Water, Risk and the Railway: A Ground Engineer's Perspective

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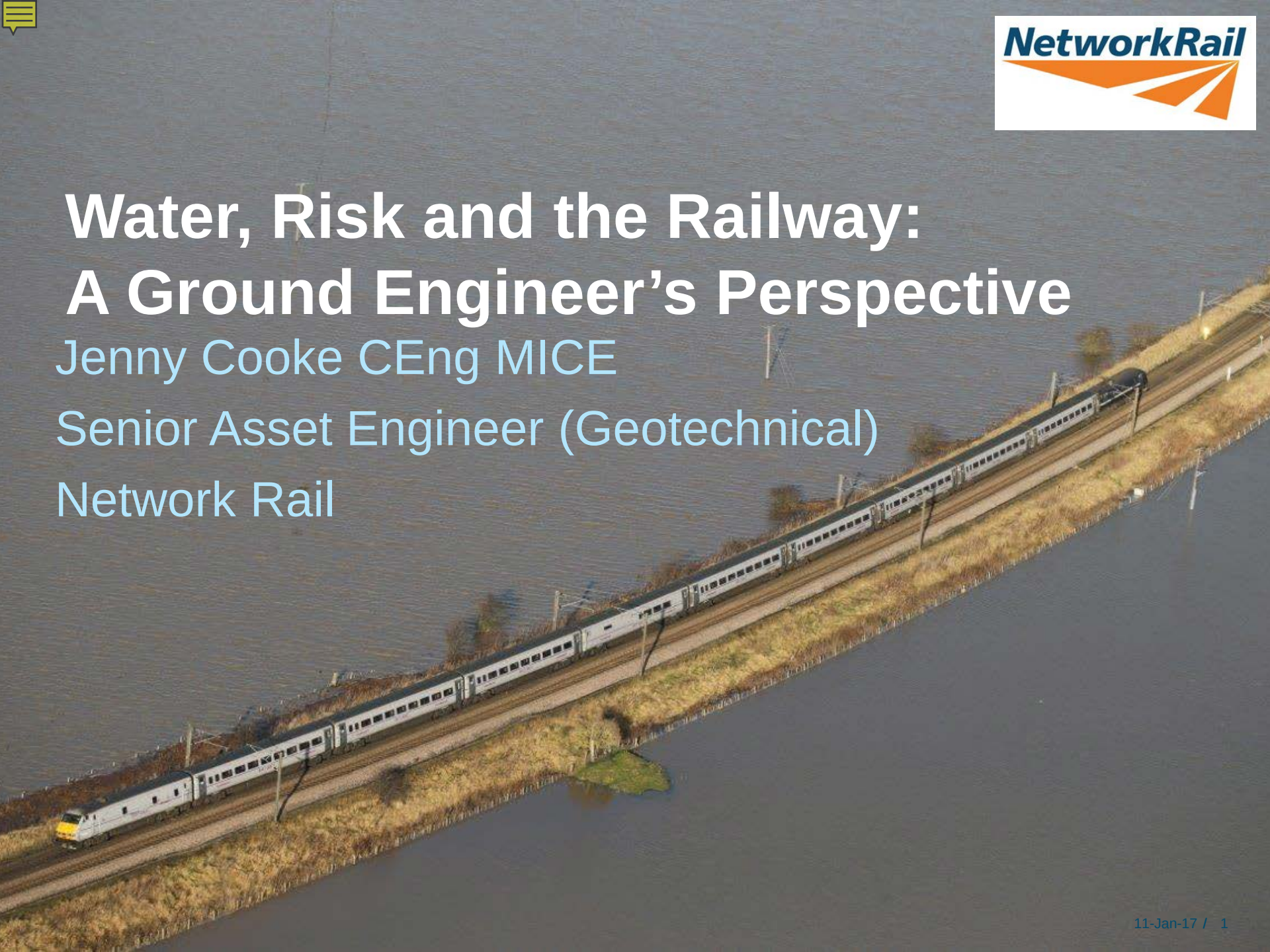
Network Rail



Ground Specialists as Risk Managers

4 steps to effective risk management:

1. **Know what's important to you**

   HOW does your system create value?

2. **Understand possible failure modes**

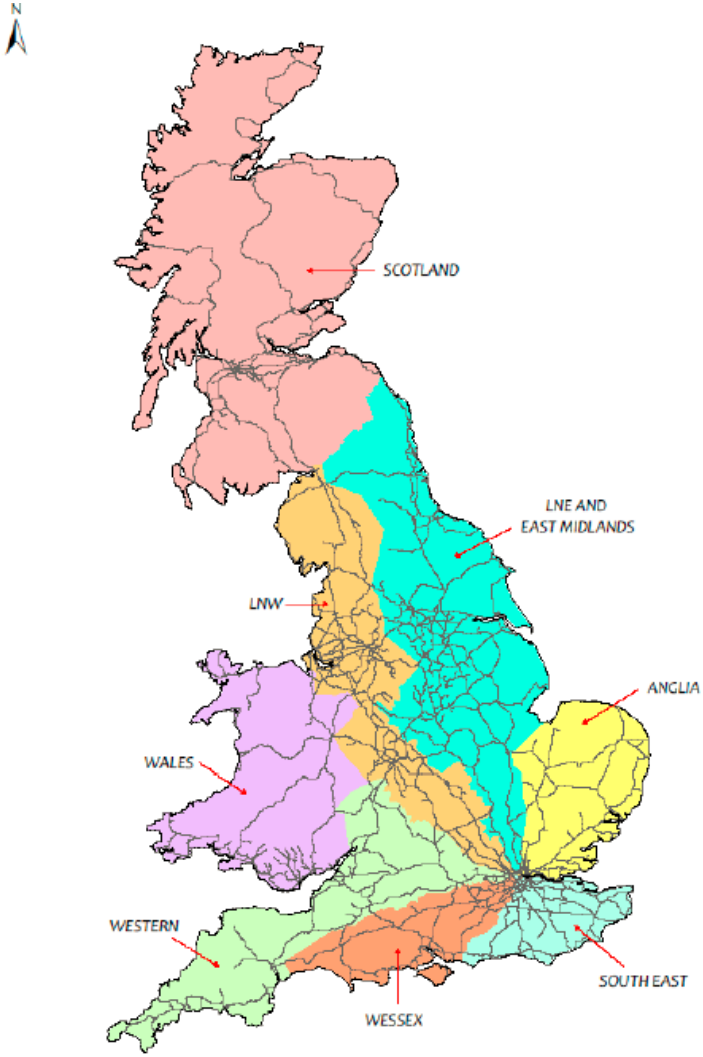
   HOW could an event occur?

3. **Assess risk at population level**

   HOW SIGNIFICANT? Likelihood of event & potential consequences

4. **Determine & implement controls**

   WHAT can we do?



1. Know what's important to you (and why)

A growing railway

1.6 billion passengers per year (2014/15)

- 40% more passengers than 2004
- 60% more freight than 2004

Fastest growing & safest railway in Europe

- 20,000 miles of track (& drainage)
- 29,000 bridges and tunnels
- 2,500 stations
- 2nd largest electricity network
- One of the largest engineering employers

What's important to the railway?

