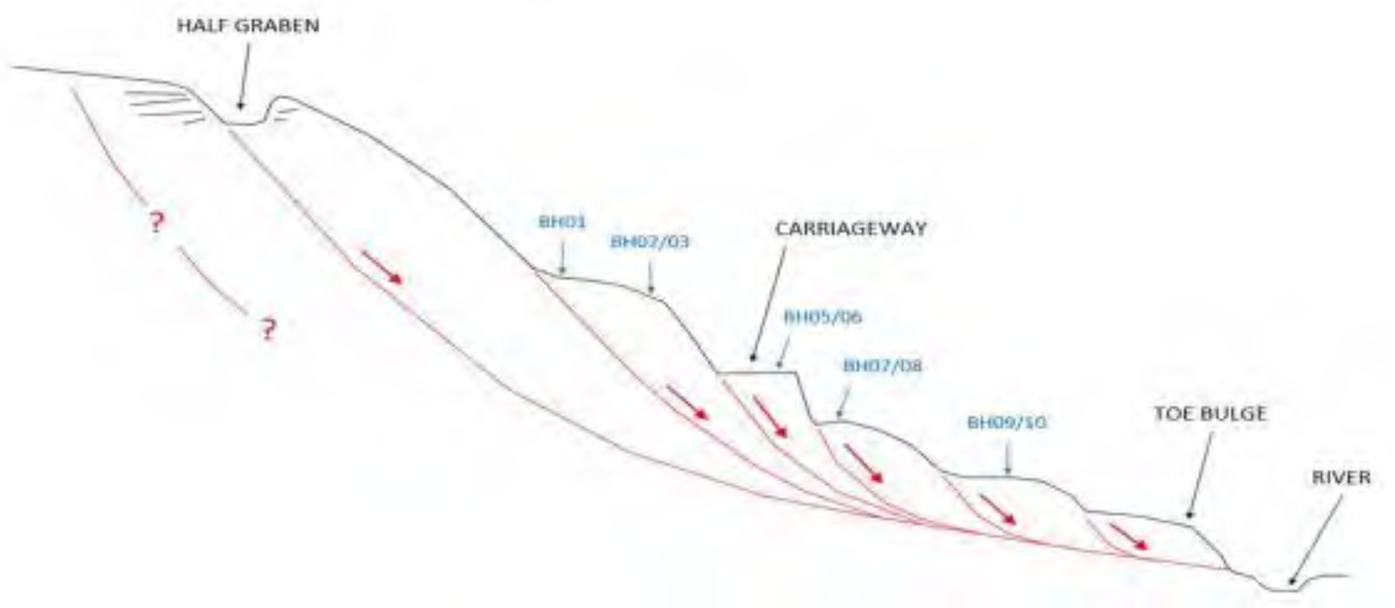
Example – Beeley Limetree Wood



Failure of a minor road, with movement beginning in January 2021.

Shallow failure of Made Ground forming the road embankment on a hillside at the base of a steep sandstone slope.

Example – A57 Snake Pass (Gillott Hey)



One of four sites currently affecting Snake Pass.

Intermittent movement of large deep-seated landslide affecting part of valley side approx. 50m high.

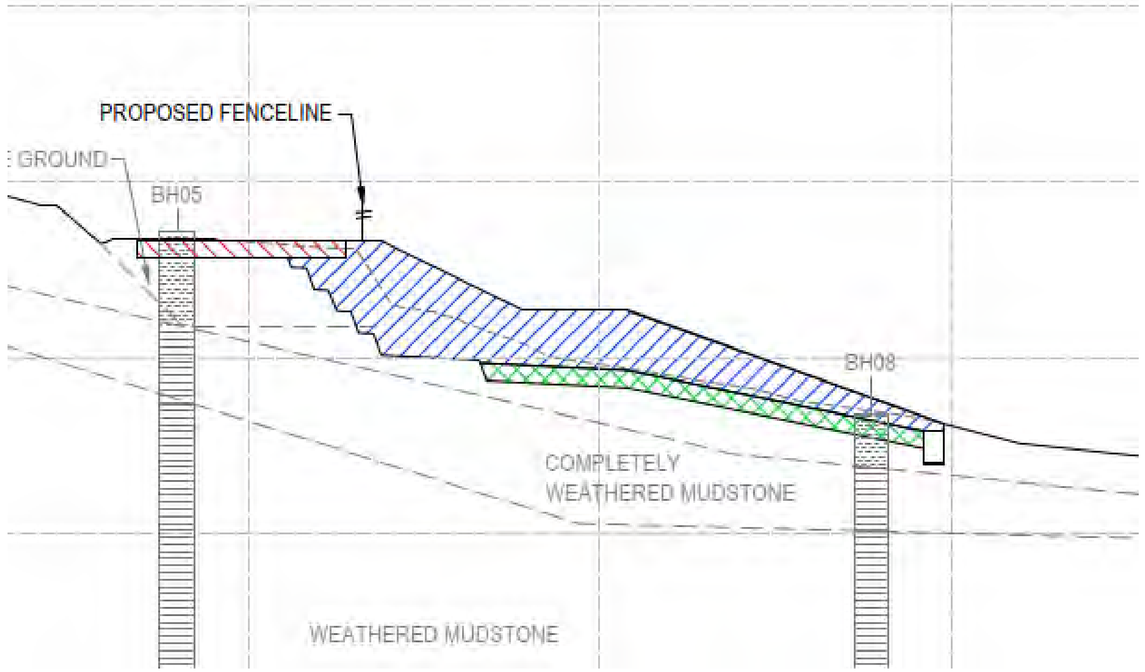
Of the other sites; two are large but localised single slips, one is extremely large affecting the entire side of the valley.

