Improving the understanding of

Weather Drivers of Earthwork Failures

along Britain's rail network:

A data-driven approach

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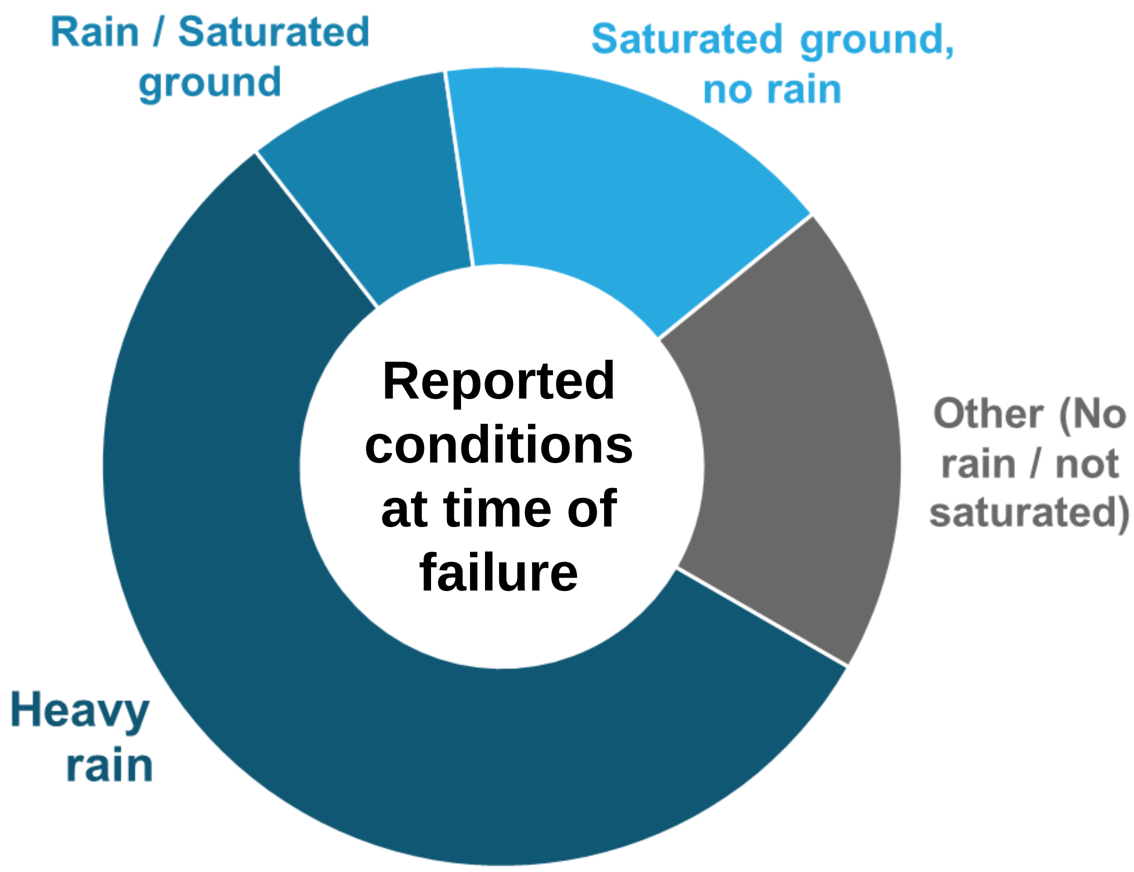
Dr. Juliet Mian
juliet.mian@arup.com