Key business-level risks:

- Public Safety
- Workforce Safety
- Performance (punctuality & reliability)
- Reputation
- Value for Money

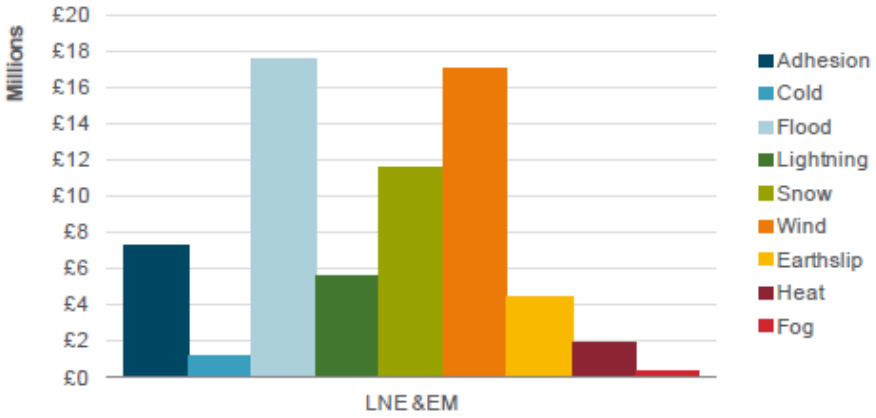


Figure 1 LNE&EM Route weather attributed Schedule 8 costs 2006/07-2013/14

Source: *LNE&EM Weather Resilience and Climate Change Adaptation Plan*

Simplified Organisational Structure

Network Rail Board

Director (IP)

Infrastructure Projects

Delivery of enhancements & complex renewals

Group Director of STE

Chief Engineer

Chief Civil Engineer

Head of Structures

Head of Geotechnics

Head of Drainage

Head of Tunnels & Mining

Head of Buildings

Practice Office
- *Principal Engineers*
- *Senior Engineers*
- *Engineers*

MD of Network Operations

Route Managing Director(s)

Director(s) of Route Asset Management

Route Asset Manager(s) (Geotechnics)
- *Senior Asset Engineers*
- *Asset Engineers*
- *Assistant Asset Engineers*

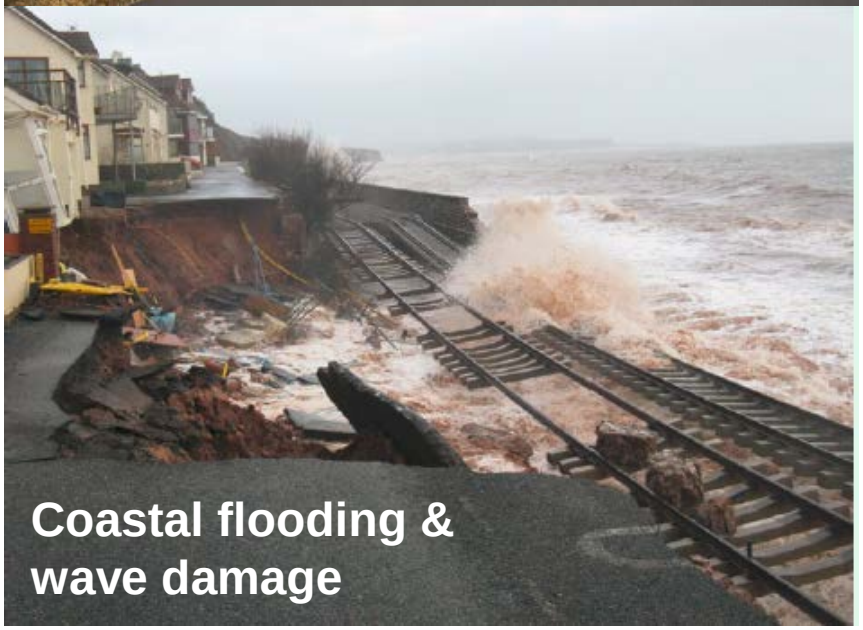
Safety, Technical & Engineering

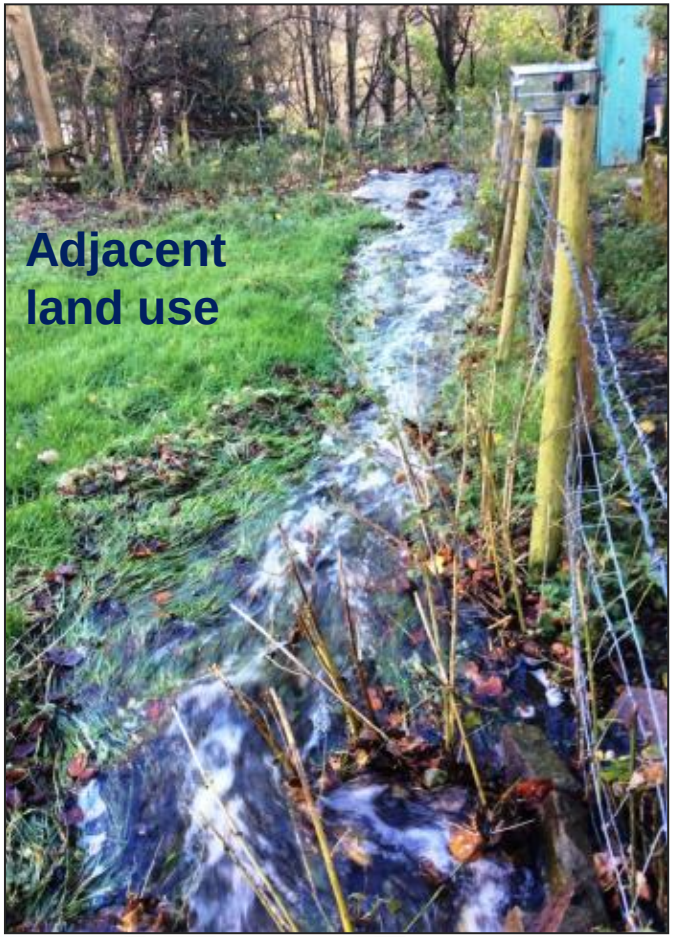
Technical authority and assurance body. Set the overall direction and corporate strategies for safety, environment, asset management and engineering. Owner of asset policies, risk control frameworks and the innovation / R&D pipelines.

Network Operations

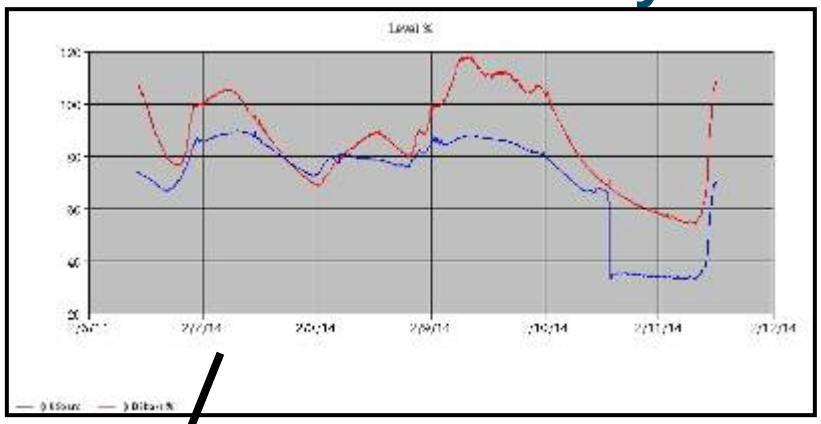
Owner of route assets with day to day accountability for the safe management of the infrastructure. Plan and deliver inspections, maintenance and renewals of assets in line with corporate policies to achieve agreed objectives.

2. Understand possible failure modes: flooding





2. Understand possible failure modes: flows under the railway



Water Impacts on Track

How were railway earthworks built?

Typical age: >150 years

A steep historical cutting shown side by side with the modern design standards used on HS1

Possible modes of failure: embankments

- Settlement of underlying natural ground
- Settlement of embankment fill over time
- Shrink / Swell of clay embankments
- Settlement due to burrowing animals
- Translational failure
- Rotational failure
- Earthflow
- Washout
- Scour

Possible modes of failure: soil & rock cuttings

Translational failure

Rotational failure

Washout

Earthflow

Rock fall

Burrowing

Which failure types are water-related?

