The Geological Society
serving science & profession

WEST MIDLANDS

Jurassic Railway:
Engineering Geology of HS2 in the South Midlands

SIMON BUTLER

14 NOVEMBER 2023

Simon Butler

Engineering Geologist

Degree (BEng) and Masters (MSc) and Chartered Geologist (FGS CGeol),

30 years in Ground Engineering practice

Chief Engineering Geologist at AtkinsRealis

Since 2017 seconded into HS2 as Senior Project Engineer and Geotechnical Discipline Lead for the Main Works Civils Contract on the Central Part (C3) of HS2 Phase 1.

HS2

edp Moving Forward Together
Jacobs·Atkins·Sener

AtkinsRéalis

Respect | Leadership | Integrity | Safety

Values Moment - Safety

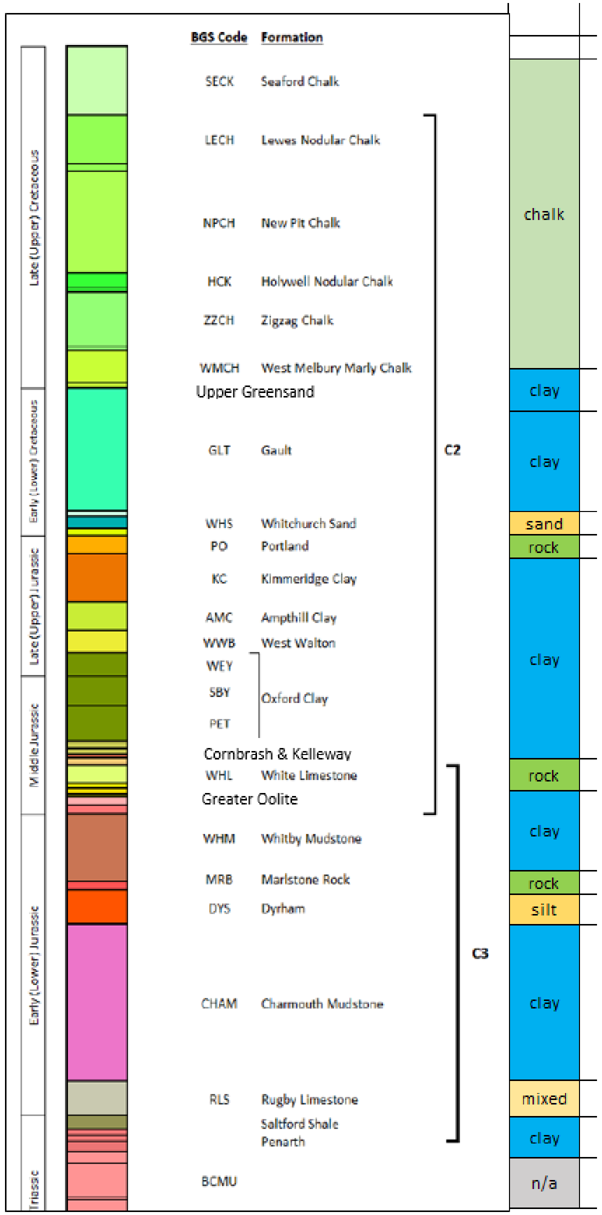
Exercise YELLOW DUMPER

multi agency exercise testing Emergency Preparedness and Response

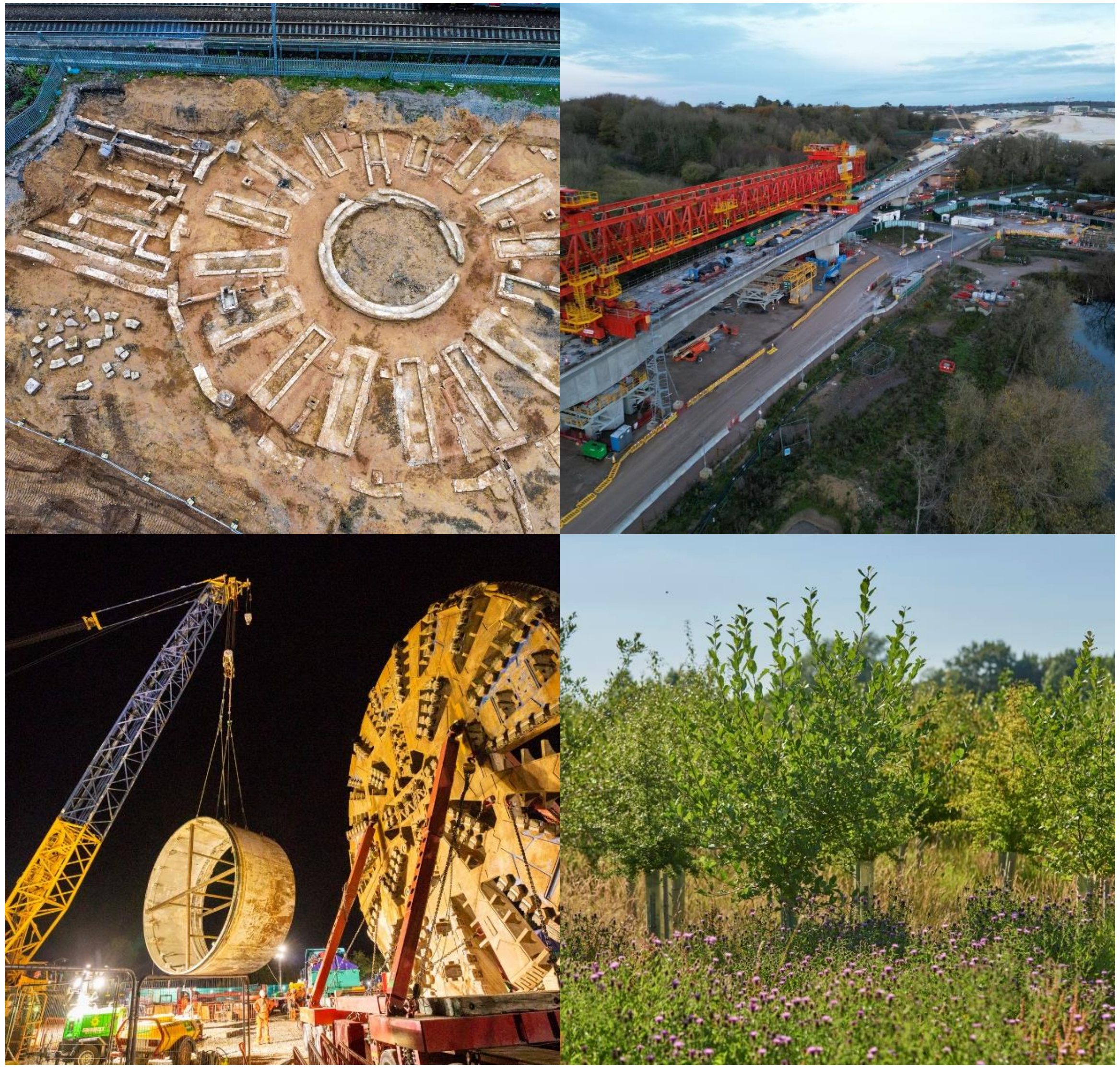
NOTE: This is an EXERCISE not a real accident

Content

1. High Speed Two (HS2) Phase 1; the project
2. The Geology and Geo-Hazards of HS2 Phase 1
3. Focus on the Jurassic Strata
4. Role of Engineering Geologists (and other Geo-professionals)
5. Industrial Learning Legacy
6. Academic Learning Legacy
7. Conclusions & Questions



Britain's mega-project



Progress update

Colne Valley Viaduct, Hertfordshire

Long Itchington Tunnel, Warwickshire

Old Oak Common station, West London

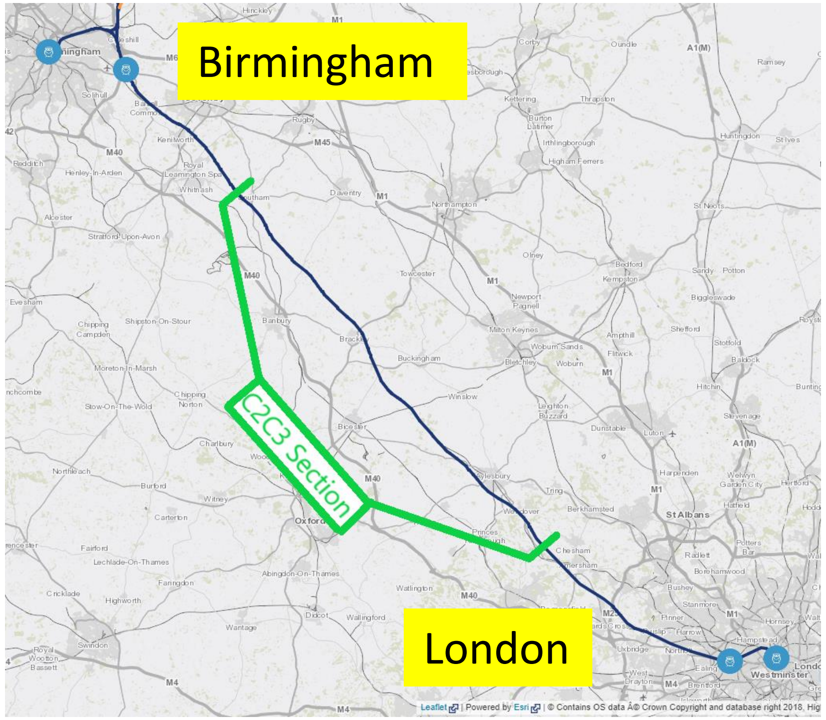
Curzon Street station, Birmingham

Progress update

Excavation at Chipping Warden North Portal

There are now over 350 active sites along the Phase One route between the West Midlands and London