Example - Remediation

Piled Wall –Barlow Commonside

Soil Nailing – A610 Buckland Hollow

Earthworks – Oker Will Shores



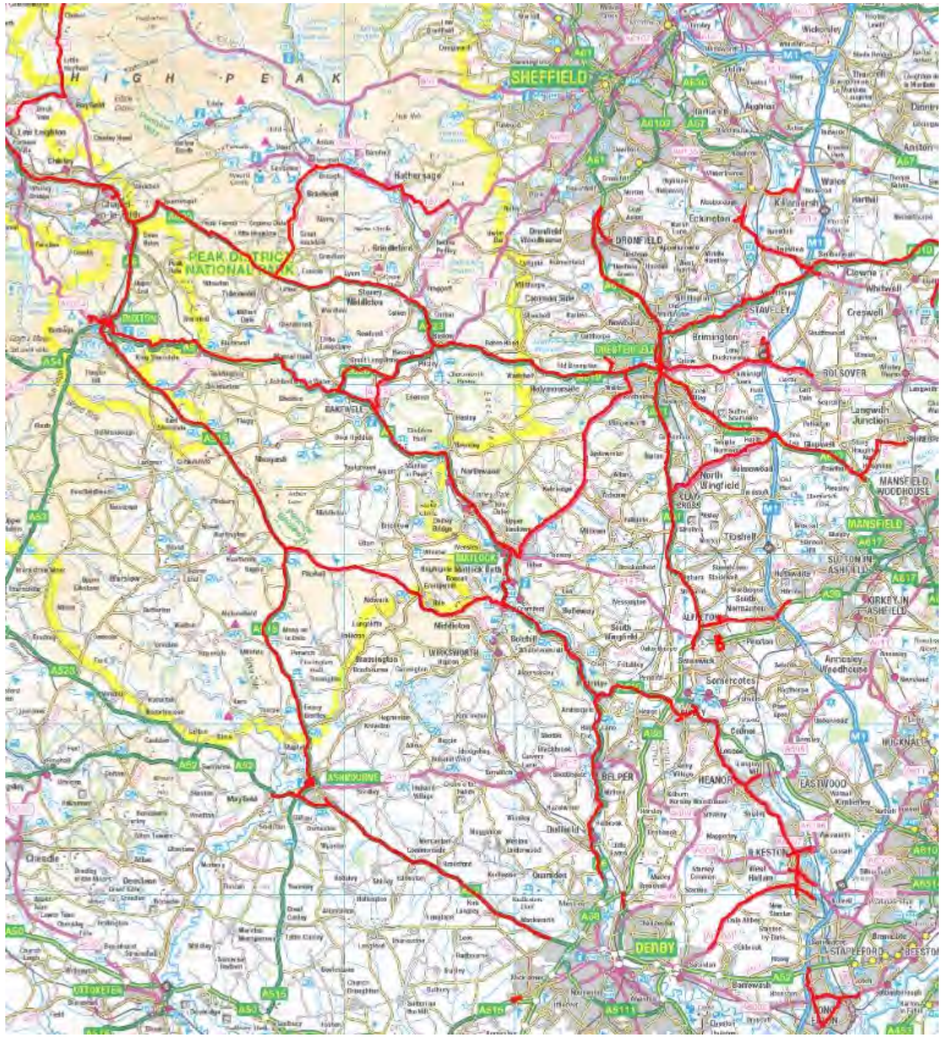
The Problem (continued)

The Client (DCC) sought to understand which parts of their Resilient Routes Network were most susceptible to landslides.

<u>Why? Proactively target early-stage interventions, reduce maintenance costs and delays, improve network safety.</u>

Needed county-wide understanding: so field-based and computationally heavy methods (e.g. FEM) cost/time prohibitive.

DCC also needed to combine landslide information with other hazard data to facilitate multi-hazard assessments.



AECOMs Solution

AECOM worked closely with DCC to agree a potential solution to their needs.

AECOM designed an innovative, custom-made, frequency ratio **landslide susceptibility model.**

Model was fully GIS-based, used predominantly open-source data, had a high (1m) spatial resolution, and was "low-cost"

Landslide Susceptibility Model

=

A model that quantifies the spatial relationships between past landslides and a range of potential controlling factors. These relationships are then combined and extrapolated to assess overall regional landslide susceptibility.

(Assumes that past landslides are behaving similarly to future ones).

Why frequency ratio landslide susceptibility modelling?

A low-cost, GIS-based, that identifies where future landslides are most likely based on the “ratios” between past landslides and different controlling factors.

Had benefits that aligned to Client needs:

Low cost compared to other susceptibility methods. No coding, no expensive software.

Easily undertaken over large spatial scales (e.g., road/rail network wide).

Provides **detailed information** about how specific factors influence landsliding. No “black boxes”!.

Produce visualizable results showing where susceptibility is highest and therefore where mitigation should be focused.

Produce digital outputs for combining with other digital datasets for holistic disciplinary assessments**.**

Methodology – GIS based frequency ratio modelling

1) Data Collection

Landslide Data:
220 client supplied LS + 77 AECOM mapped

Predisposing Data
- BGS 1:50k geology
- EA 1m DEM and derivatives
- ESRI Land use
- Distance buffers to roads and streams

2) Data Validation

Landslide Data:
Independently review data, ensure sufficient coverage, validate.

Predisposing Data:
Check resolutions are sufficient for purpose, spot check. E.g compare land use model to aerial imagery.

3) Statistical Analysis

Calculate Frequency Ratios for each Factor and sum to get final LSI
(Landslide Susceptibility Index)

$$FR = \left[\frac{N_{pix}(SX_i) / \sum_{i=1}^{m} SX_i}{N_{pix}(X_j) / \sum_{j=1}^{n} N_{pix}(X_j)} \right]$$

$$LSM = \sum_{j=1}^{n} FR,$$

4) Final Map Production and Validation

Plot LSI across AoI to get final susceptibility map.