Embankment Failure

Settlement of underlying natural ground

Settlement of embankment fill over time

Shrink / Swell of clay embankments

Settlement due to burrowing animals

Translational failure

Rotational failure

Earthflow

Washout

Scour

Cutting Failure

Translational failure

Rotational failure

Washout

Earthflow

Rock fall

Burrowing

Water Sources

Surface water

Groundwater

Pipes & drains

Key

Failure triggered by water

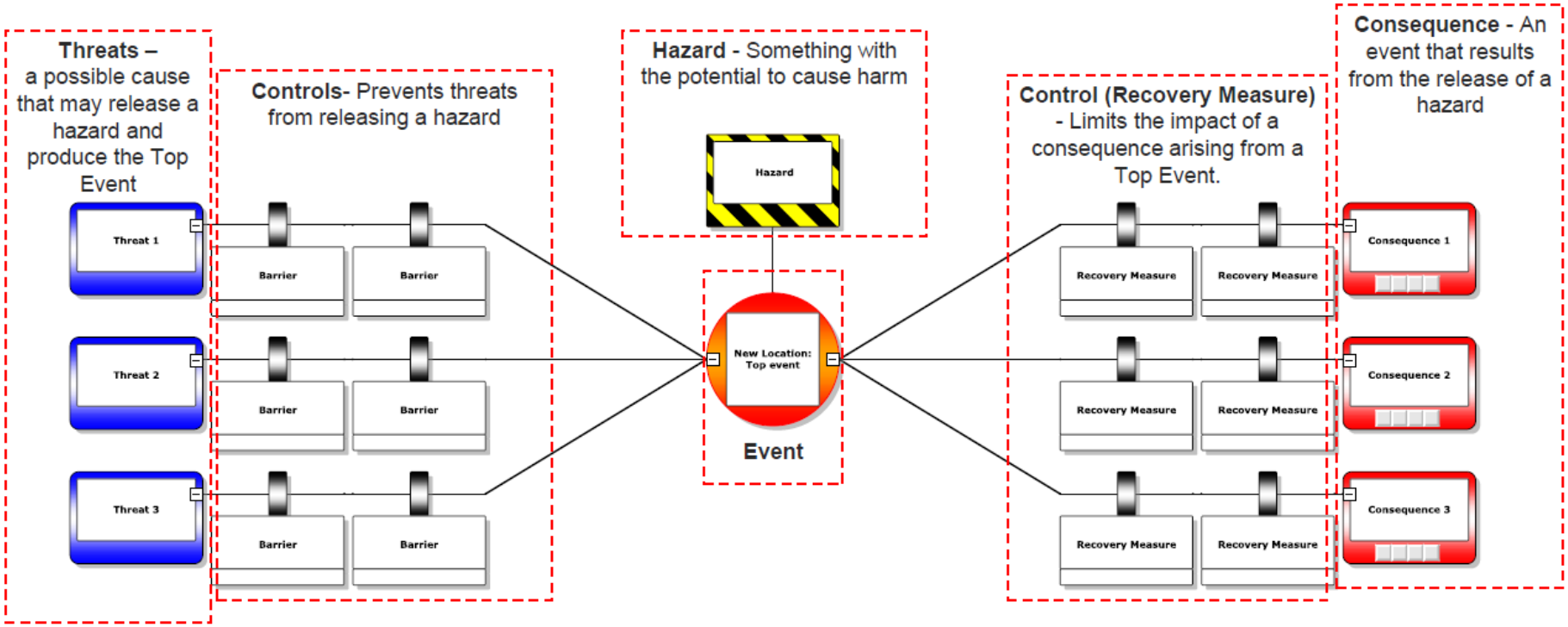
Failure exacerbated by water

3. Assess risk at population level

Threat: Assess probability of earthworks failure
Control: Earthworks/ drainage interventions

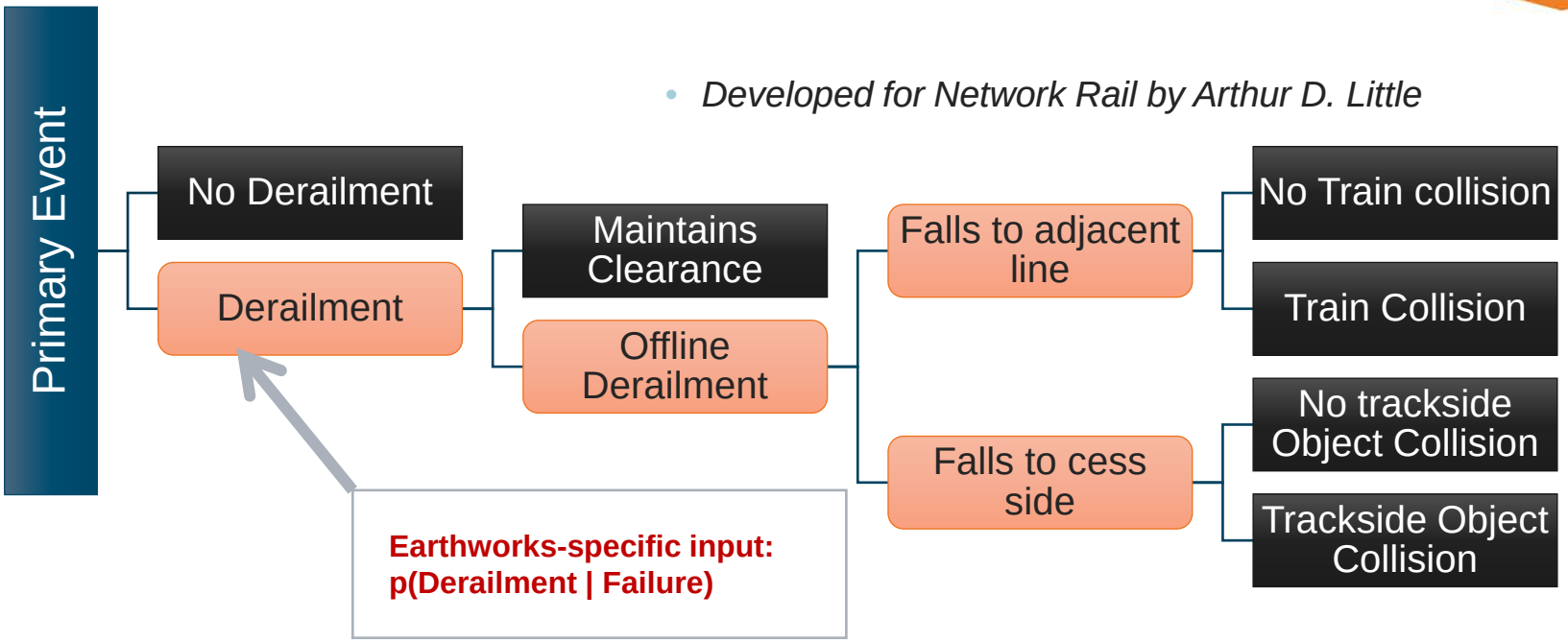
Event: Probability of derailment given failure

Consequence: Assess severity & probability of consequence
Control (Recovery): Limit the consequence



Improving our understanding of consequence

- *Developed for Network Rail by Arthur D. Little*



Features associated with consequence:

- Strong influencing factors:
  - P(derailment | failure) / asset type
  - Line speed
- Moderately influencing factors
  - High passenger/freight ratios
  - Route classification (Primary vs Freight)
  - Presence of tunnel or viaduct
- Less significant factors
  - Qty tracks, trains/hr, OLE, bridges, lineside obj (buildings), stations, w/body, signals