High Speed Two (HS2) Phase 1

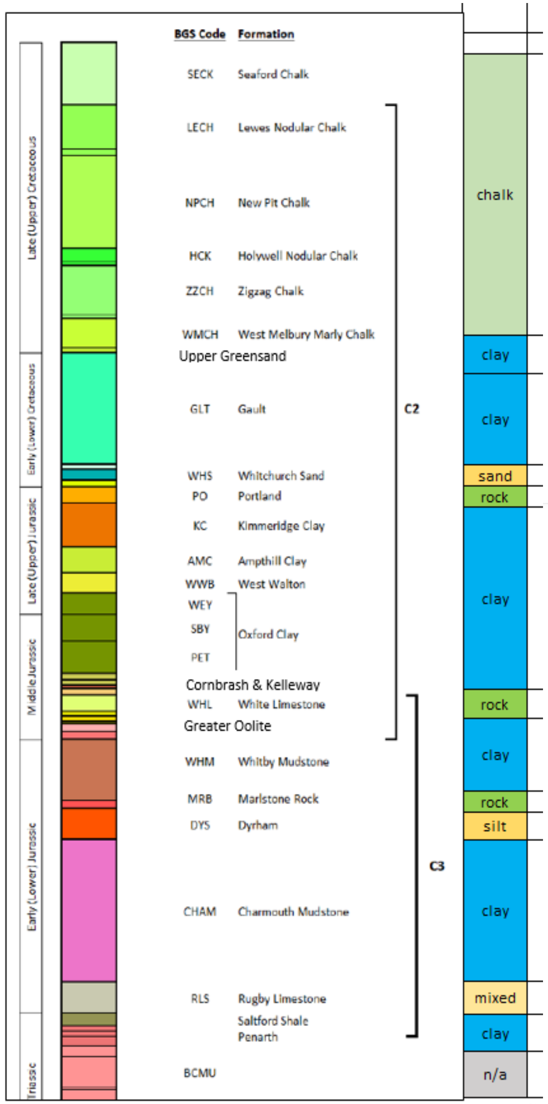


Sector C2C3 in numbers

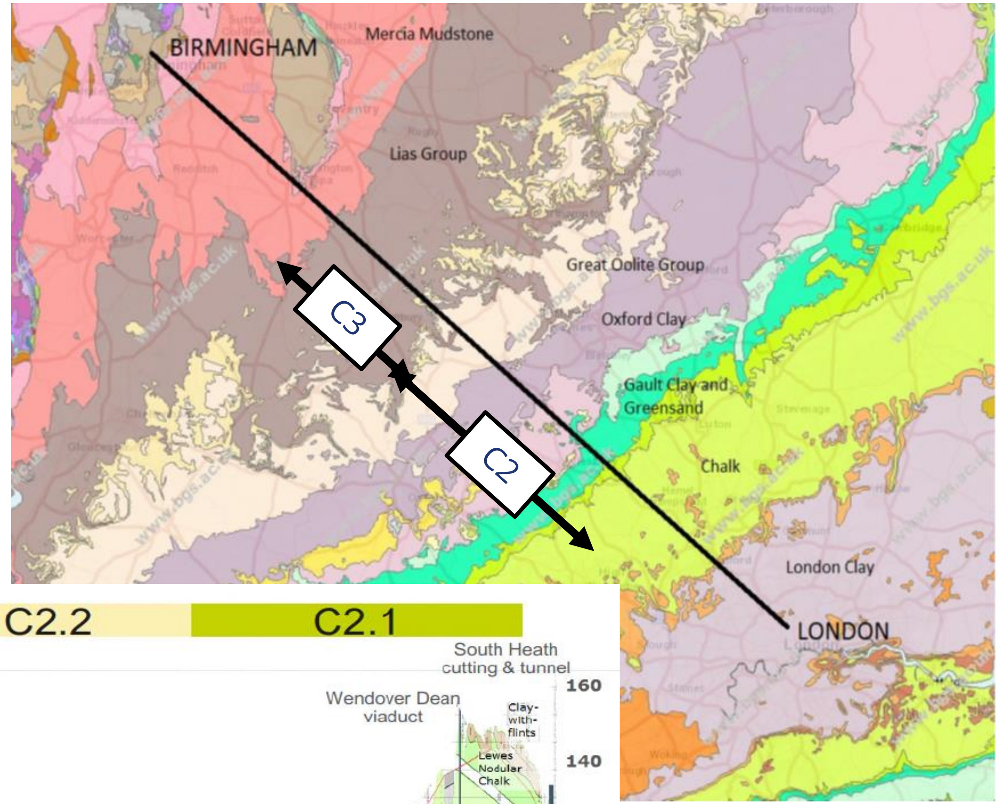
80 km Length	96 Primary Assets 2101 Secondary Assets	48 (27 km) Mainline Embankment	30 (42 Km) Mainline Cutting
15 Viaducts (4.5km)	3 Tunnels Cut and Cover (6.5 km)	26 Mm3 Earthworks	70 Overbridges 15 Underbridges

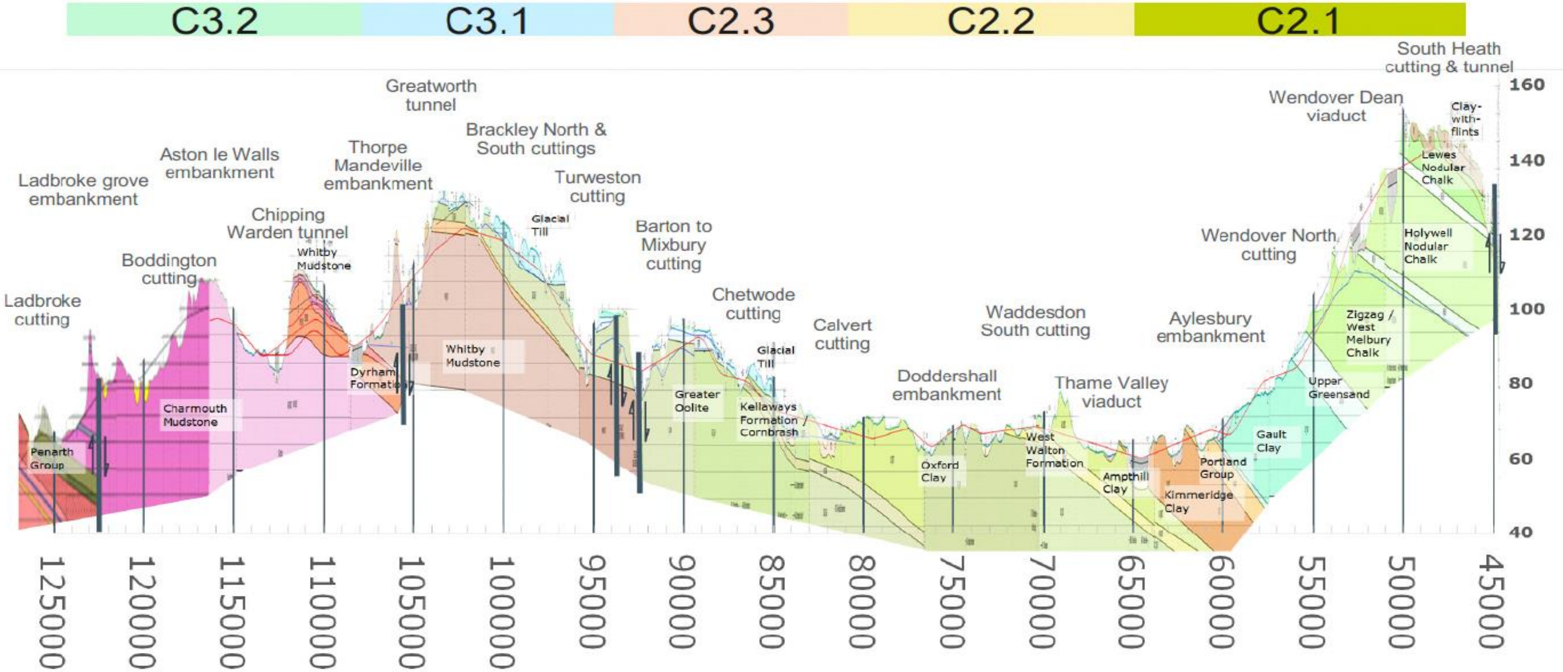
HS2 EKFB asc A High-Speed Design Partnership ARCADIS COWI

The Geology and Geo-Hazards

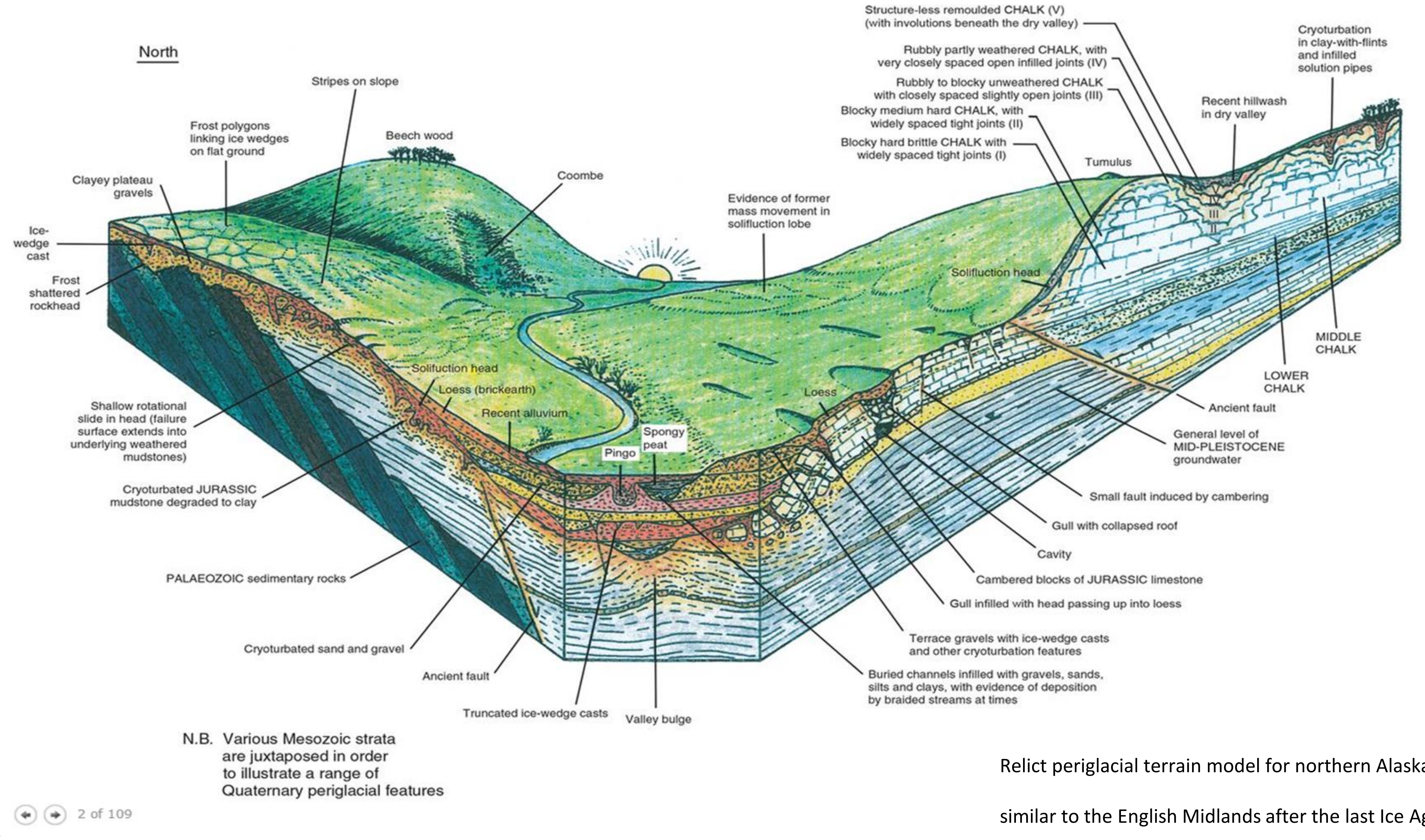


- 16 major bedrock formations getting older towards NW
- Overlain by Glacial Deposits
- Topography; Chalk Downs south of Aylesbury, flat wide Thame Valley, ‘Cotswolds Extension’ North of Brackley