Validate using field observations or independent testing landslide data (e.g. AUROC analysis). **<u>Iterate modelling if necessary.</u>**

1. Split each predisposing factor into subclasses → **2. Calculate % of landslides in each subclass** → **3. Calculate % of the landscape in each subclass** → **4. For each subclass, divide 2. by 3. to get an FR for each subclass** → **5. Apply the FR values to each subclass and sum across the AoI**

The Importance of Geology

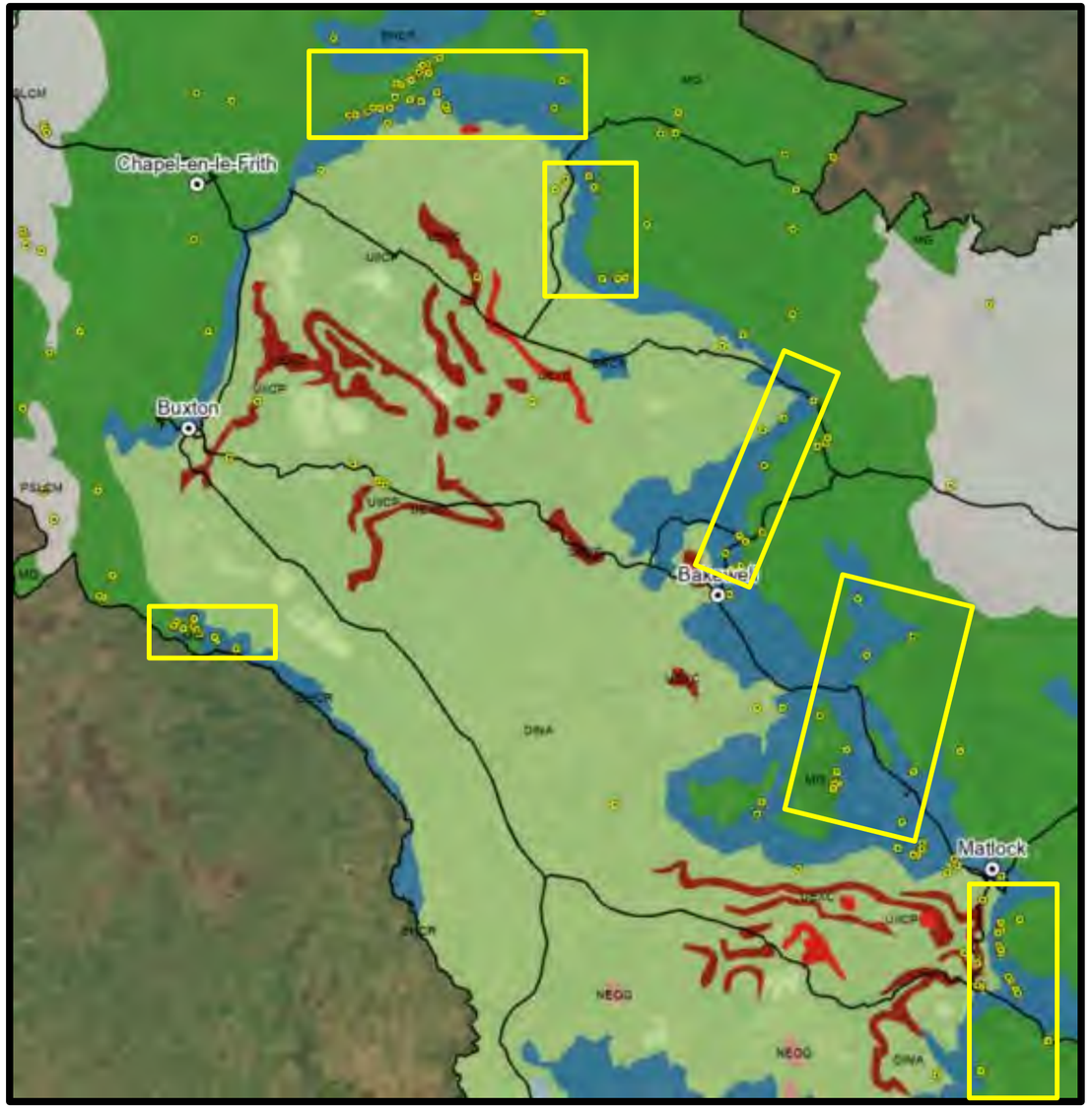
Many landslides clustered on the Bowland Shale (blue) and Millstone Grit Group (green) boundary.

Geologically sensible: Gritstone is permeable, Bowland Shale is less permeable (forming of spring lines) and contains high plasticity clay.

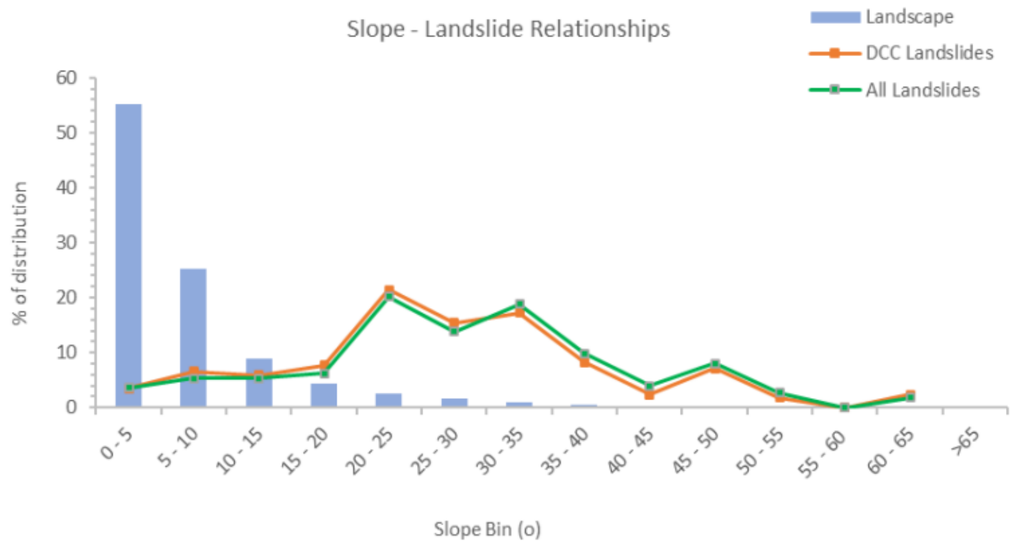
However, initial model treated geological units independently… limitation/area for improvement?