Probability branch

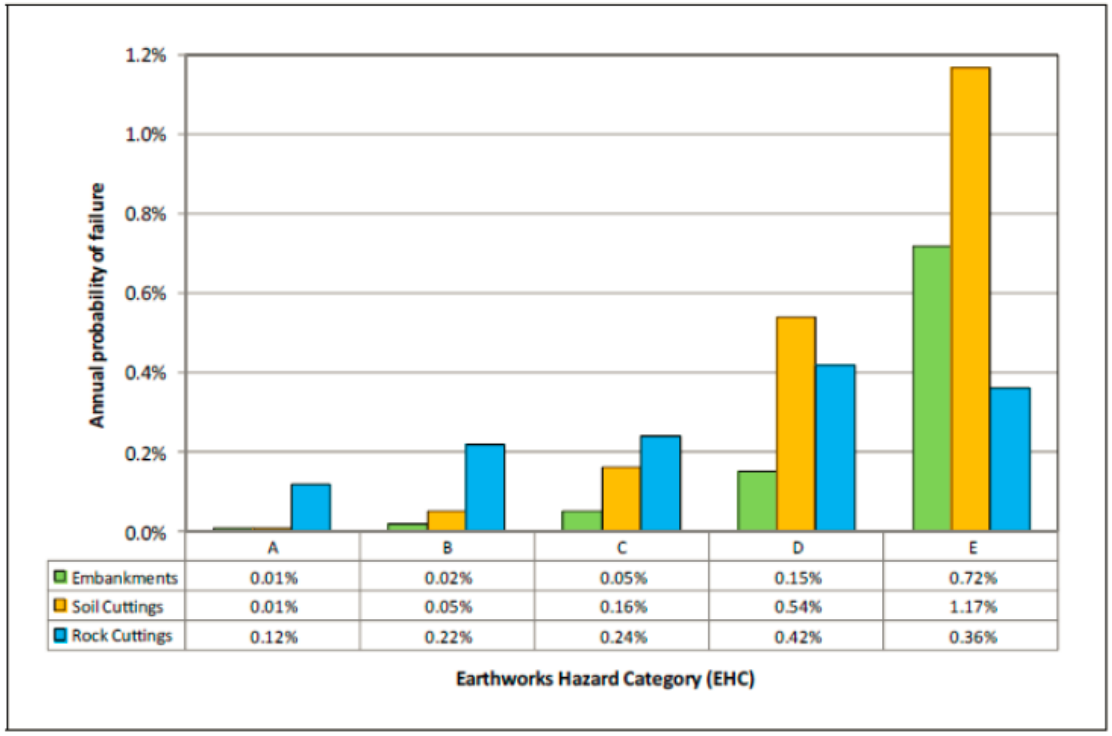
End of branch FWI risk

FURTHER INFO SEE: Power, C., Mian, J., Spink, T., Abbott, S., Edwards, M. (2016). Development of an Evidence-based Geotechnical Asset management Policy for Network Rail, Great Britain. *The 3rd International Conference on Transportation Geotechnics. Procedia Engineering. Volume 143, p.726-733.*

How do we assess earthworks condition?

Earthworks examinations (NR/L3/CIV/065)

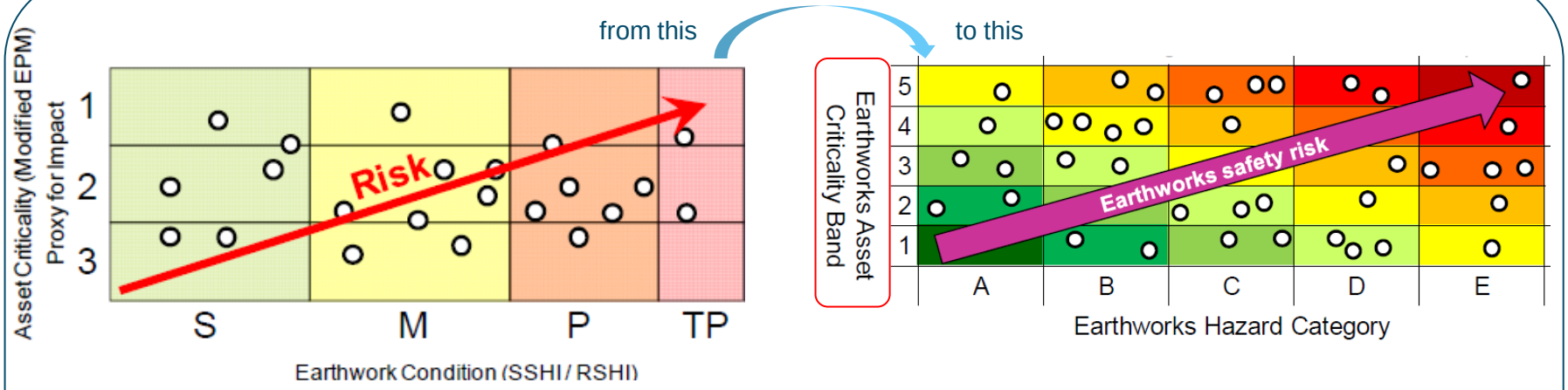
- Visual inspection
- Consistent template
- Movement indicators



	A	B	C	D	E
Embankments	0.01%	0.02%	0.05%	0.15%	0.72%
Soil Cuttings	0.01%	0.05%	0.16%	0.54%	1.17%
Rock Cuttings	0.12%	0.22%	0.24%	0.42%	0.36%

Annual failure probability by earthwork condition

Recent Improvements & Emerging Work



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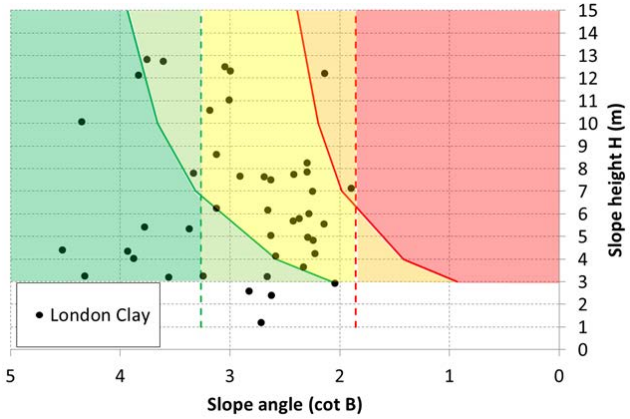
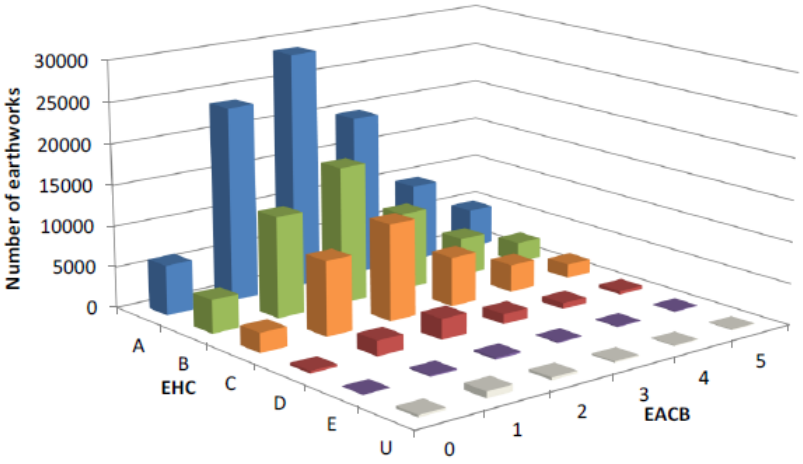
Emerging work: the development of morphology curves



- **Better geometry data from LiDAR**
- **New DST for preliminary analysis of slope stability at portfolio level**
- **Based on geotechnical groupings and variable plasticity & under drainage**

Number of earthworks by EHC and EACB
(All earthworks. May 2015 data)



Using Consequence & Condition in Earthworks Asset Policy

Maintain: earthwork managed at steady state by carrying out regular or targeted clearing of drainage, management of vermin and minor repairs. No improvement in resilience, capability or likelihood of asset failure.