The Geology and Geo-Hazards



Relict periglacial terrain model for northern Alaska (after Fookes et al. 2015)

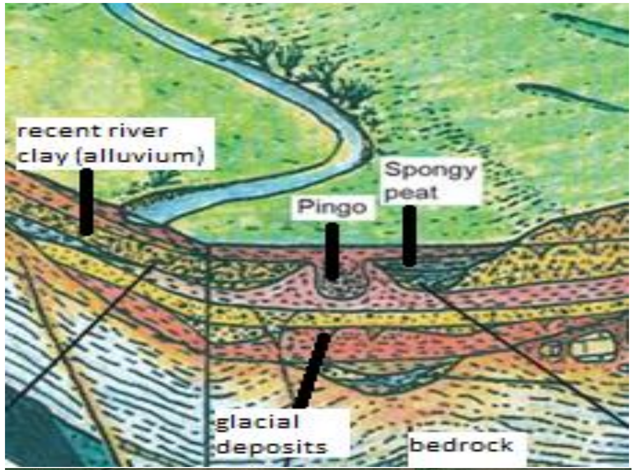
similar to the English Midlands after the last Ice Age

Geology Specific Hazards C2C3

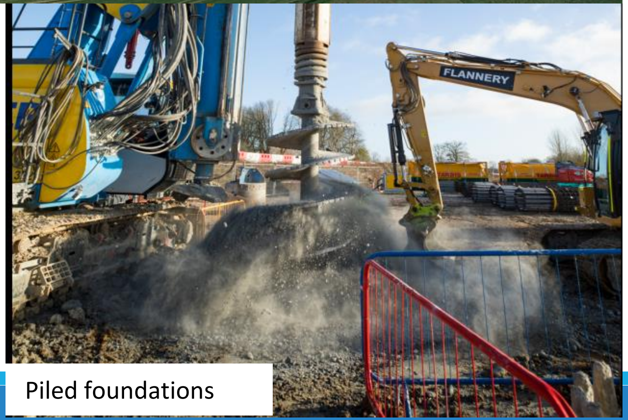
- Range of Geologies
- Variable layered strata
- Relict Periglacial effects:
  - deep weathering
  - relic shear surfaces
  - shallow slope movements
  - cambering and valley disturbances
  - rock head anomalies
  - cryo-turbation wedges
- Faulting effects
- Chalk Solution Features
- Materials Availability
- Progressive Slope Failure
- Aggressive Ground / Sulphates
- Cutting Heave
- Embankment Settlement
- Rayleigh Waves
- Groundwater inflow

HAZARD IMPACT x UNCERTAINTY = RISK

Settlement of Soft Ground

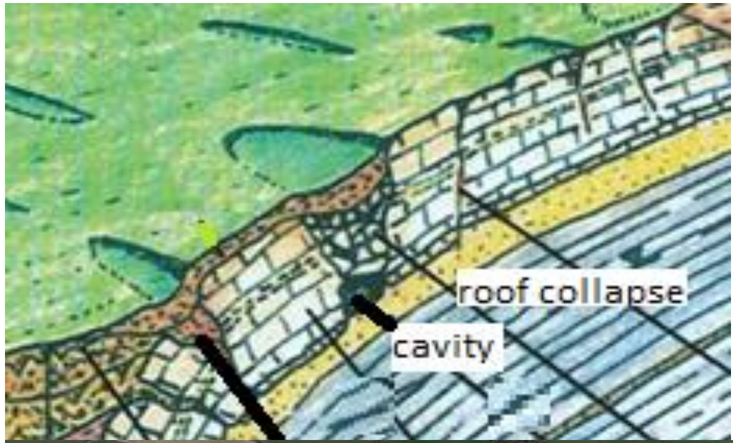



Padbury Brook valley

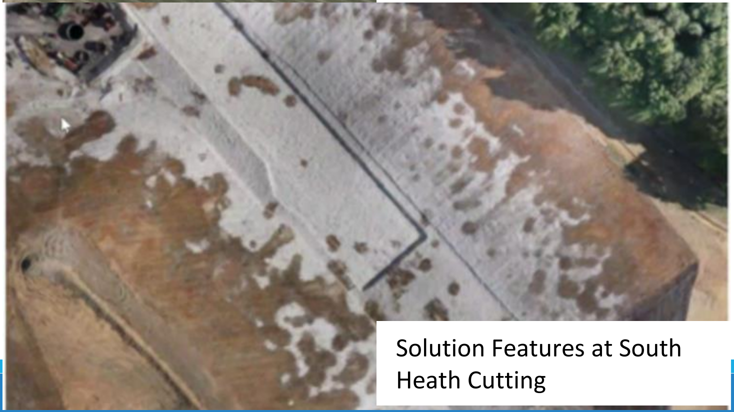


Piled foundations

Collapse of Solution Features

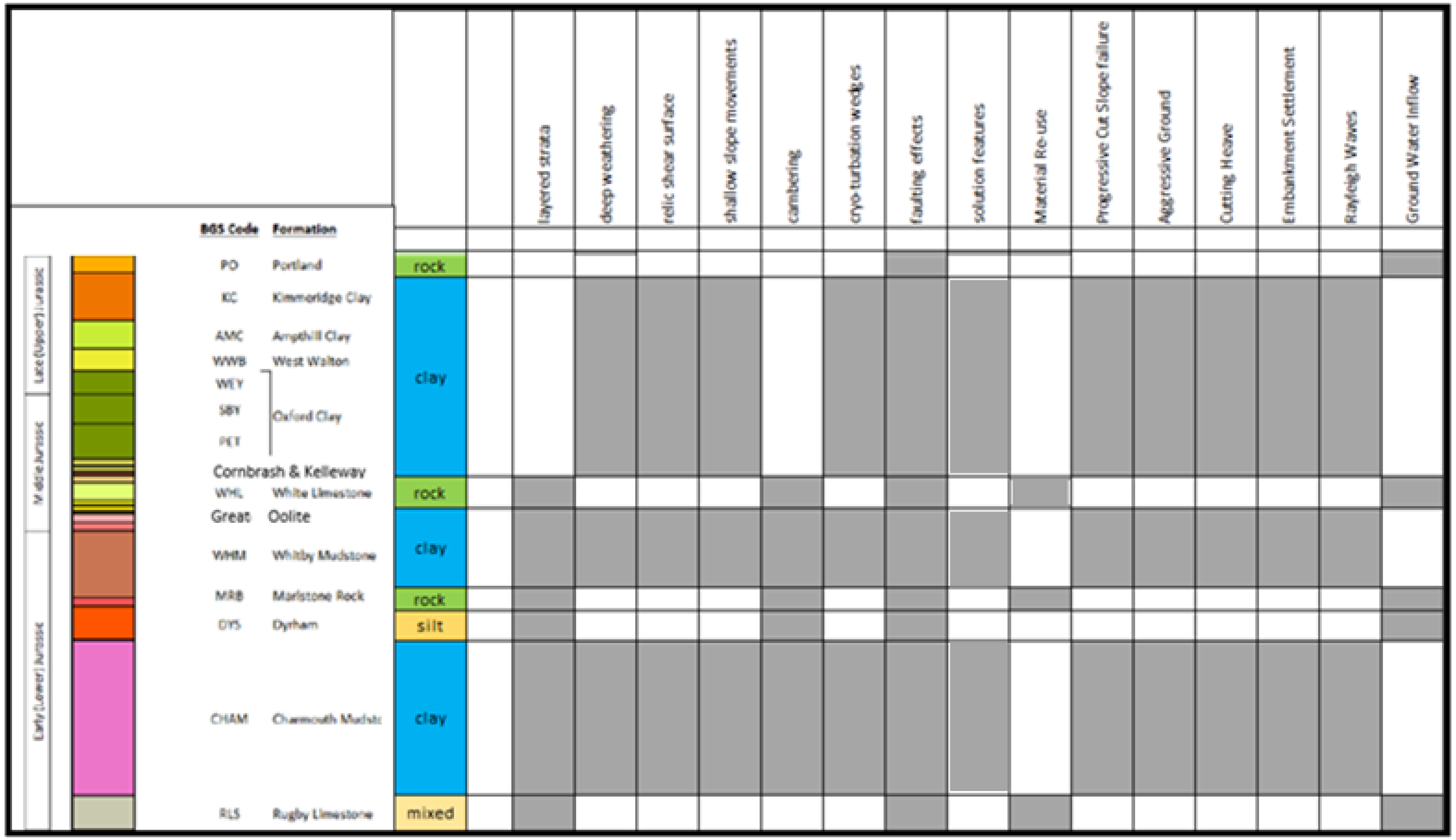



Possible Solution Features near South Heath

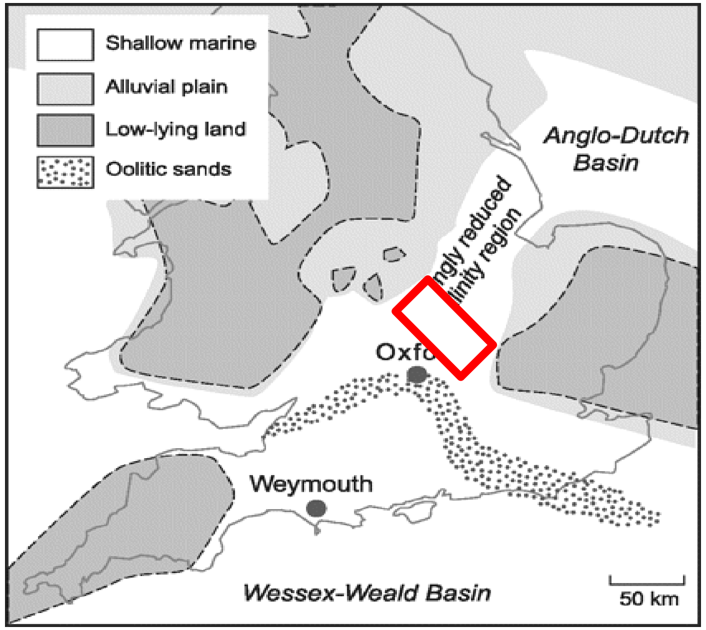

Solution Features at South Heath Cutting

Focus on the Jurassic Strata

Overview and Principal GeoHazards



A life restoration of *Ichthyosaurus anningae*. Artwork courtesy of James McKay: http://www.jamesmckay.info.