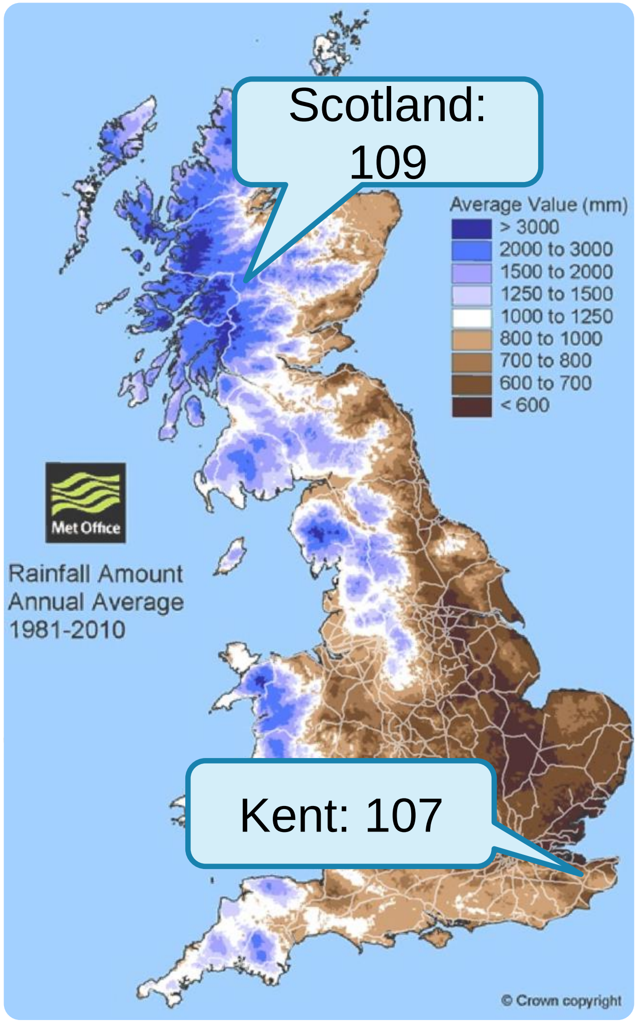
Chris Merrylees
chris.merrylees@arup.com

NetworkRail

ARUP

Earthwork failures, and regional weather





Weather Data

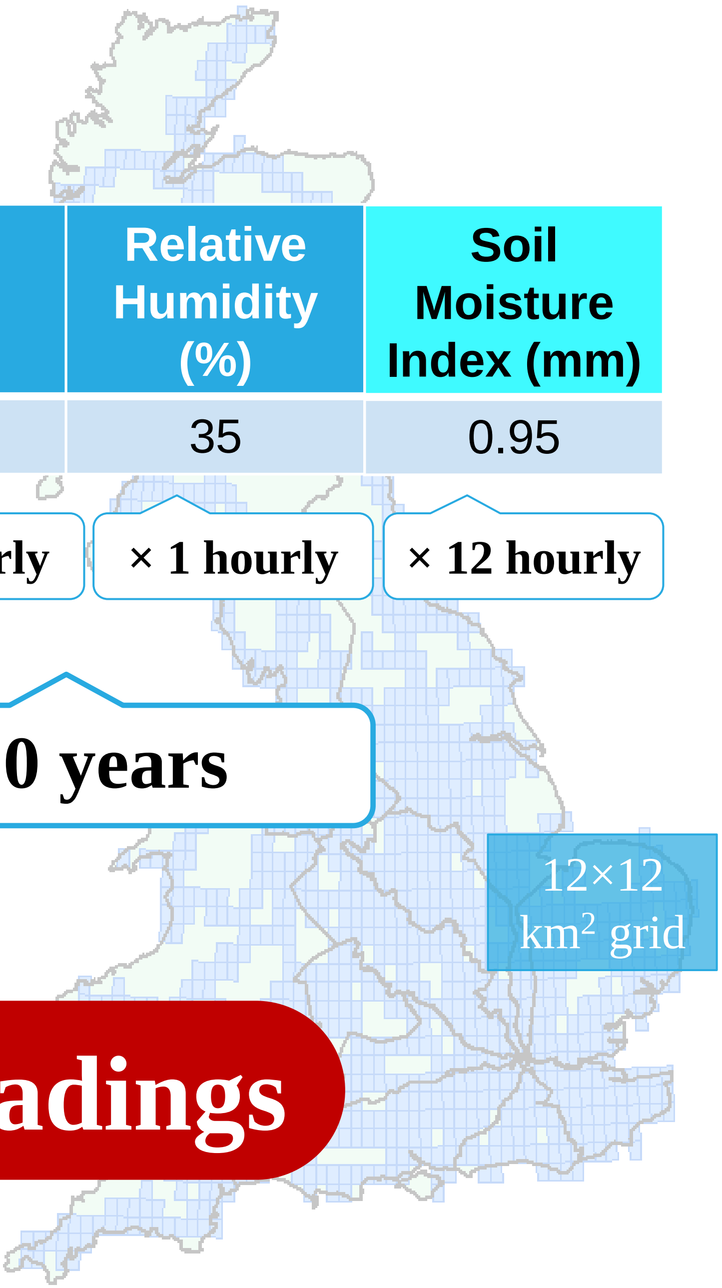
Rainfall (mm)	Snowfall (mm)	Temp. (°C)	Wind Speed (mph)	Relative Humidity (%)	Soil Moisture Index (mm)
11	0	17	6	35	0.95