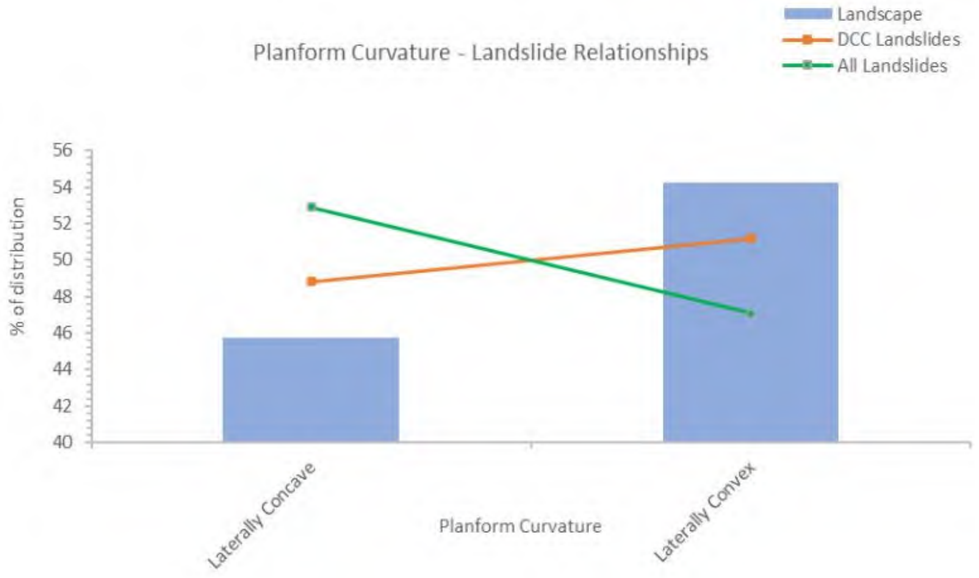
Used structural trends / topography to define near-surface areas with MGG over BS and created a custom input to the model for this.

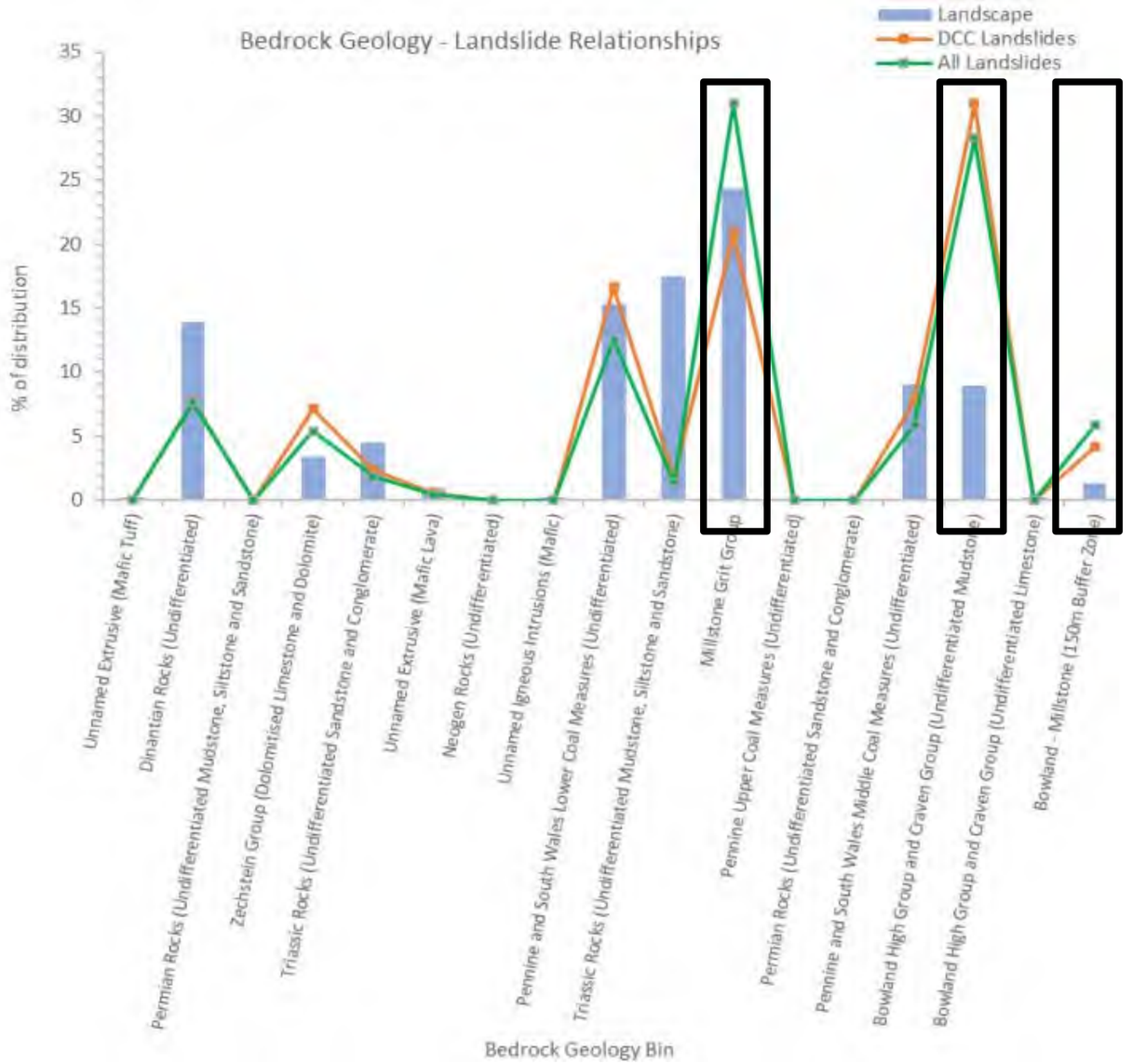
This new layer was found to have the most dominant frequency ratio value of any geological unit, and increased the model accuracy from 75% - 84%