From Price and Teece,2010: Bathonian palaeogeography of the southern part of the UK (modified from Bradshaw & Cripps 1992; Hendry & Kalin 1997).

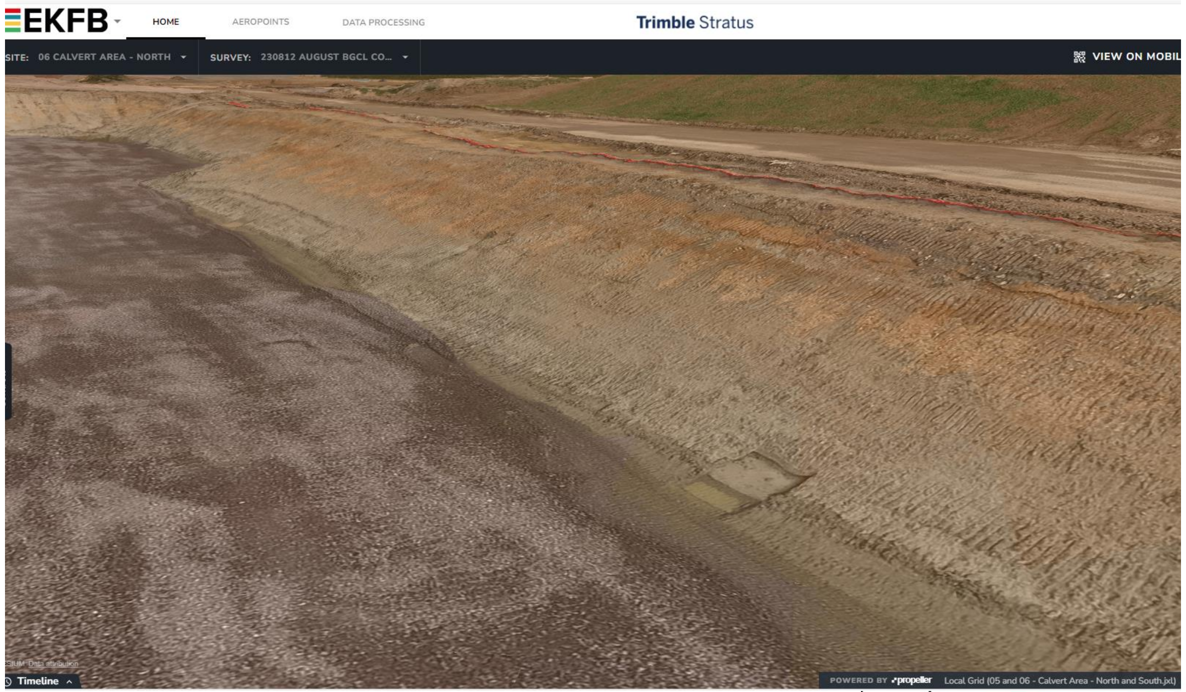
Focus on the Jurassic Strata

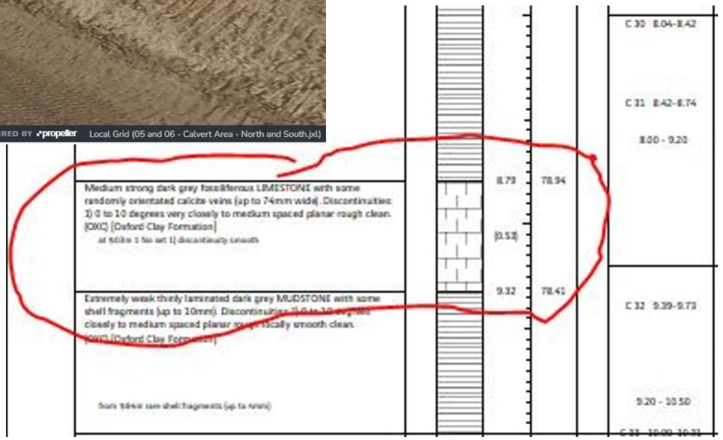
Late Jurassic – Ampthill Formation – Waddesdon

Geohazard:
Sulphate rich strata (Selenite)

Focus on the Jurassic Strata

Late Jurassic – Oxford Clay Group – Calvert





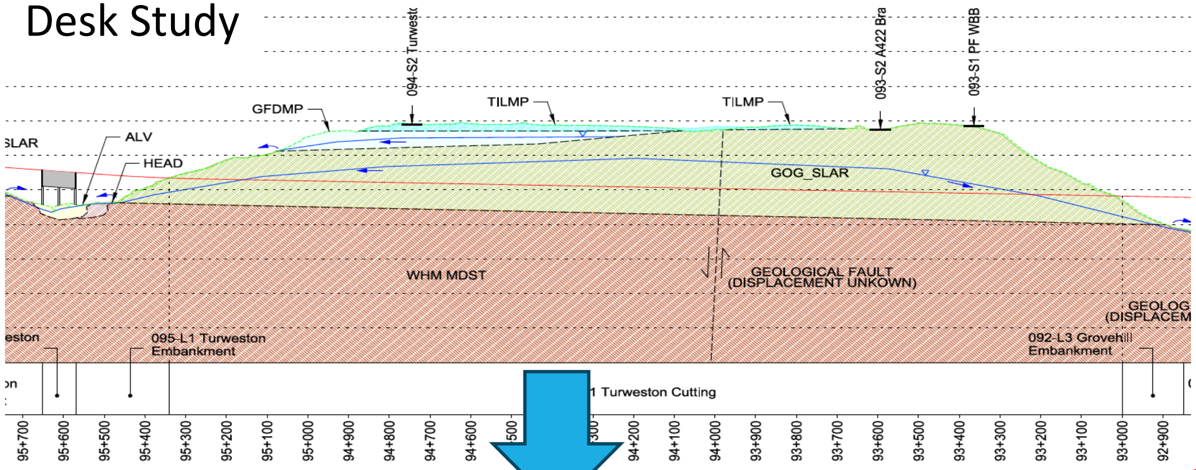
Geohazard:

Obstructions (Septarian nodules/concretions)

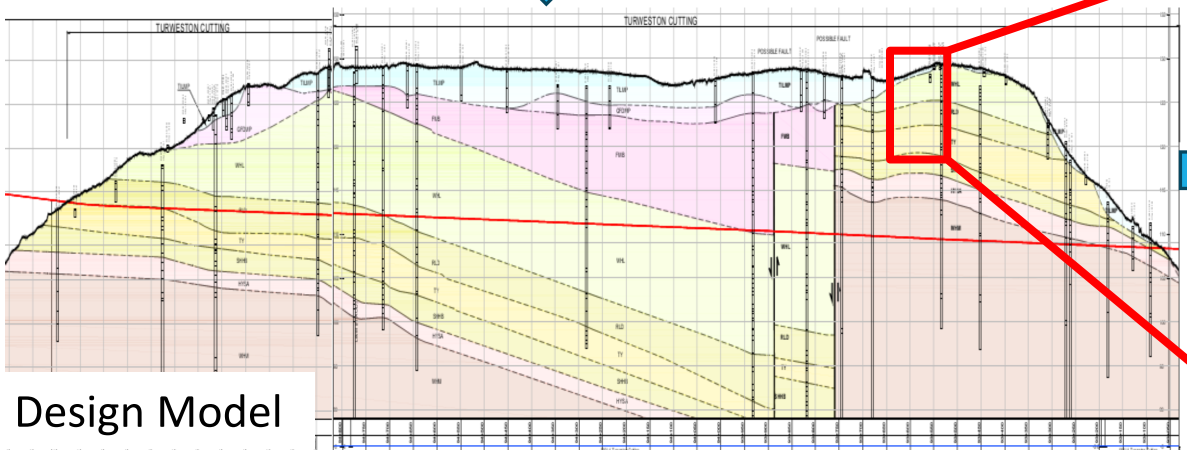
Focus on the Jurassic Strata

Middle Jurassic - Great Oolite Group - Turweston

Desk Study



Design Model



Geohazard:
Geomaterial availability

Resource

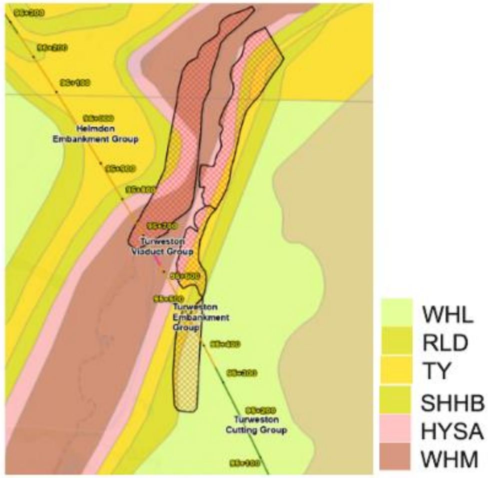
Construction

Credit: Benedict Madinier and Cedric Guyonnet at Setec

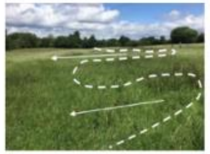
Focus on the Jurassic Strata

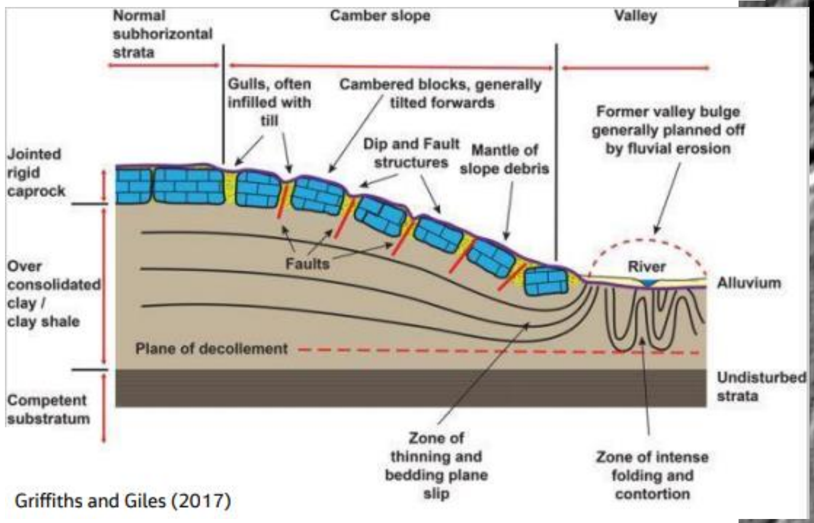
Middle Jurassic - Great Oolite Group – Brackley