Refurbish: the likelihood of the earthwork failing is reduced by carrying out localised repairs, installation of additional drainage works or local support

Renew: the likelihood of the earthwork failing is significantly reduced by carrying out major works that result in permanent changes to the asset. Significant improvement to the resilience and capability of the asset.

What can we do?

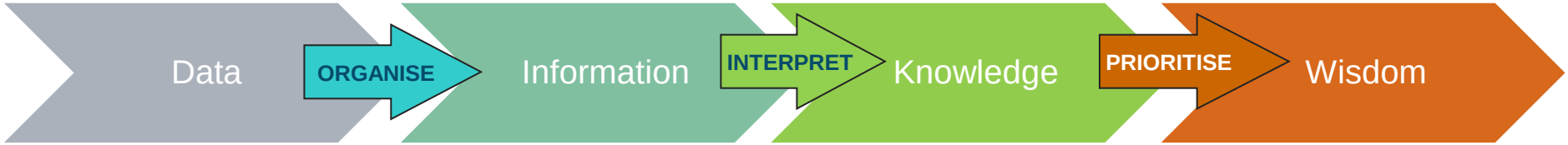
Precursor controls

- Better understand the root cause and potential triggers (GI/desk study)
- Surveillance: Examination regime, inclinometers, track geometry
- Improve the earthwork condition
- Maintain or improve drainage system capacity

Consequence controls

- Weather forecasting & rainfall trigger levels
- Adverse weather procedure
- Remote monitoring (identify when failure/blockage has occurred)
- Reactive repair

From Data to Optimised Decisions



- **INPUTS**
- Earthworks examination
- Track geometry trace
- Photo of fenceline

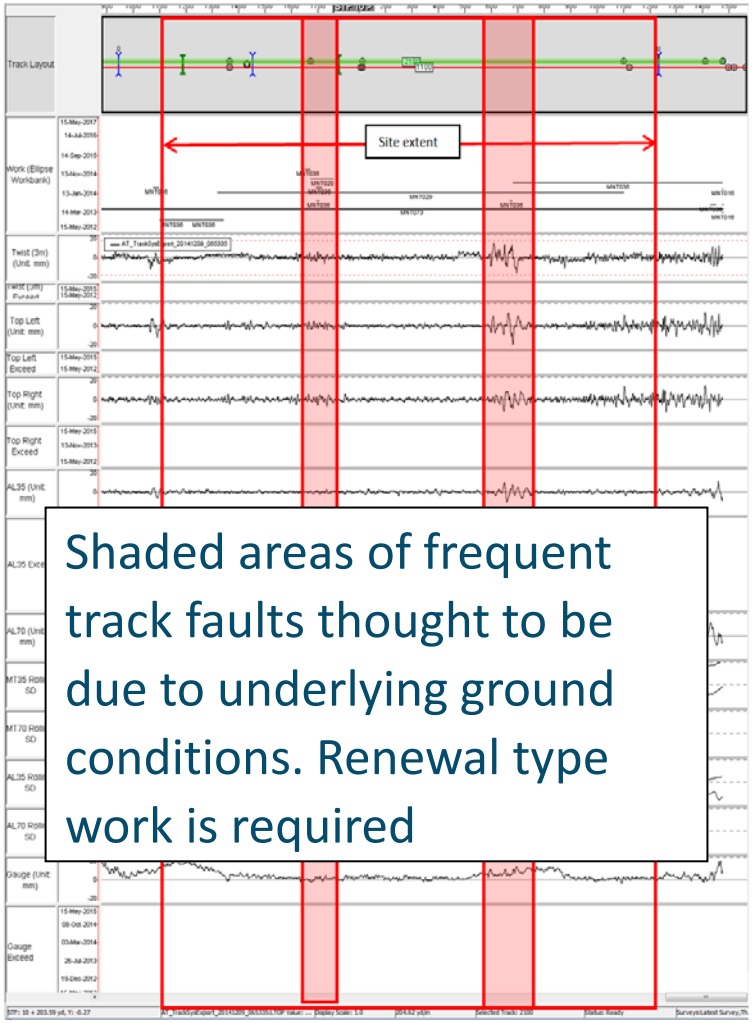
- **TRENDS**
- Trends in movement indicator
- Track geometry "signature"
- Fenceline seems to move over time

- **CAUSE** (why is this happening?)
- **TRIGGERS** (what could make it fail suddenly?)
- **CONSEQUENCE** (what happens if it fails?)

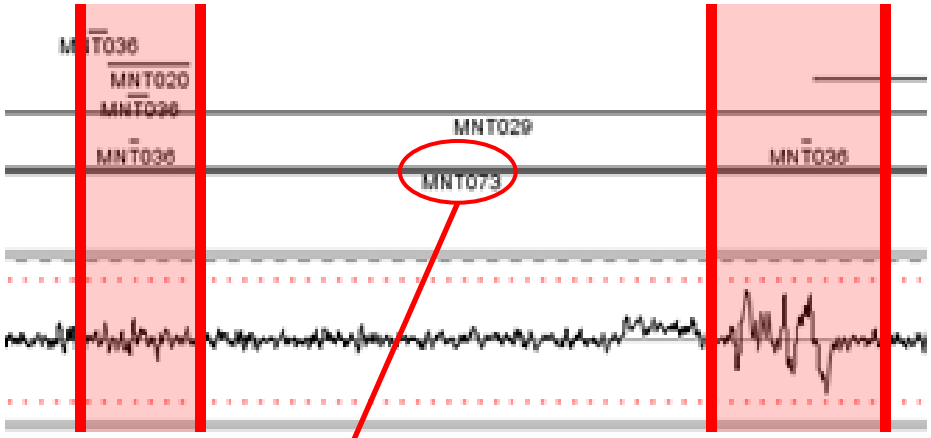
- **PRIORITISE/RISK RANKING**
- "No significant risk at Site 1. Maintain only."
- "Site 2 is likely to fail if the crest drain blocks. Therefore it will be inspected every 6 months and monitored for blockages"

How do we make use of track data?

How do we use LADS?



Shaded areas of frequent track faults thought to be due to underlying ground conditions. Renewal type work is required



MNT Code & Desc
MNT036 - Manual Correction PLTrack Geometry (CWR)
MNT020 - Manual Reprofiling of Ballast
MNT007 - S&C Tamping
MNT004 - Plain Line Tamping
MNT005 - Stoneblowing Plain Line
MNT017 - Mechanical Reprofiling of Ballast
MNT073 - Drainage
MNT006 - Manual Wet Bed Removal
MNT026 - Replenishment of Ballast Train
MNT037 - Manual Correction PLTrackGeometryJointed
MNT019 - Manual Correction of Plain Line Track Geometry
MNT025 - Replenishment of Ballast Manual
MNT012 - Mechanical Wet Bed Removal

How do we monitor earthworks?