× 3 hourly | × 3 hourly | × 1 hourly | × 1 hourly | × 1 hourly | × 12 hourly

× 1,300 locations

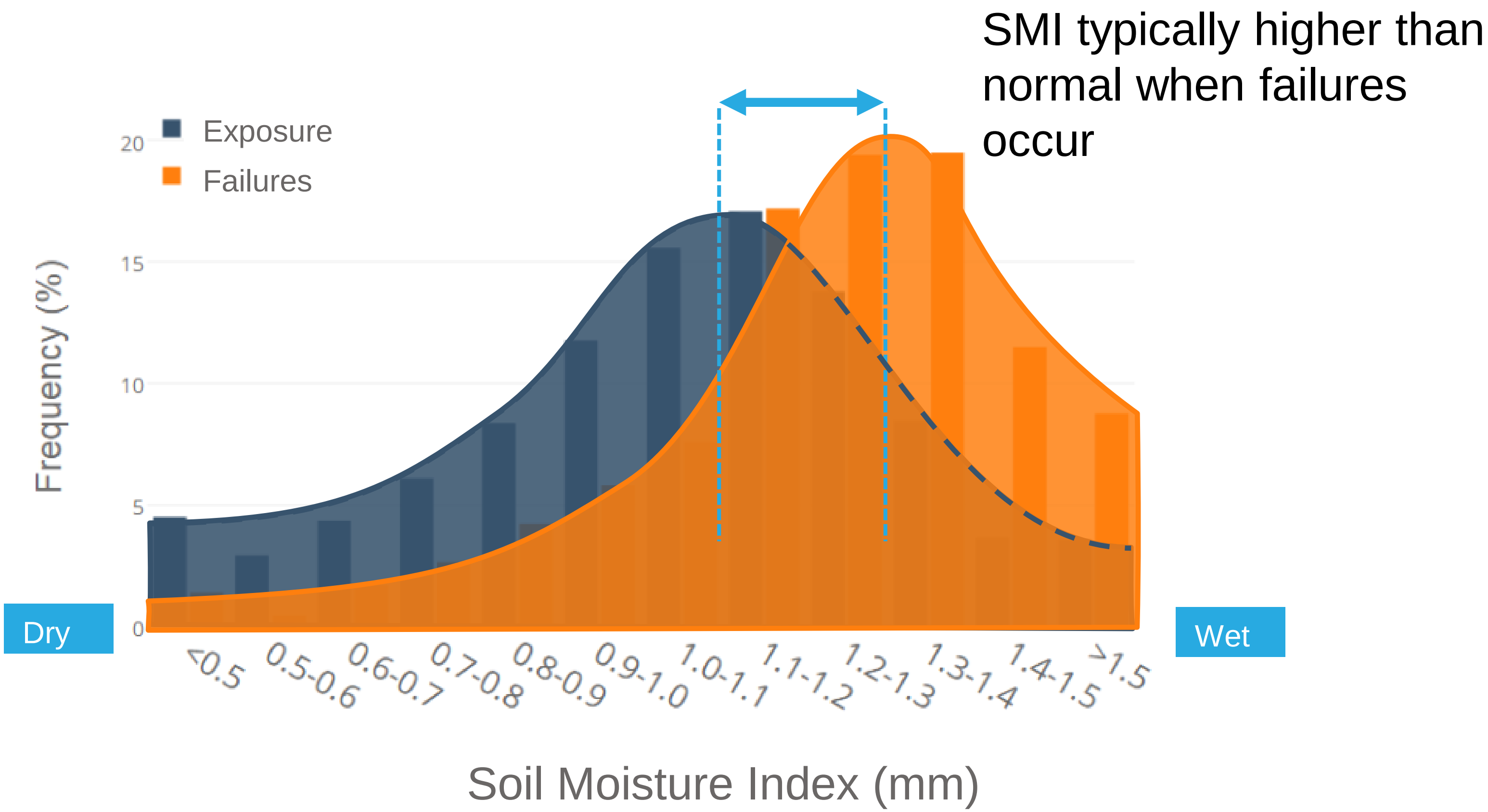
× 10 years

= 427,000,000 readings



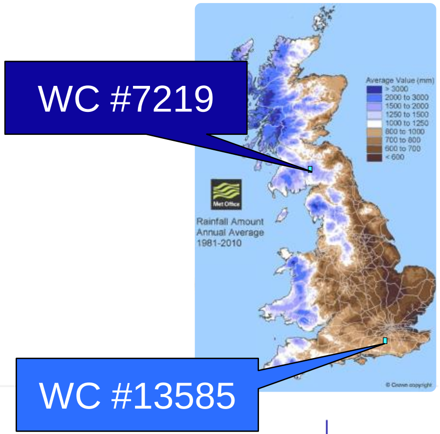
Soil Moisture Index and Earthwork failures