- **Existing landslide** – associated as valley-side slopes - area during walkover survey

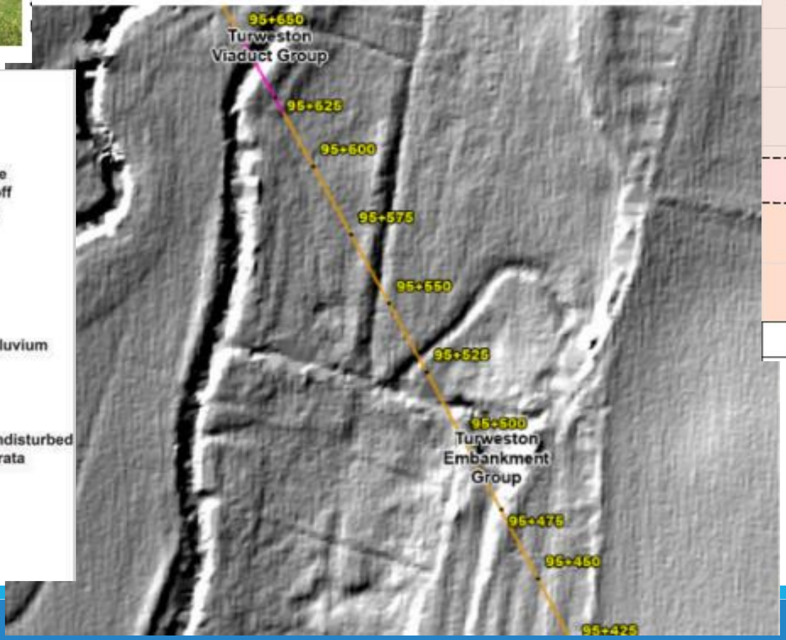


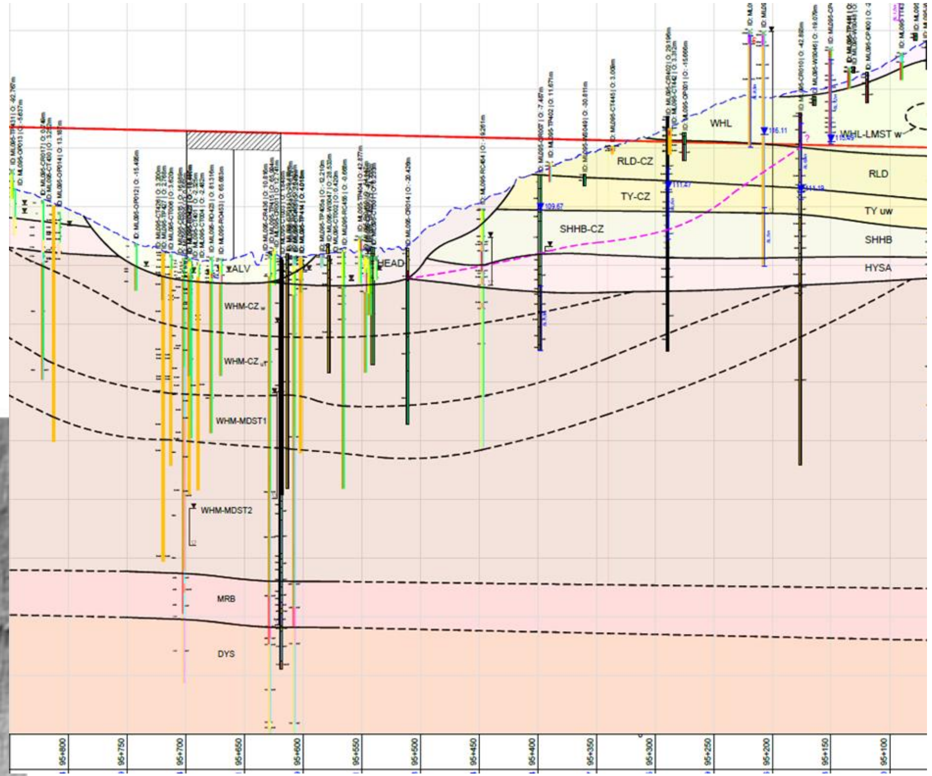
© Arcadis 2015





Griffiths and Giles (2017)