Geotechnical monitoring instruments

Slip indicators

Inclinometers

Piezometers

Topographic surveying (Pegs)

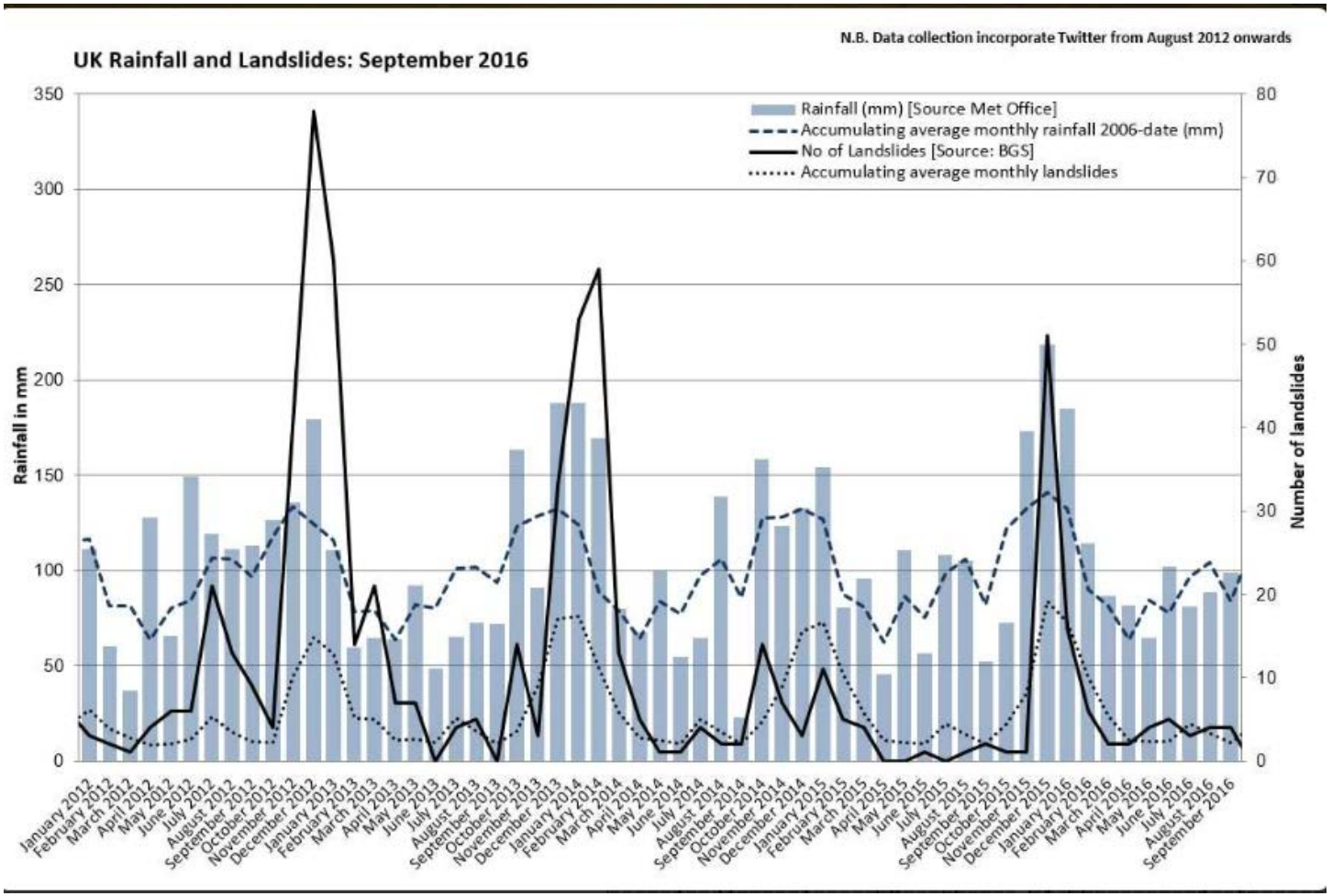
Operational monitoring instruments

- Cant sensors
- Landslip detectors with CCTV (RCM pilot study)
- Acoustic systems