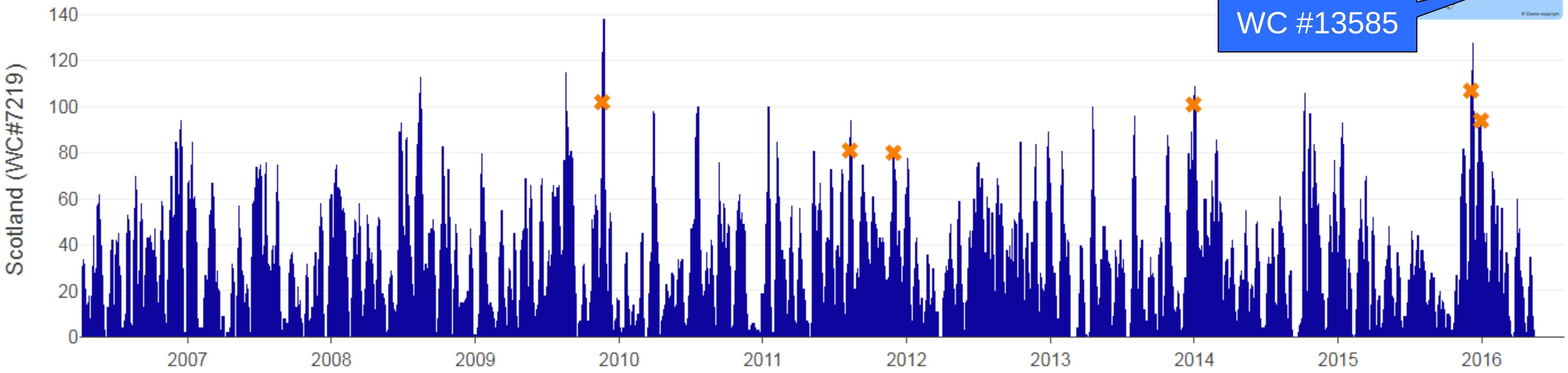
- Early indications that SMI correlated well with earthwork failures