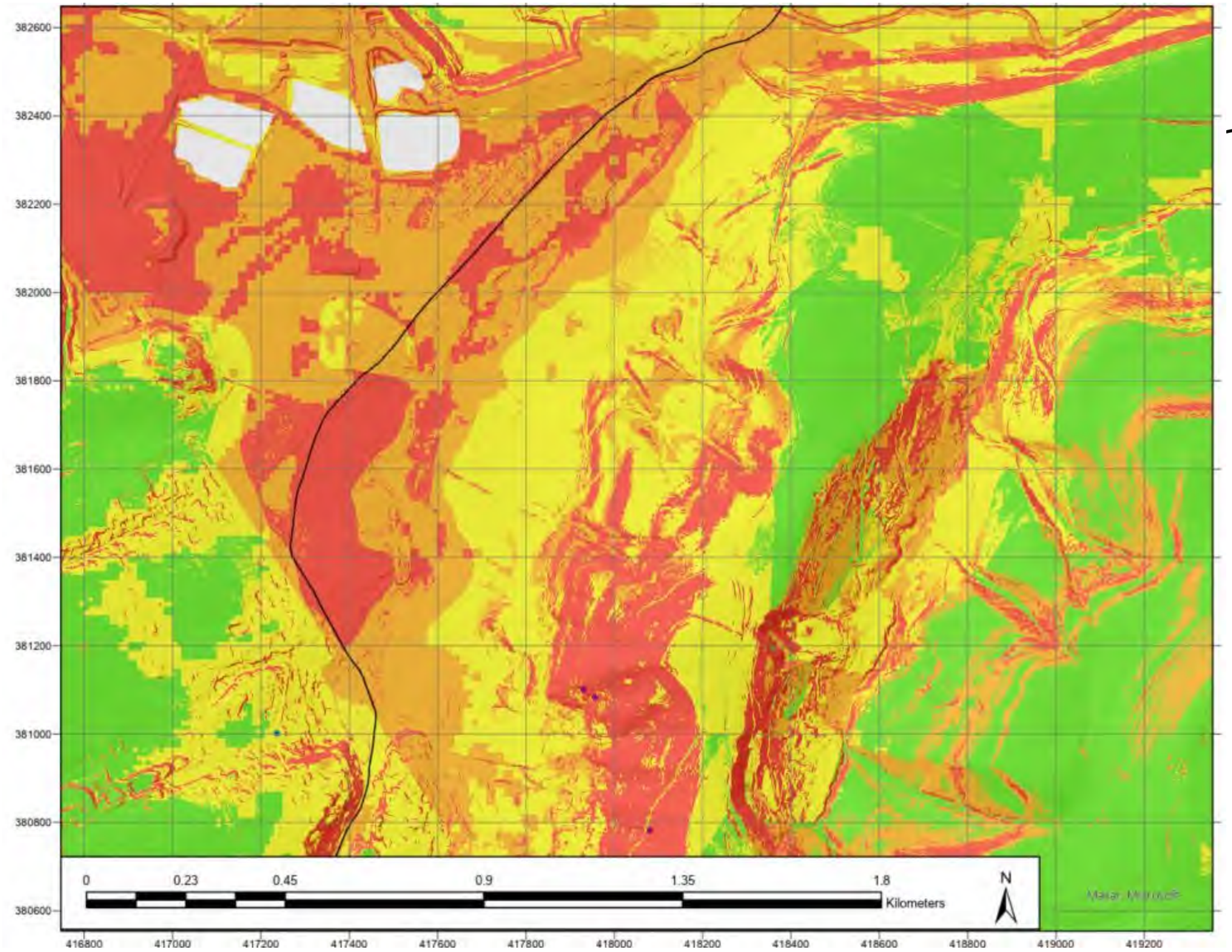
Key Results

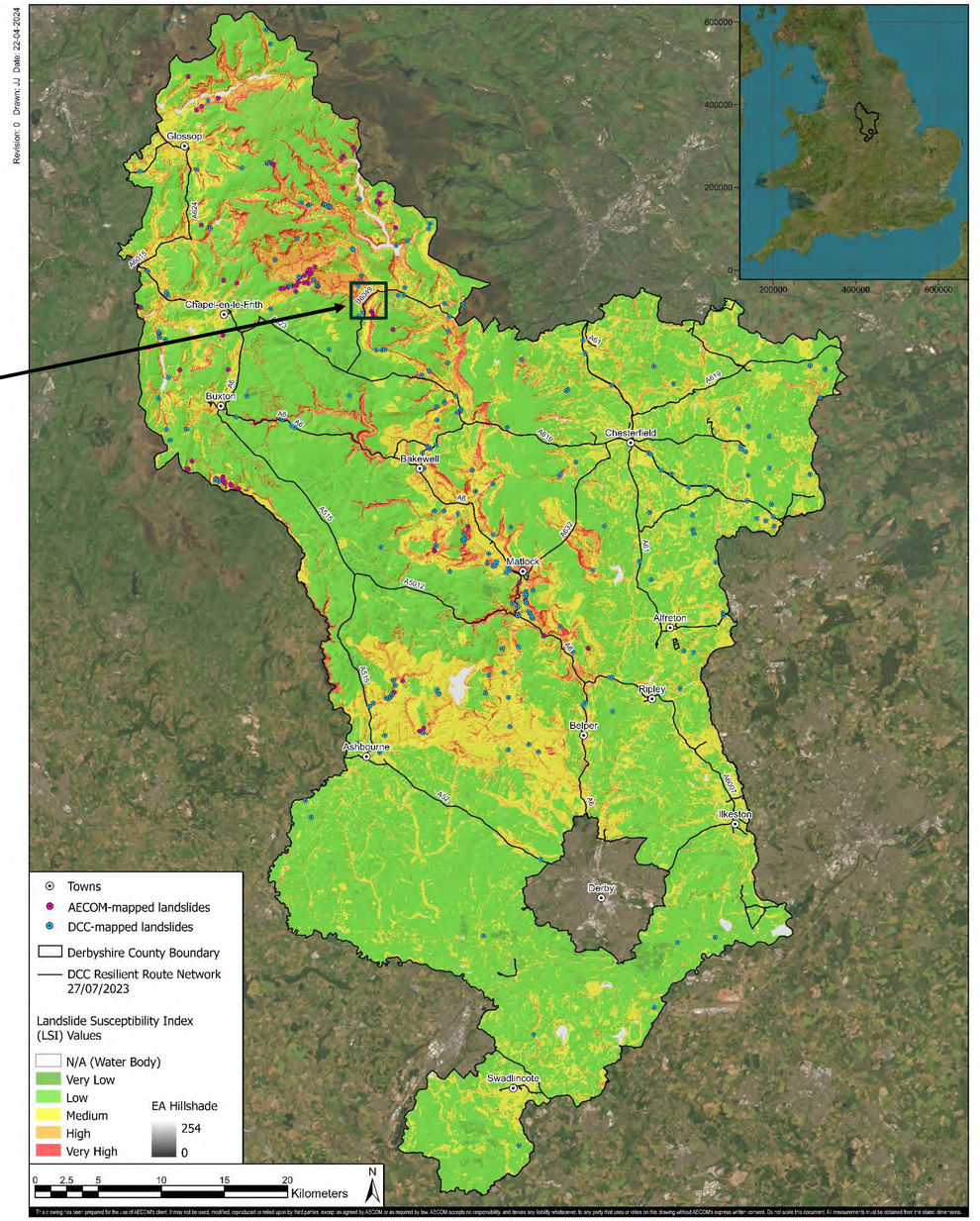

Slope - Landslide Relationships
Landscape
DCC Landslides
All Landslides
% of distribution
0
10
20
30
40
50
60
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
>65
Slope Bin (o)


Planform Curvature - Landslide Relationships
Landscape
DCC Landslides
All Landslides
% of distribution
40
42
44
46
48
50
52
54
56
Laterally Concave
Laterally Convex
Planform Curvature


Bedrock Geology - Landslide Relationships
Landscape
DCC Landslides
All Landslides
% of distribution
0
5
10
15
20
25
30
35
Unnamed Extrusive (Mafic Tuff)
Dinantian Rocks (Undifferentiated)
Permian Rocks (Undifferentiated Mudstone, Siltstone and Sandstone)
Zechstein Group (Dolomitised Limestone and Dolomite)
Triassic Rocks (Undifferentiated Sandstone and Conglomerate)
Unnamed Extrusive (Mafic Lava)
Neogen Rocks (Undifferentiated)
Unnamed Igneous Intrusions (Mafic)
Pennine and South Wales Lower Coal Measures (Undifferentiated)
Triassic Rocks (Undifferentiated Mudstone, Siltstone and Sandstone)
Millstone Grit Group
Pennine Upper Coal Measures (Undifferentiated)
Permian Rocks (Undifferentiated Sandstone and Conglomerate)
Pennine and South Wales Middle Coal Measures (Undifferentiated)
Bowland High Group and Craven Group (Undifferentiated Mudstone)
Bowland High Group and Craven Group (Undifferentiated Limestone)
Bowland - Millstone (150m Buffer Zone)
Bedrock Geology Bin

Key Results





CLIENT
Derbyshire County Council

PROJECT
CoSPAR (Countrywide Slip Prone Area Review)

PROJECT NUMBER
60710545

ISSUE PURPOSE
Final

FIGURE TITLE
DCC Landslide Susceptibility Map

NOTES
1. Base maps [ESRI, Earthstar Geographics]
2. Resilient Routes Network [Derbyshire County Council, data provided for project use].
3. Both the main and inset map are projected onto the British National Grid System.
4. Hillshade data [Environment Agency, open access].
5. Note that the hillshade layer is used as a base layer below the other data layers.
6. For details on how the susceptibility map was produced, see the accompanying Countywide Slope Prone Assessment Review (CoSPAR) report.

CONSULTANT
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Tailyour Road, Crownhill, Plymouth
PL6 5DH
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AECOM