Understanding the Bigger Picture – Trend Analysis & Changes in Risk over Time

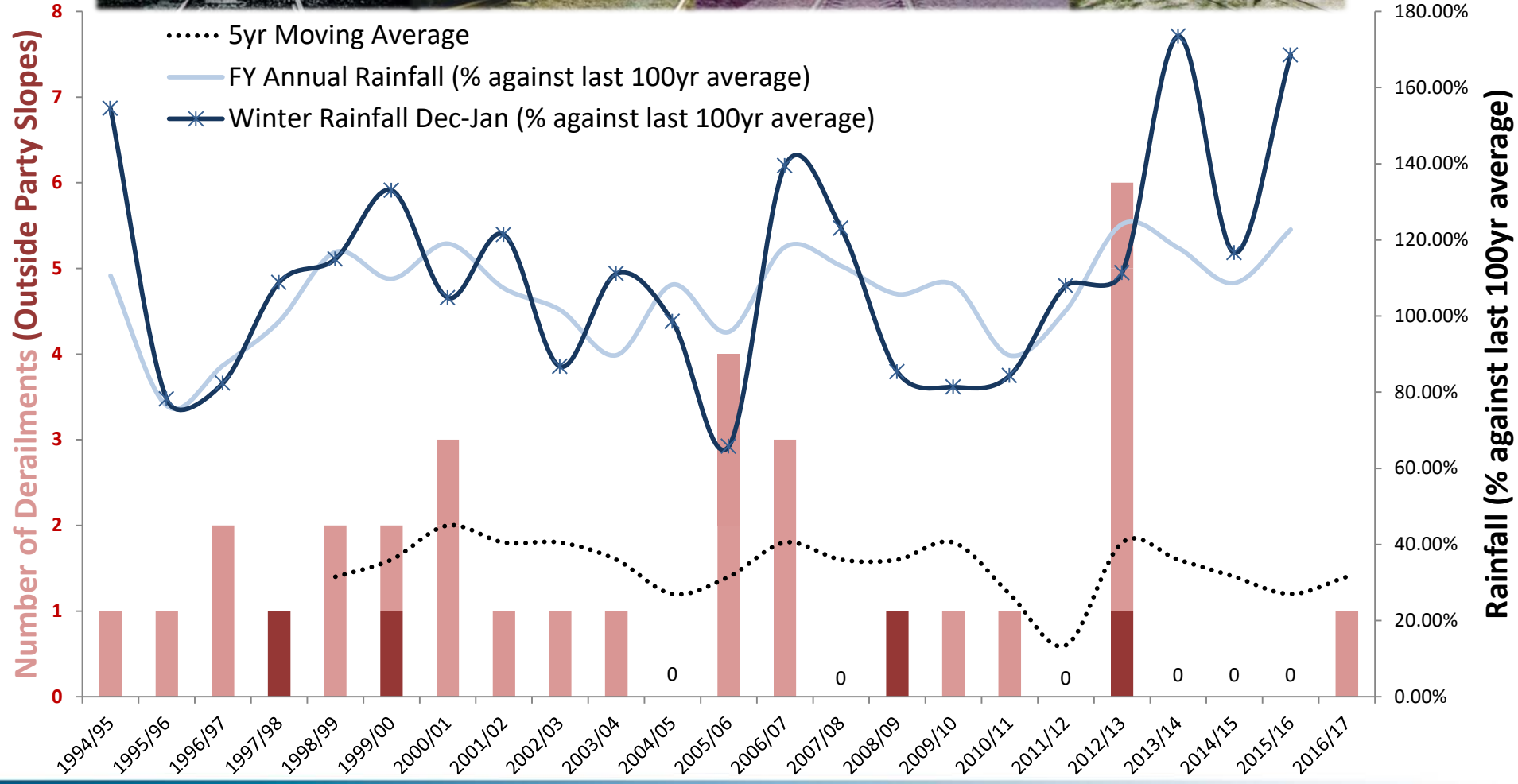
Understanding Rainfall Trends

Correlation between rainfall and UK landslips

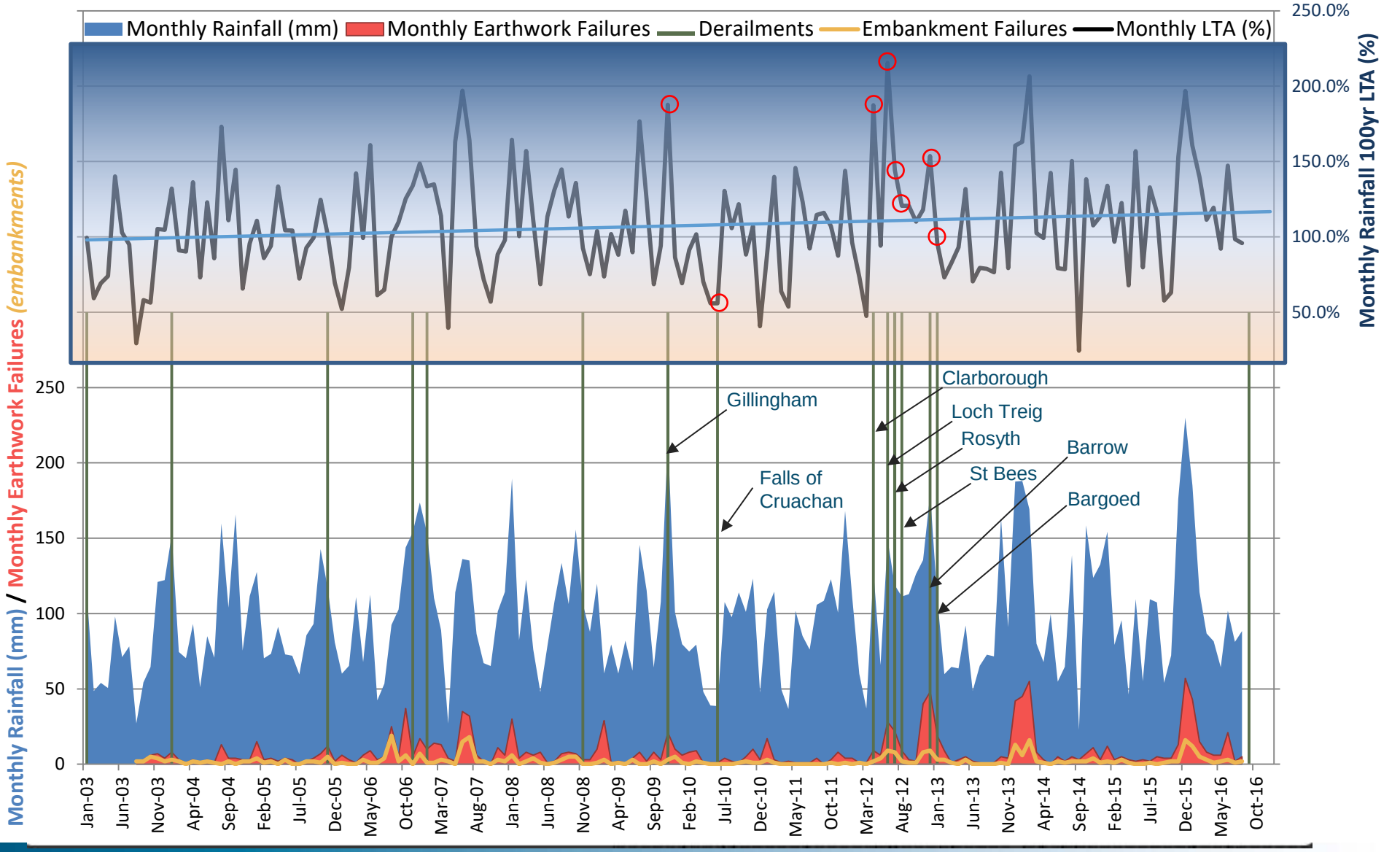


Source: BGS (Landslide data); Met Office (rainfall data)
http://bgs.ac.uk/research/engineeringGeology/shallowGeohazardsAndRisks/landslides/landslidesAndRainfall.html

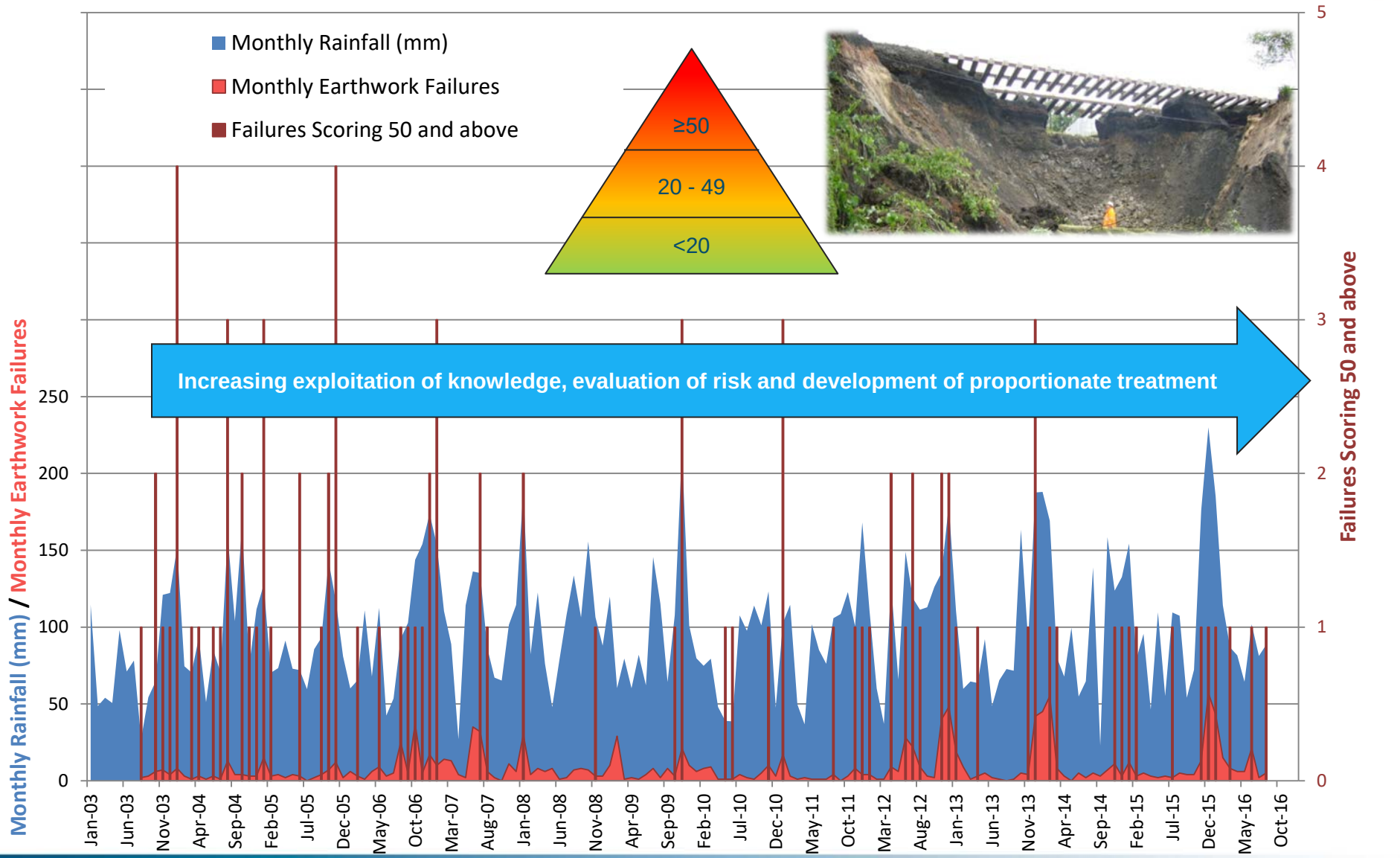
Past / Present / Future?