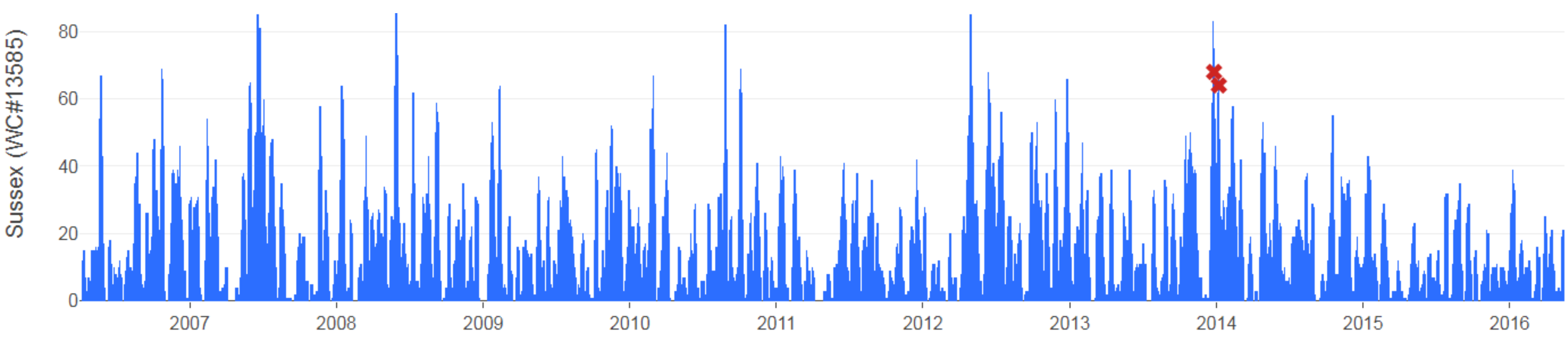


Confirmed SMI >0.9 to be an indication of conditions more prone to failure

Rainfall and Earthwork failures

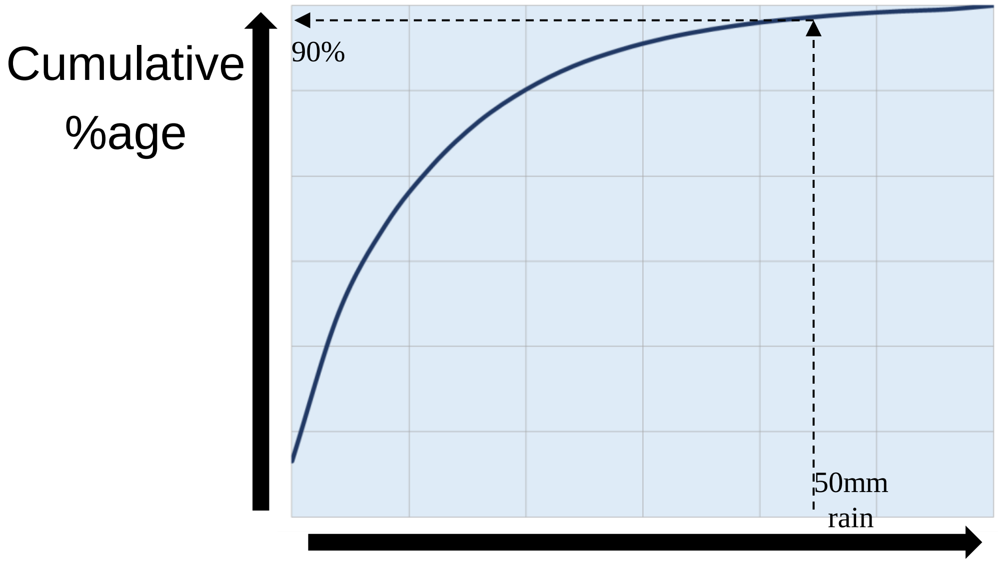






Relative severity of weather

$$\text{Weather severity (\%)} = \frac{\text{Days seen of Weather} \leq \text{magnitude X}}{\text{All Days in record}} \times 100\%$$



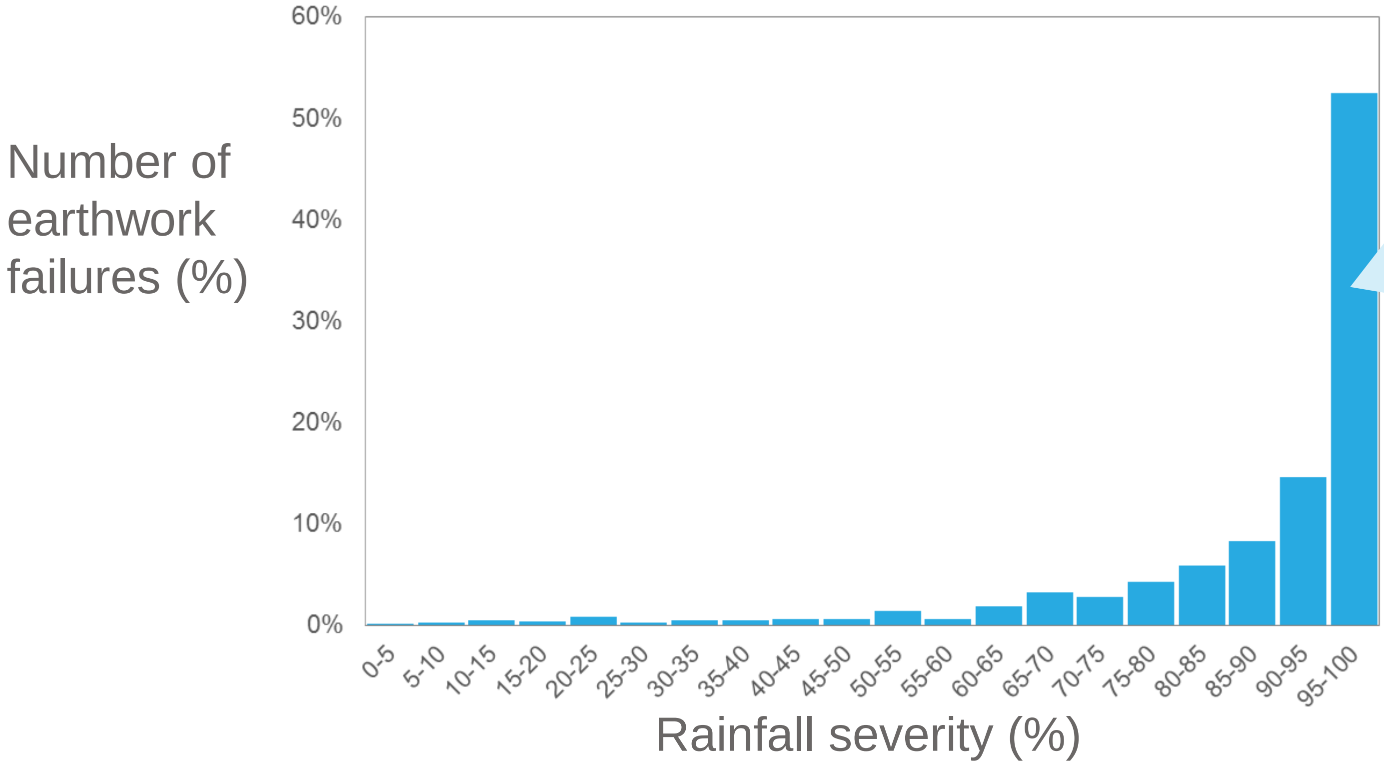
e.g. less than 50 mm of rain is seen 90% of time:

⇨ 90% severe event

Effectively a proxy for return period, but based on own data history

Failures by Rainfall Severity

- Representing earthwork failures in terms of their rainfall weather history



Scotland and Sussex failures occurred during similarly ‘severe’ rainfall conditions.

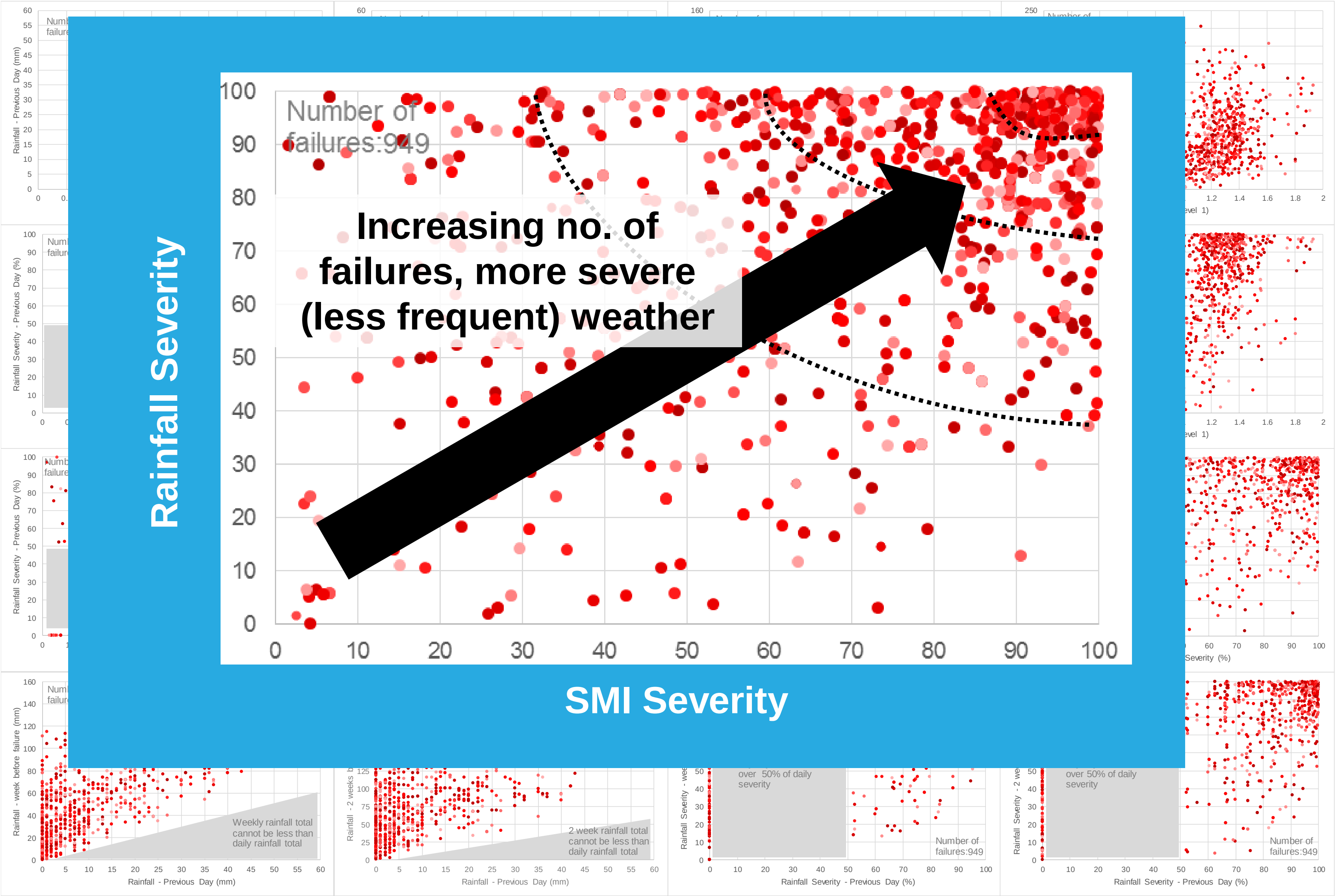
Enables failures in different local climates to be considered together