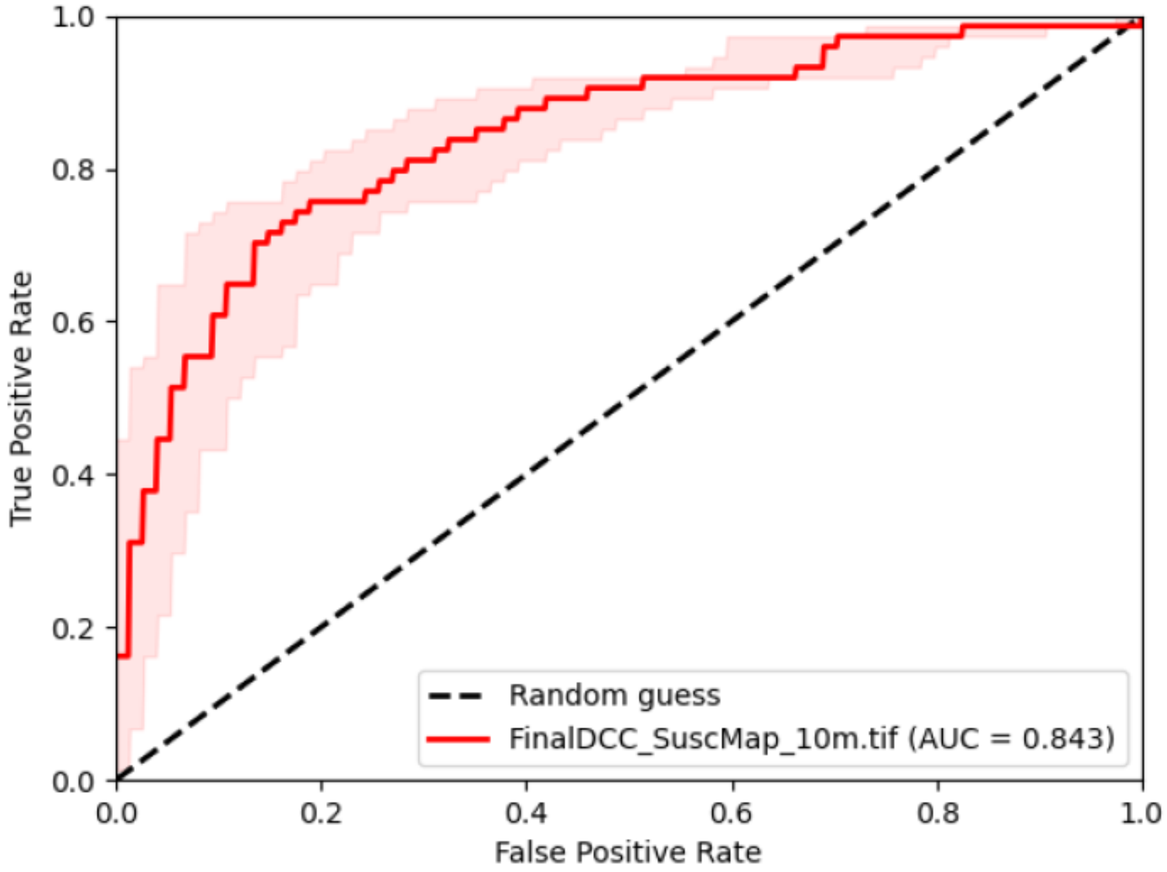
Key Results

Model Accuracy when including the Bowland Shale - Millstone Grit Group input is ~84%.

Highest susceptibility areas correspond with combinations of:

- Locations of Bowland Shale overlying the Millstone Grit Group.
- Slope angles of 30 – 50°.
- Southwest to west-facing slopes.
- Areas of historical mass-movement / head deposits.

^*This information highlights the usefulness of FR over other "black box" machine learning type methods, that don't provide landslide-factor specific relationships.*



Understanding and Communicating Uncertainty

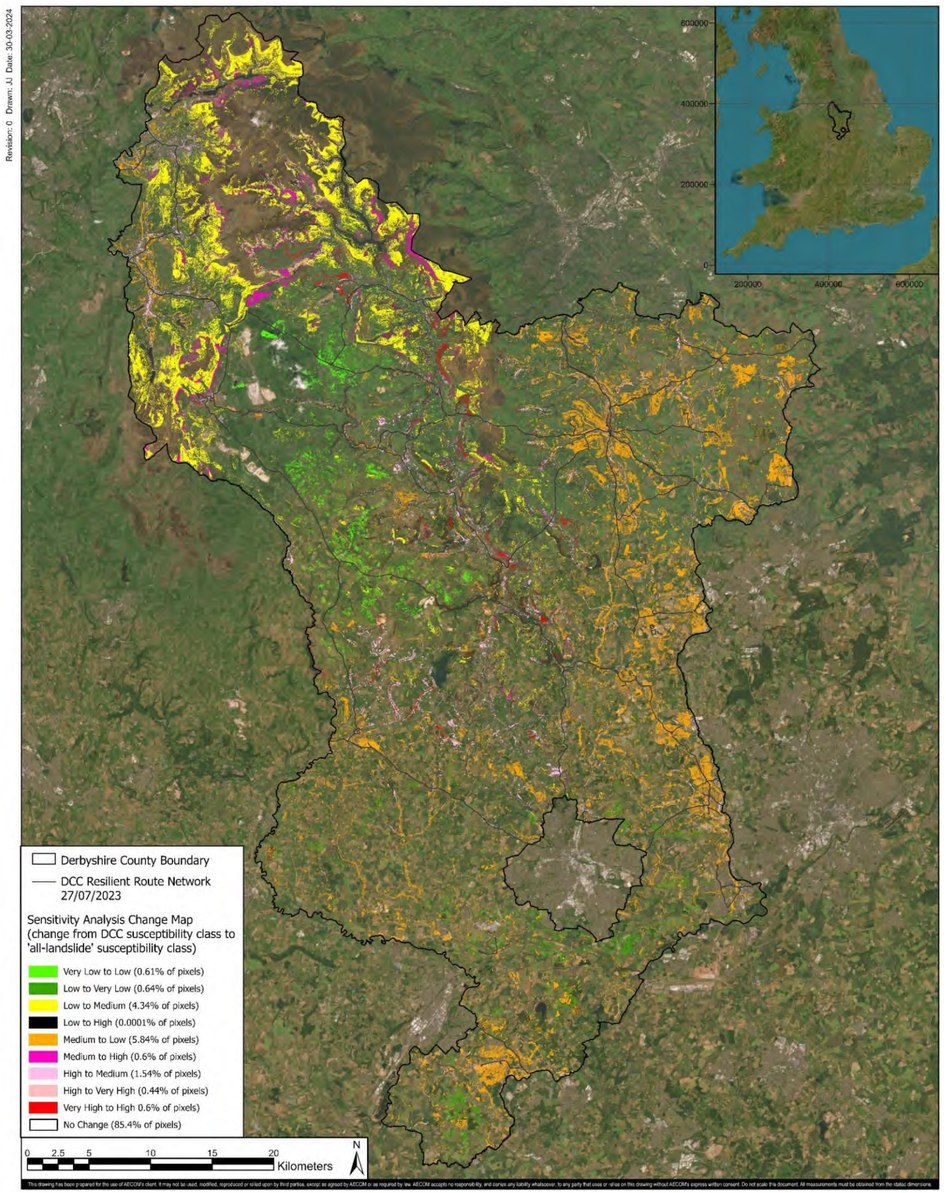
Due to the implications for funding and safety-based decisions, understanding and communicating model uncertainty was vital.

Key question – how sensitive was the model to the input landslide data?

To test this, we made a second FR susceptibility model using just additional AECOM-mapped landslides.