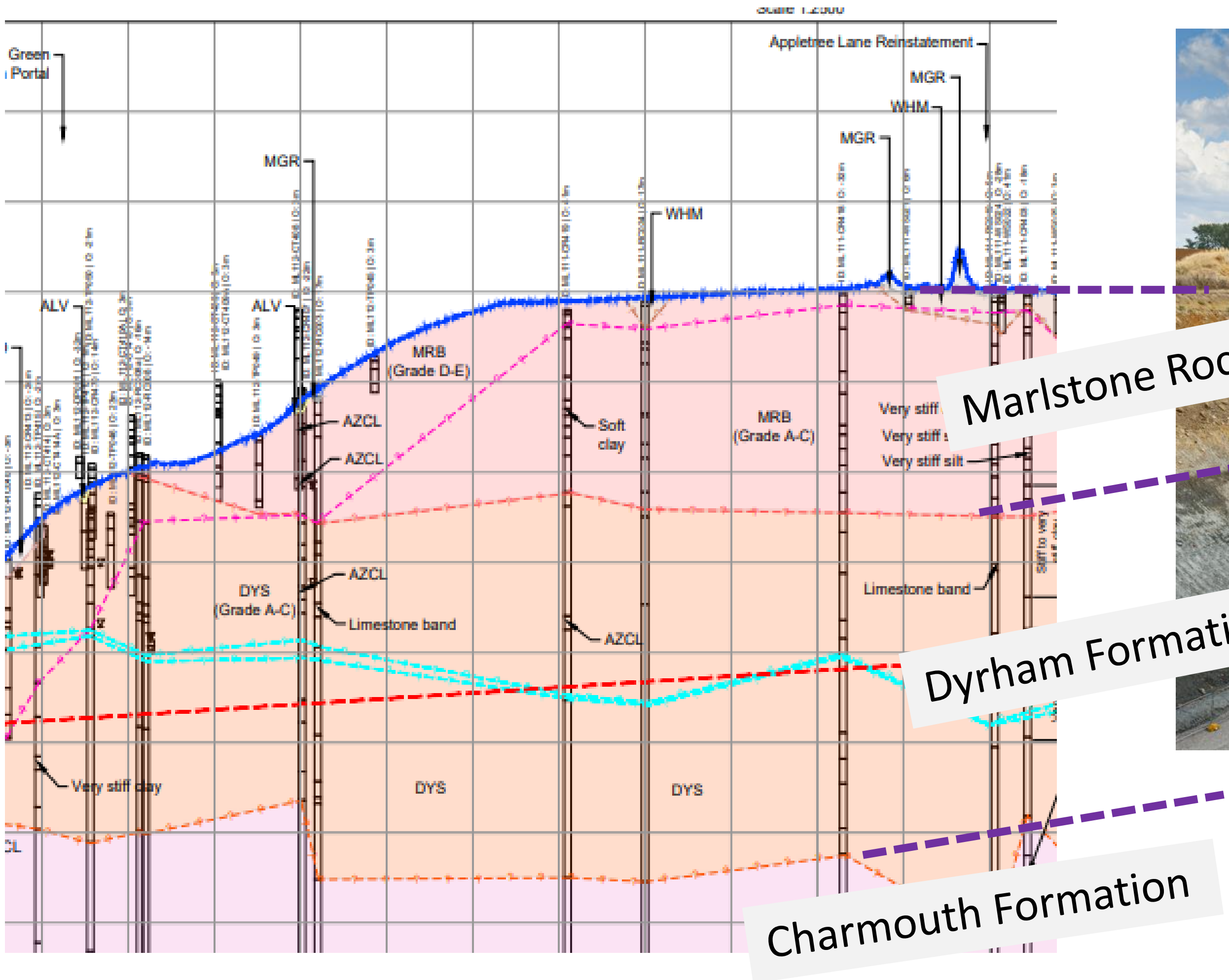


Geohazard: Landslip / Cambering

Credit: Paul Fish at Jacobs

Focus on the Jurassic Strata

Early Jurassic – Marlstone Rock and Dyrham Formations - Chipping Warden

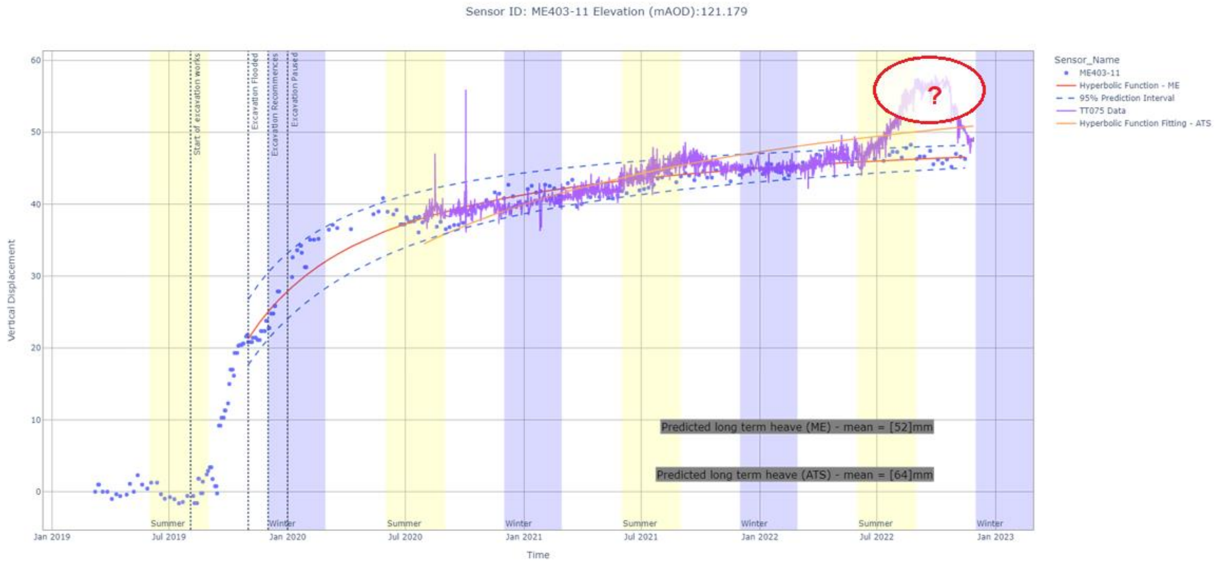


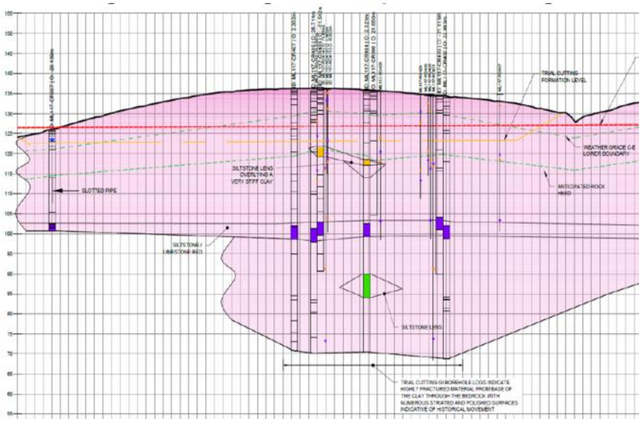
Geohazard:
Hard Strata

Credit: Martin Huggins and Michelle Miller at Cowi
And: Jim Webster and Matt Fleetwood at EKFB

Focus on the Jurassic Strata

Early Jurassic – Charmouth Mudstone Formation – Boddington Earthworks Trial Site



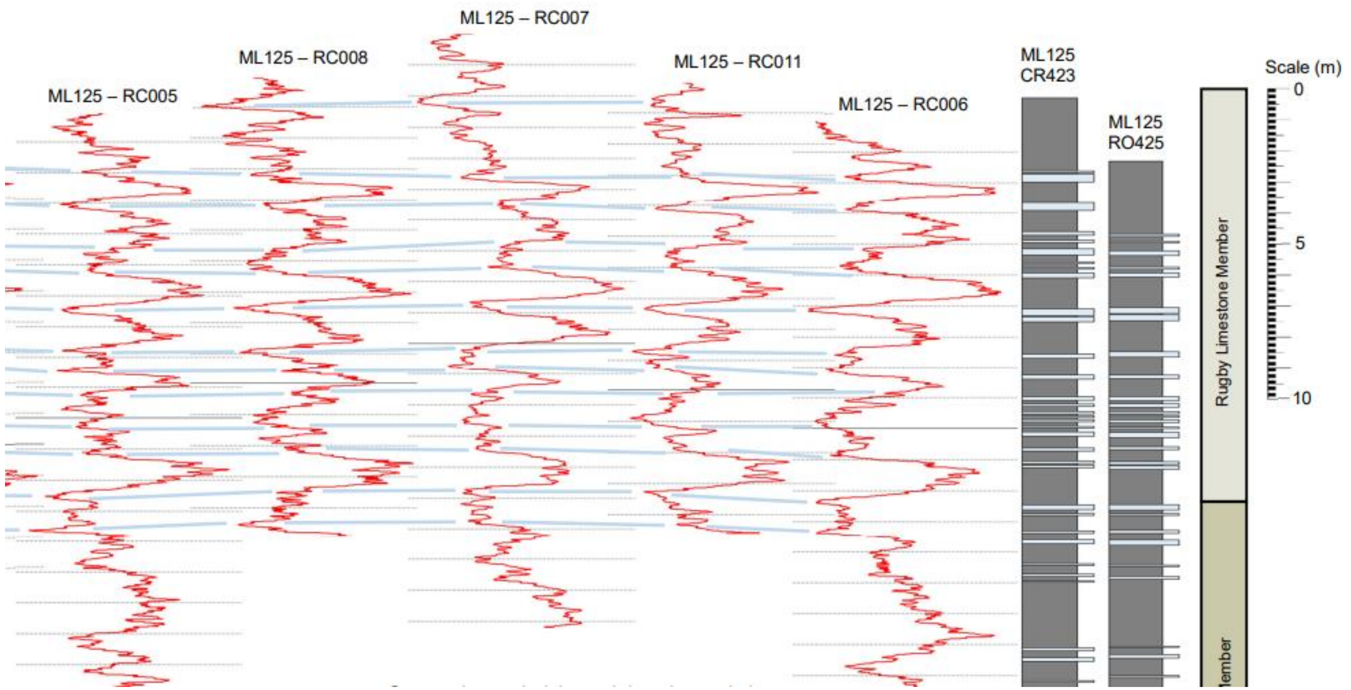


Geohazard:
Deep cutting heave

Credit: Andreas Zillas at Atkins and Andy Hope at Arcadis
Also: Paul Cooper, Dave Williams and Uma Shanker at HS2

Focus on the Jurassic Strata

Early Jurassic – Blue Lias Formation – Southam



Geohazard:
Layered Strata Hazards

Role of Engineering Geologists

Communicating Ground Uncertainty Through the Life of the Project

ii - Critical evaluation of geoscience information to generate predictive models. ….. competence in the acquisition, observation and description of geological data, appreciation of the limitations of and conditions under which the data were collected or how they arrived in their present state, and an assessment of certainty/uncertainty. The Geological Society (geolsoc.org.uk)

Known unknowns…Quote:

"….because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know..."

Donald Rumsfeld, US Secretary of Defence, 2002

Ground Uncertainty…Quote:

"It is essential to expect the unexpected, and to deal with soils (the ground conditions) as they are, not as we might wish them to be."

Prof. James Mitchell, 12th Terzaghi Lecture, ASCE Journal of Geotechnical Engineering, 1986

Site Investigation…Quote:

"...you pay for a site investigation whether you have one or not…."

Prof. Stuart Littlejohn Proceeding of the ICE, 1994

Role of Engineering Geologists

Communicating Ground Uncertainty Through the Life of the Project

Sources of Uncertainty:

Contract let with Uncertainty in Ground Conditions Risk (NEC3 ECC Cl 60.1.12)

Design starts before all the GI is available (design risk and compliance risk)

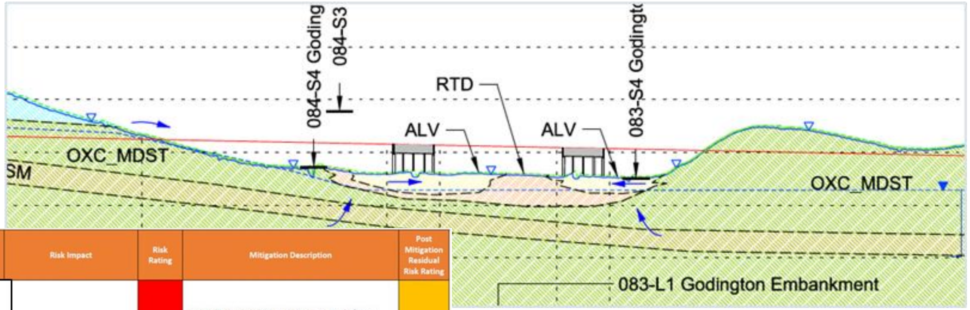
Design assumptions create risk

Some Ground Conditions cannot be fully assessed until construction, but some risks are mitigated at design stage

Uncertainty can be mitigated by an increased degree of caution (conservatism)

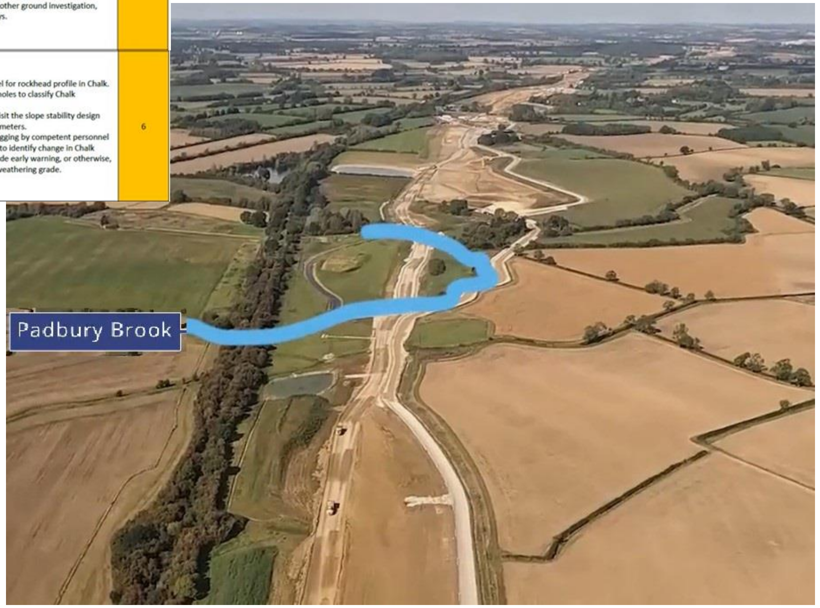
Efficient design can be enabled by reduced uncertainty