Summary of derailment events



Summary of significant events



Summary of significant events

Earthwork Failures Scoring 50 and Above

12 Month Moving Average

Cum. Monthly Moving Average

Cumulative MMA at lowest level ever for events with potentially high consequence

12 MMA and CUM. MMA

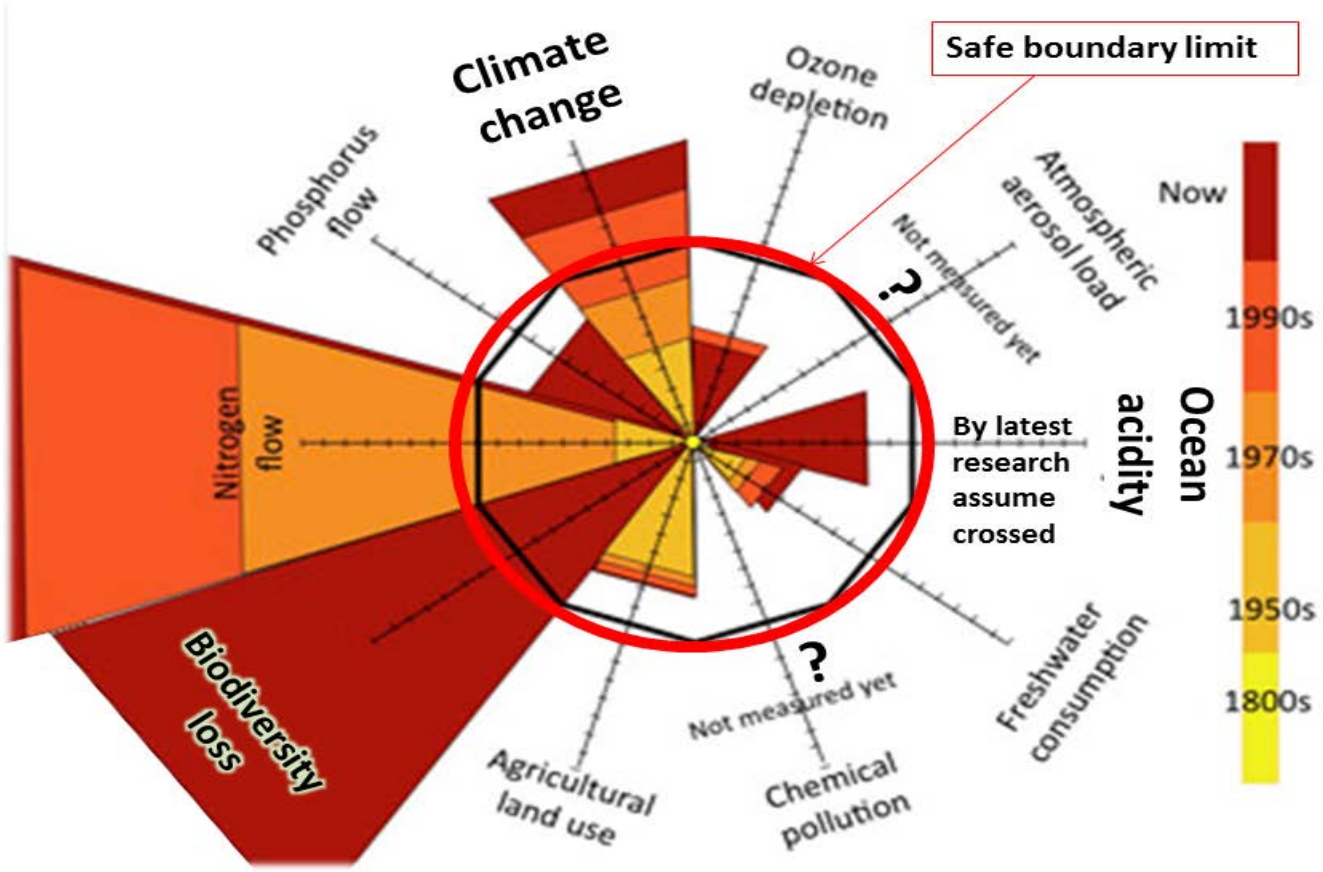
Failures Scoring 50 and Above

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

5
4
3
2
1
0

Jan-03 Jun-03 Nov-03 Apr-04 Sep-04 Feb-05 Jul-05 Dec-05 May-06 Oct-06 Mar-07 Aug-07 Jan-08 Jun-08 Nov-08 Apr-09 Sep-09 Feb-10 Jul-10 Dec-10 May-11 Oct-11 Mar-12 Aug-12 Jan-13 Jun-13 Nov-13 Apr-14 Sep-14 Feb-15 Jul-15 Dec-15 May-16 Oct-16

The Wider Context in 3 Charts



Planetary Boundaries

Geotechnical Skills & Risk Communication

UK-wide shortage of geotechnical expertise

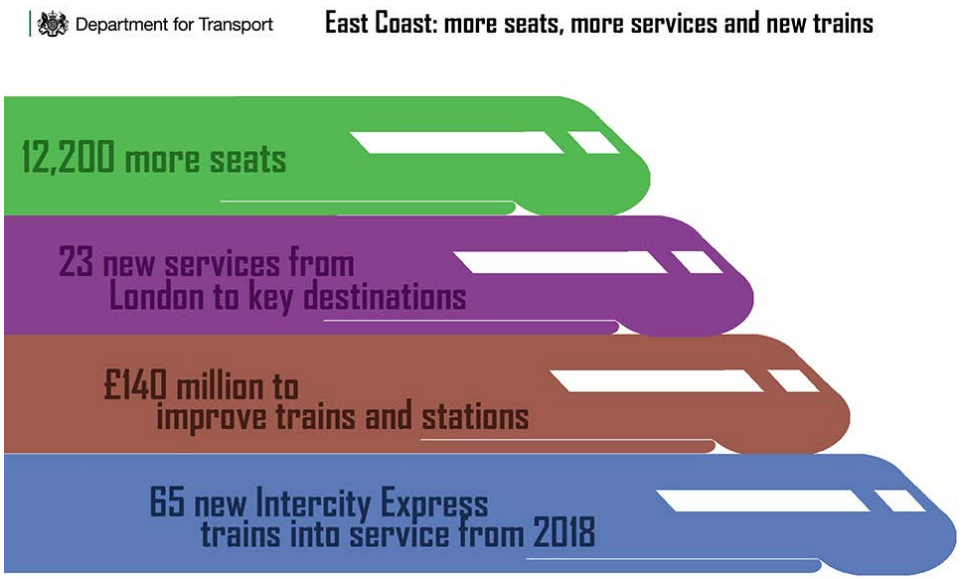
Geotechnical skills training & recognition:

- ROGEP (CEng/Cgeol)
- EngTech
- Short courses for contractors/supply chain

Risk communication

- Always test your message!
- Understand the research (www.climateoutreach.org.uk/)
- Framing the issue wisely

Concluding Remarks



WITH:

- Historic earthwork assets
- More trains
- Higher speeds
- More passengers & freight

AND

- Worsening weather (more intense rainfall, more dry periods)

The UK railway needs ground engineering specialists more than ever!

Questions?