Further exploration of trends

- Considered different aggregated durations of rainfall prior to failure:
  - 24 hour
  - 7 day
  - 14 day
- Explored rainfall and soil moisture simultaneously
- Absolute values (e.g. mm) and Severity (%)

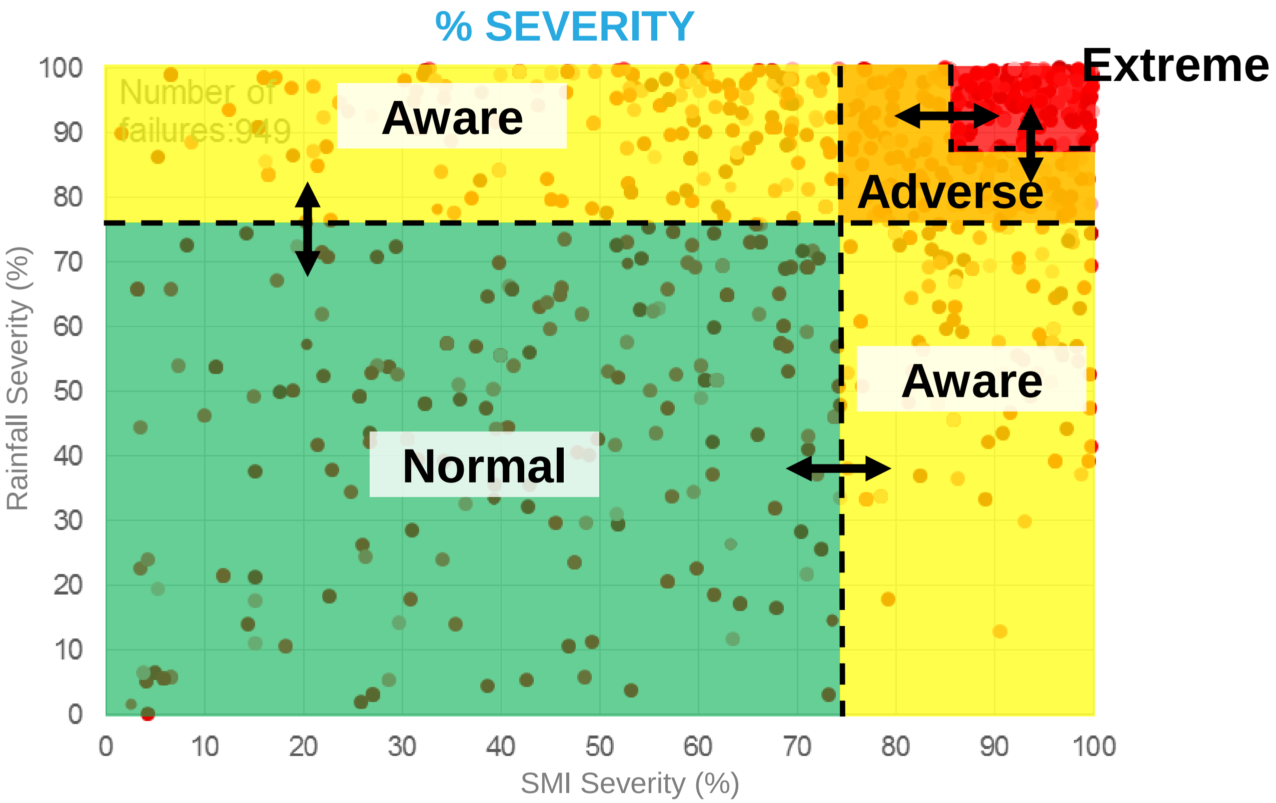
Representing failures in different dimensions

Representing failures in different dimensions

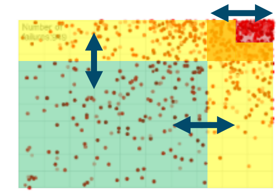


Choosing warning threshold levels

- From understanding the conditions of failure, we are in a position to assign meaningful warning thresholds and triggers.