<u>HAZARD IMPACT x UNCERTAINTY = RISK</u>



Geotechnical Risk Register

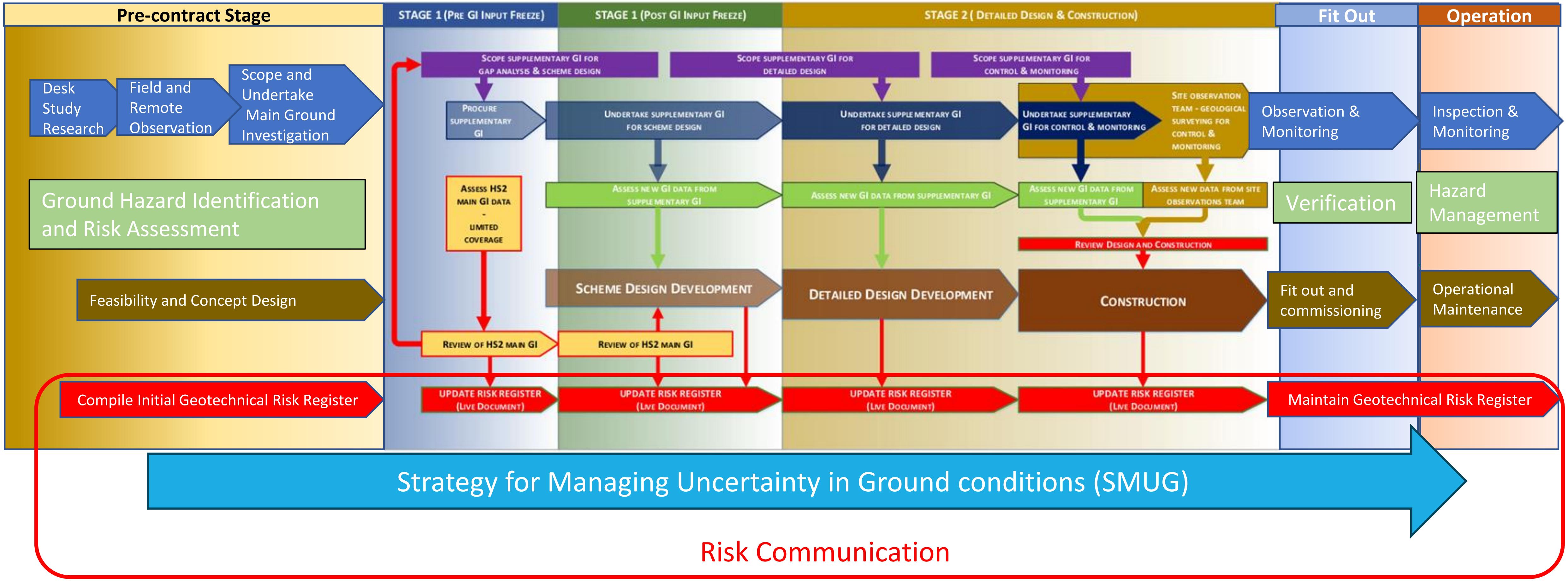
Geotechnical Risk ID	Level 2 Asset	Risk Title	Risk Description	Risk Cause	Risk Impact	Risk Rating	Mitigation Description	Post Mitigation Residual Risk Rating
GEO_2789	Rocky Lane Cutting	Dissolution Features	Potential solution features under landscape bunds and within mainline cutting	The soluble nature of chalk, limestone or evaporite layers within mudstones	1. Presence of typical feature types in soluble rocks: sinkhole, dissolution pipe or shallow hole that may develop rapidly subject to loading from HS2 works. 2. Potential ground collapse beneath the landscape bund and/or within the cutting.	10	1. Visual inspection by competent personnel of area identified as potential solution feature prior to construction and following topsoil/sub-soil stripping works at this location. 2. Trial pit(s) to be located in area of potential solution feature prior to placing of landscape bund. 3. Where there remains a risk of a potential solution feature being present that may impact the works then further intrusive of other ground investigation shall be carried out prior to any works in this specific area. 4. If required, intrusive or other ground investigation, such as geophysical surveys.	6
GEO_2795	Rocky Lane Cutting	Variable Weathering Profile	Unexpected poor ground conditions being encountered during construction	Insufficient existing GI data to determine suitable ground models for the full extents of the earthwork	Unsuitable geotechnical solution, such as cut slope inclinations, with respect to interpreted weathering grade in Chalk.	16	1. Adopt conservative level for rockhead profile in Chalk. 2. Further GI using cored holes to classify Chalk weathering grade. 3. Where GI available, revisit the slope stability design based on the revised parameters. 4. Visual inspection and logging by competent personnel during cutting excavation to identify change in Chalk weathering grade to provide early warning, or otherwise, of as-encountered Chalk weathering grade.	6



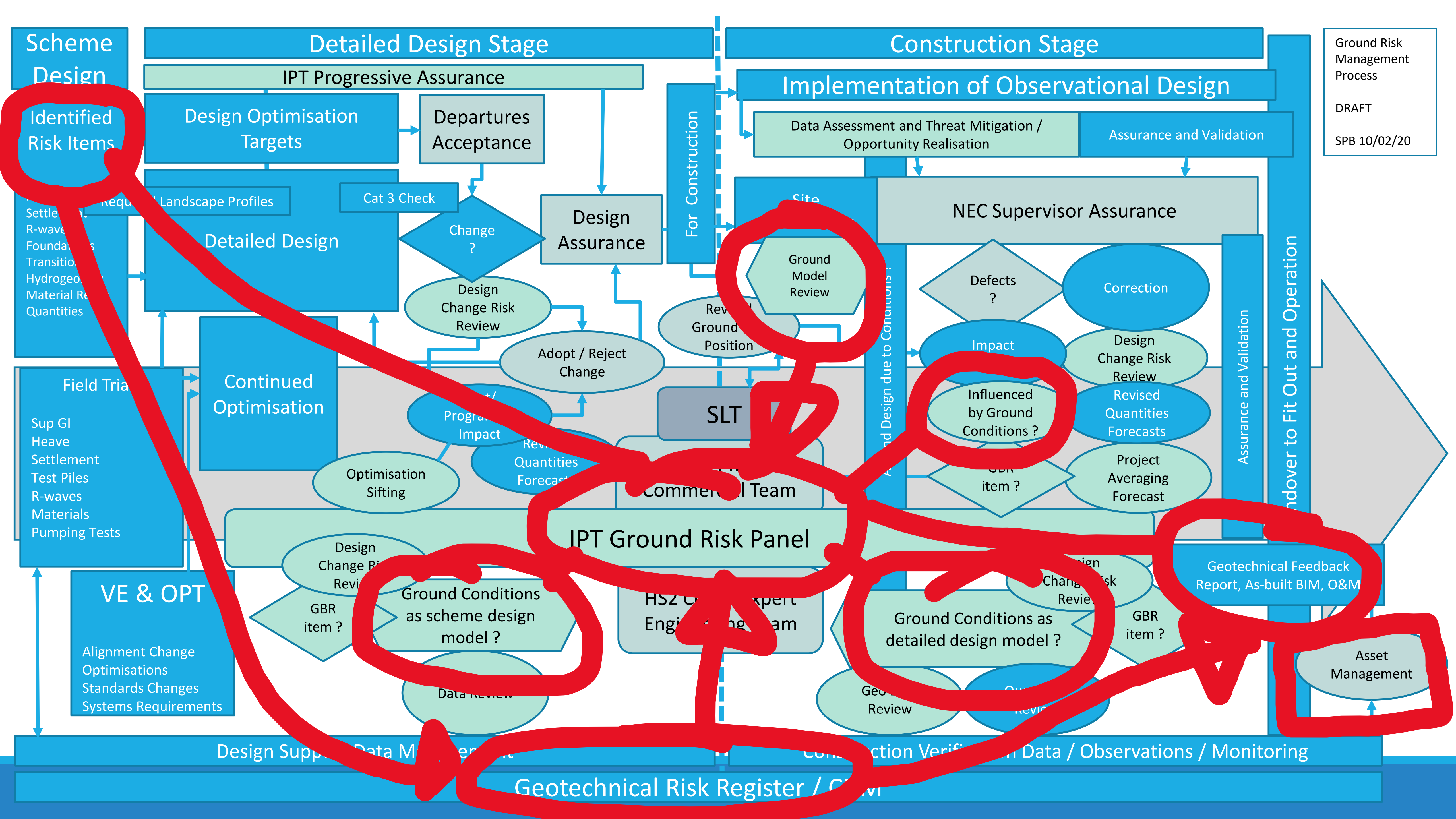
Credit: James Dudfield at HS2

Role of Engineering Geologists

Communicating Ground Uncertainty Through the Life of the Project



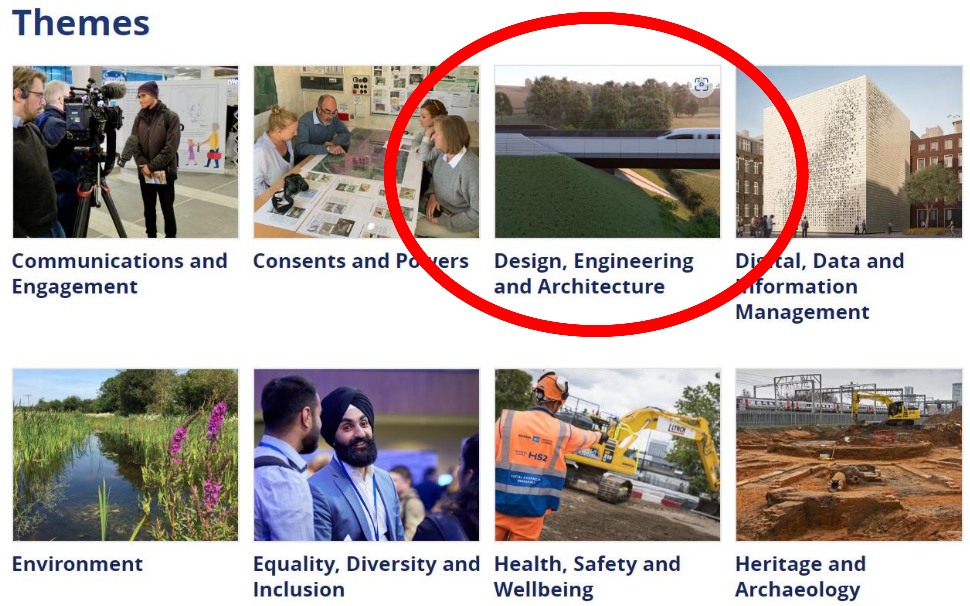
Credit: Georgios Katsigiannis at EKFB, Hugo Wood at Cowi (now WSP)