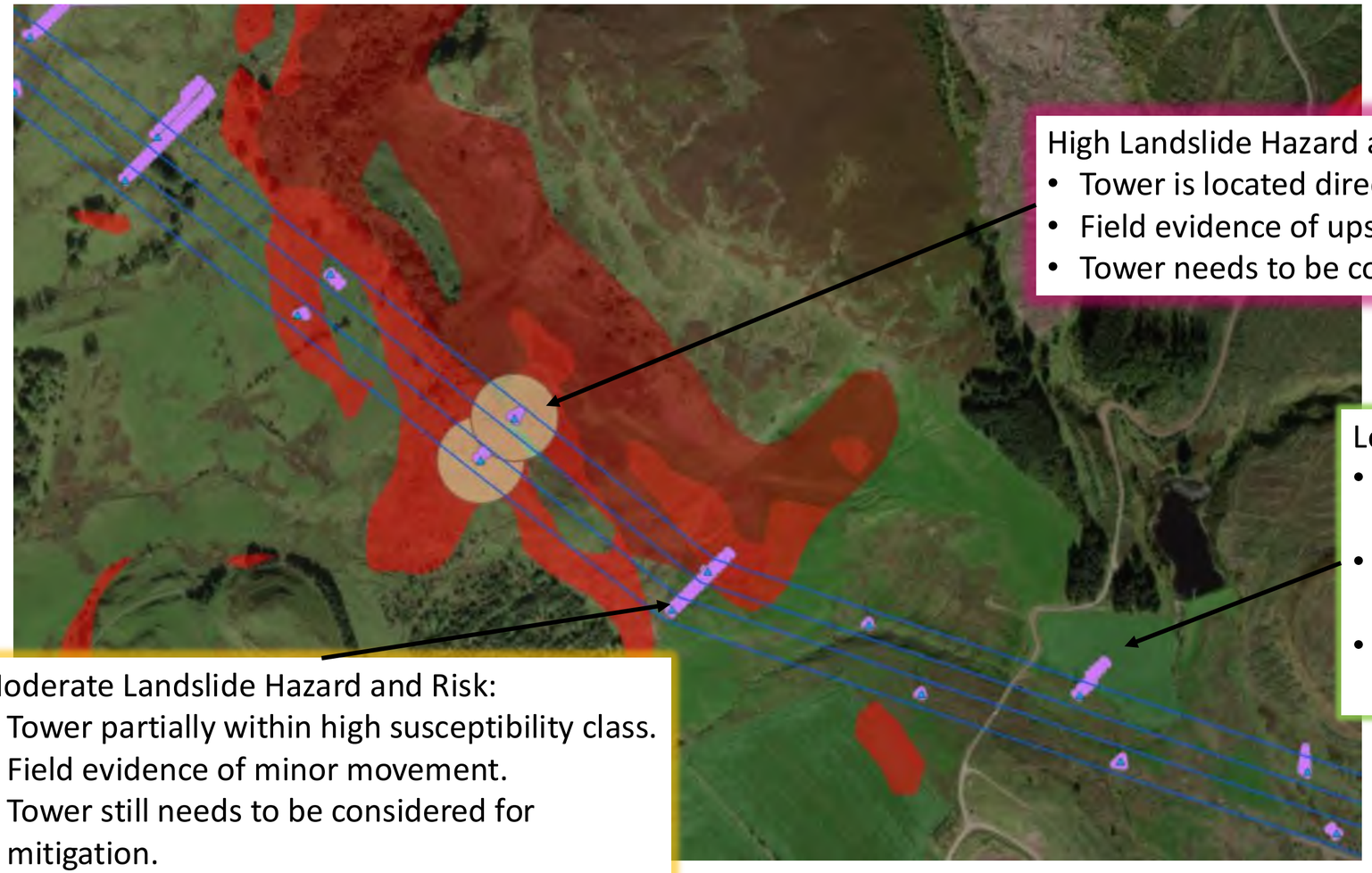
Then compared the two models on the pixel level. This showed an 85% class agreement, with the remaining minor differences due to slight biases towards roads in the DCC inventory.

Other limitations included that some areas with high slope angles were being given unrealistically high susceptibilities – e.g. rock cuttings.



Potential Next Steps...

Undertake field work (geomorphological and landslide mapping) in high-susceptibility areas to understand landslide hazard (and by extension risk).



High Landslide Hazard and Risk:
- Tower is located directly within high susceptibility class.
- Field evidence of upslope instability suggests high hazard.
- Tower needs to be considered for mitigation.

Low Landslide Hazard and Risk:
- Tower is not located directly within high susceptibility class.
- Field inspection suggests no upslope or downslope instabilities are present.
- Tower does not need to be considered for mitigation.

Moderate Landslide Hazard and Risk:
- Tower partially within high susceptibility class.
- Field evidence of minor movement.
- Tower still needs to be considered for mitigation.

Potential Next Steps...

Consider potential mitigation options/interventions that could be taken forward for detailed design.

Suitability:
Debris Flow
Rock Fall
Translational Slide

Drainage techniques

Regrading slopes

Rock Scaling

Retaining Walls e.g. Gabions

Reinforced slope- Geosynthetics Rock Mesh & Anchors

Catch Bund/Nets

Summary and Implications

- For a relatively low-cost, developed a countywide, high resolution landslide susceptibility map that consider geological complexities.
- Successful **early client engaged** ensured a **“right first time” approach**, keeping the project within programme and budget and fully meet client needs.
- There was a strong focus on **understanding and communicating limitations and uncertainty** – this is very important in the field of geohazard management where results have implications for safety and client resource management.
- **Short and Long Term Client Benefits** – Shows the client which portions of their network need prioritising in the short term for more detailed assessment. Vital in their efforts to reduce long term costs and increase network safety. For the cost, provides significant value.
- **Wider Long Term Benefits**- The approach developed here can be readily applied to other high landslide risk areas, providing a crucial component for large-scale risk and resilience assessments in the UK and beyond. This is particularly important in the context of climate change.
- Potential to **Further Targeted Investigate Key Risk Areas** for targeted maintenance and preventative works.

Thanks for Listening

Questions?

June 2024