Achieving a balance in threshold levels



☹ More weather warnings

☺ Few failures in ‘Normal’ weather

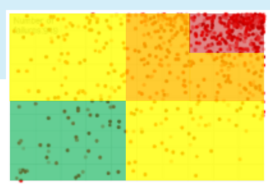
Low thresholds

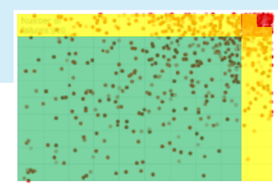
TRADE OFF

High thresholds

☺ More ‘Normal’ weather

☹ Many failures in ‘Normal’ weather

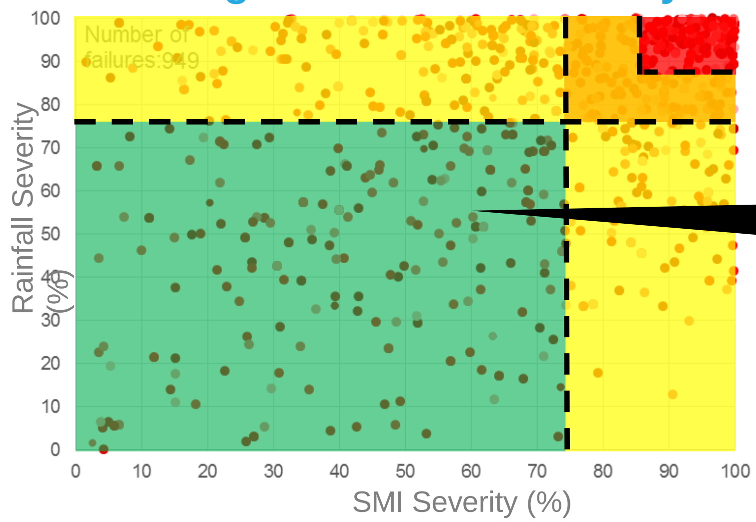




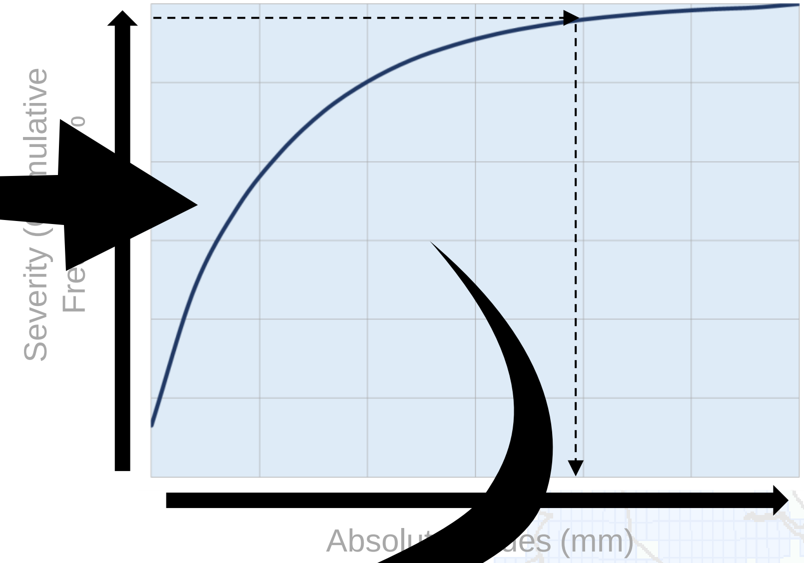
- Trialled 40 combinations to find optimum thresholds

Severity to real thresholds

Warning thresholds - Severity



Local climate mm to severity conversion



Operational Warning thresholds in absolute values

From a national analysis local operational thresholds can be set

Conclusions (1)

- Weather in the context of the local climate gives a convenient way to describe conditions more prone to earthwork failures
  - Soil Moisture Index is a useful parameter
  - Total rainfall aggregated over different durations are useful parameters

- A ‘Severity’ approach enables earthwork failures in different local climates to be grouped for statistical analysis. Further, the severity of different weather events, e.g. short sharp rainfall vs prolonged period of rain, can be grouped for analysis.

- Weather warning thresholds can be derived for local climates from a national back-analysis

Conclusions (2)

- Earthworks fail most often when weather events are more severe. But, earthwork variability means that:
  - Some slope will failures when weather is not particularly severe
  - Not all earthworks that experience the same ‘Severe’ weather will fail

- Climate change will increase the frequency of what is severe weather

- Maintaining assets in their current condition is not sustainable for maintaining current rates of slope failures

Acknowledgements

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Weather warnings visualised