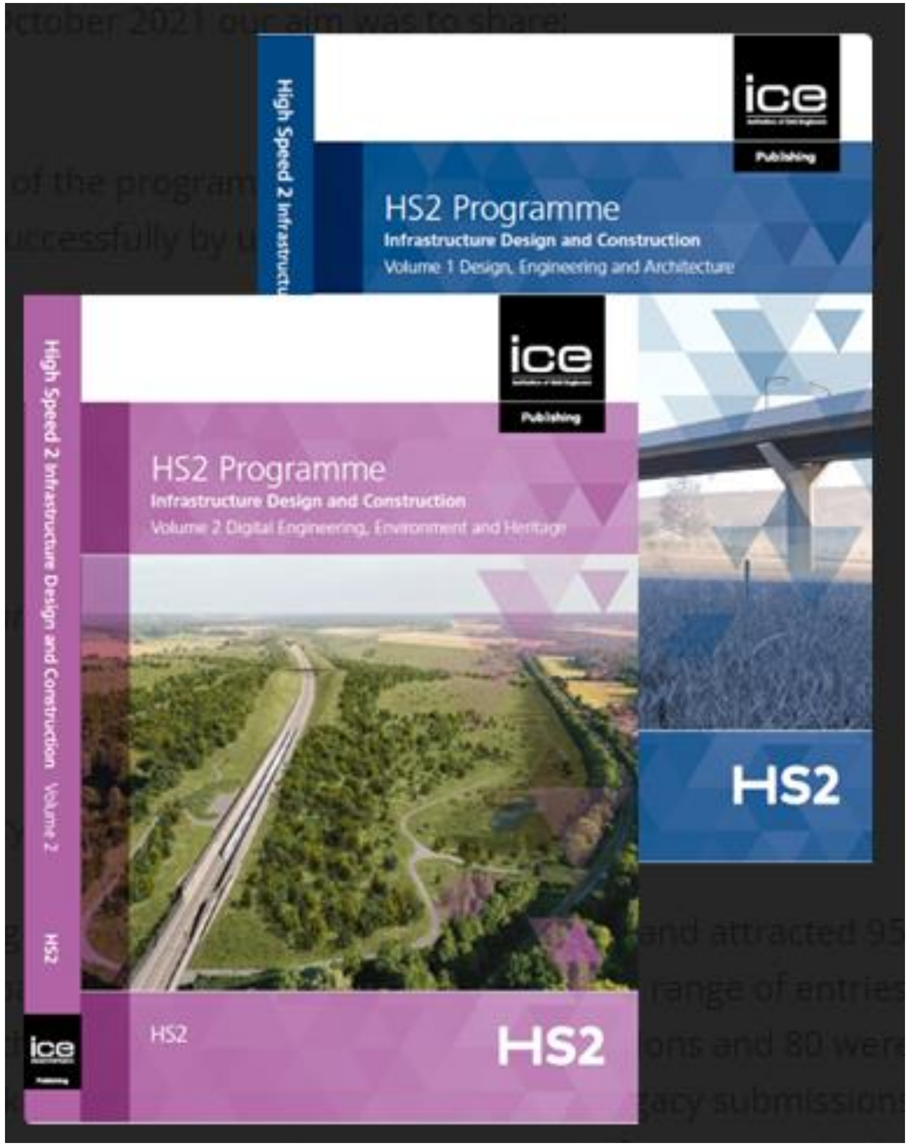


Scheme Design
Detailed Design Stage
Construction Stage
Ground Risk Management Process
DRAFT
SPB 10/02/20
IPT Progressive Assurance
Implementation of Observational Design
Identified Risk Items
Design Optimisation Targets
Departures Acceptance
Data Assessment and Threat Mitigation / Opportunity Realisation
Assurance and Validation
Landscape Profiles
Cat 3 Check
Change ?
Design Assurance
For Construction
NEC Supervisor Assurance
Quantities
Detailed Design
Ground Model Review
Defects ?
Correction
Design Change Risk Review
Adopt / Reject Change
Impact
Design Change Risk Review
Field Tria
Sup GI
Heave
Settlement
Test Piles
R-waves
Materials
Pumping Tests
Continued Optimisation
SLT
Influenced by Ground Conditions ?
Revised Quantities Forecasts
Assurance and Validation
Impact
Quantities
Optimisation Sifting
item ?
Project Averaging Forecast
IPT Ground Risk Panel
Design
GBR item ?
Ground Conditions as scheme design model ?
Geotechnical Feedback Report, As-built BIM, O&M
VE & OPT
Ground Conditions as detailed design model ?
GBR item ?
Alignment Change
Optimisations
Standards Changes
Systems Requirements
Data Review
Review
Asset Management
Data / Observations / Monitoring
Geotechnical Risk Register

HS2 Learning Legacy

The HS2 Learning Legacy is the collation and dissemination of good practice, innovation and lessons learned from HS2 aimed at raising the bar in industry, improving UK productivity and showcasing UK PLC.

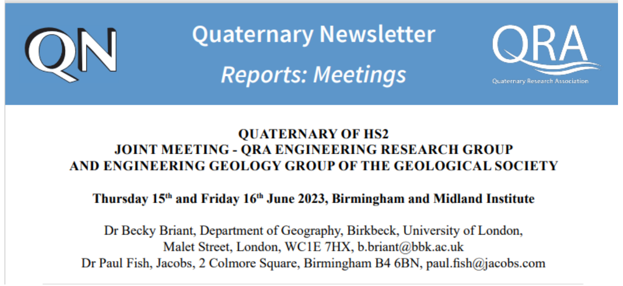


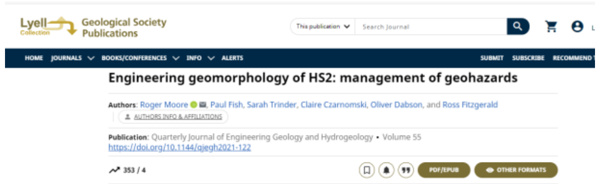


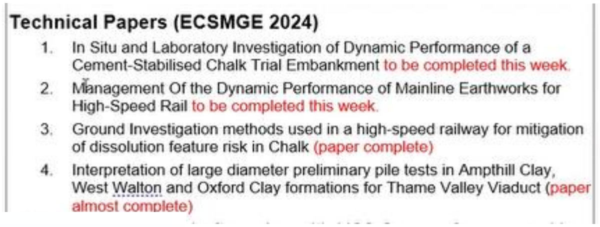
https://learninglegacy.hs2.org.uk/

Industry Learning Legacy

- HS2 learning Legacy
- Lectures and Presentation
- Seminars and Working Groups
- Magazine articles and Journal Publications
- Conference Presentations and Proceedings
- Training and Chartership Experience







From the HS2 Learning Legecy website	
Shaft friction design for piles in extremely weak to weak Mercia Mudstone	Driving efficiency and sustainability in material reuse through GeoBIM
Colne Valley Viaduct foundation design	Incorporation of digital ground investigation data and geological model into the 3D BIM environment
Ground Heave in Deep Cuttings: Evolution From Generic to Specific Models to Enable Refinement of a Risk Management Strategy	Managing uncertainty in ground conditions in design on a megaproject where ground investigation is highly variable
Investigation of the behaviour and the design for piles subject to ground heave	Innovative ground data management
Route-wide contamination risk assessment modelling in support of a sustainable earthwork material reuse framework	Test pile design, construction and testing – maximising the benefits of preliminary pile test results in pile design and construction at Euston Approaches

Credit: Nick Sartain and Sarah Trinder at HS2

Academic Learning Legacy

Engineering Geology Published Papers (Examples)		
Yuderka Trinidad Gonzalez, Kevin Briggs, William Powrie, Nick Sartain, Simon Butler	The Spatial Variability of the cone tip resistance of Weathered Mudstone Profiles from CPT testing	The 8th International Symposium on Geotechnical Safety and Risk (ISGSR 2022) - Newcastle, Australia,
Kevin M. Briggs, Letisha Blackmore, Aleksandra Svalova, Fleur A. Loveridge, Stephanie Glendinning, William Powrie, Simon Butler and Nick Sartain	The influence of weathering on index properties and undrained shear strength for the Charmouth Mudstone Formation of the Lias Group at a site near Banbury, Oxfordshire, UK	Quarterly Journal of Engineering Geology and Hydrogeology Volume 55 https://doi.org/10.1144/qjegh2021-066
Kevin M. Briggs, Yuderka Trinidad González, William Powrie, Simon Butler and Nick Sartain	Quantifying CPT cone factors in clays derived from weathered mudstone	Quarterly Journal of Engineering Geology and Hydrogeology Accepted 2023

Research interests of third party (Examples)

Late Tithonian (Portland-Purbeck) sedimentology, stratigraphy, palaeoenvironments, climatic and tectonic frameworks.

British Lower Jurassic Stratigraphy and Palaeontology.

To undertake detailed stratigraphic and palaeontological analysis of the Jurassic Lower – Upper Lias sections exposed through enabling works between Southam/Chipping Warden areas where appropriate and to collect and research on fossil material uncovered from excavations

Credit: Dr Kevin Briggs, Prof William Powrie

Ammonites and Ichthyosaur vertebra (backbone) from the “Transition Bed” which forms the base of the Whitby Mudstone formation as seen in the field. Greatworth Green Tunnel section. These fossils are about 183 million years old from the Lower Jurassic

Credit: **Dr Neville Hollingworth, Ross Bichener, Giles Hemmings**

Conclusions

- HS2 traverses 250M years of geological time
- It's a unique opportunity to study the strata exposed
- These strata present a range of challenges to the construction of the railway, not least the Jurassic strata
- The risk associate with these challenges is created by the uncertainty in their occurrence
- It is the role of the Engineering Geologist to communicate ground uncertainty through the life of the project
- It is important to have a Strategy to Manage that uncertainty
- It is important to record and communicate the management of the risks identified through the Risk Register
- Successful management of ground risk requires communication and contribution from all parties involved
- As we progress we are learning
- And as we learn we should share that learning to improve understanding and promote good practice
- HS2 will leave a learning legacy and a skills legacy for future project
- Ichthyosaurs are not a prevalent as you might hope.

Questions