Dr. GM Reeves

For

The Stonehenge Alliance

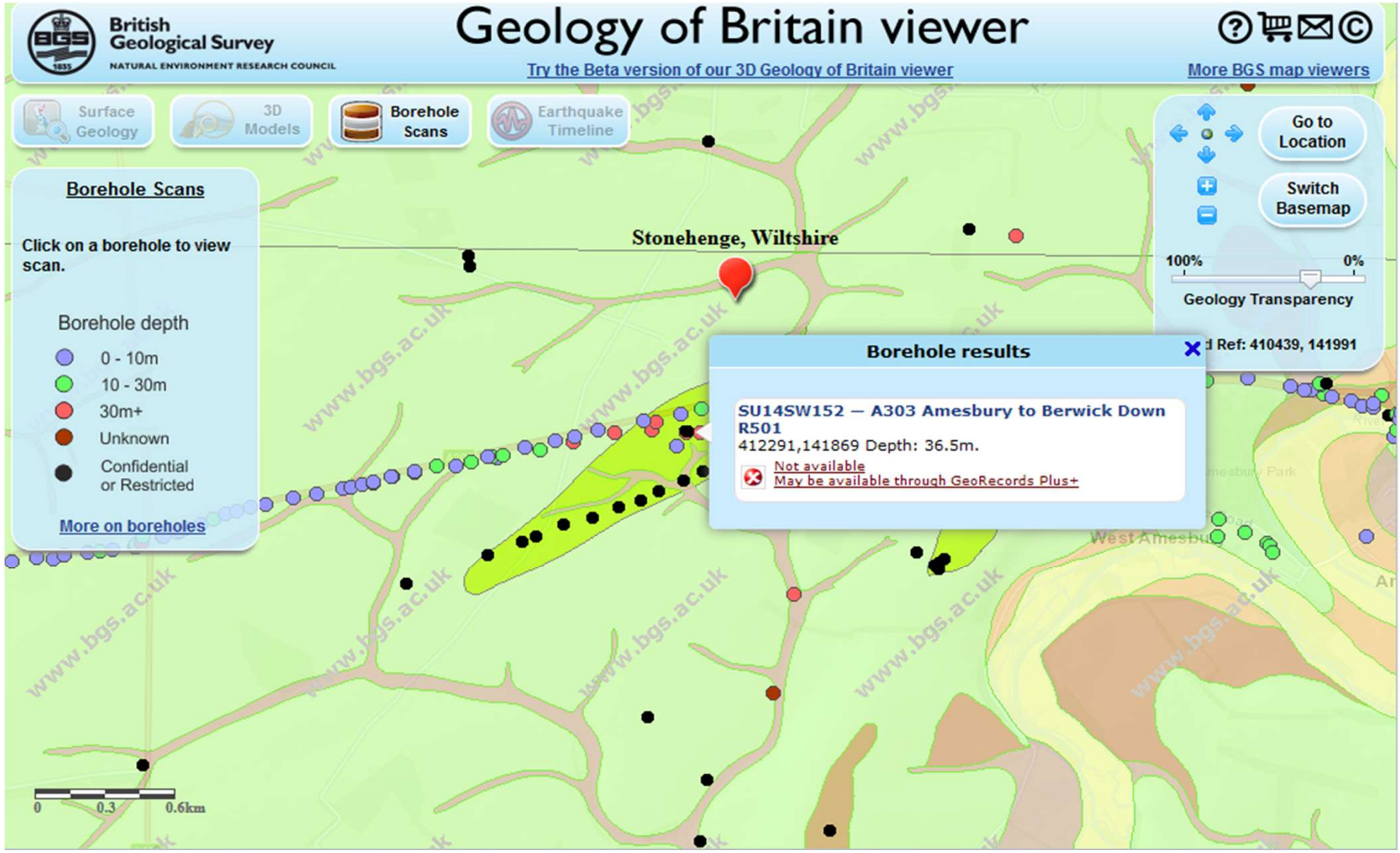
On

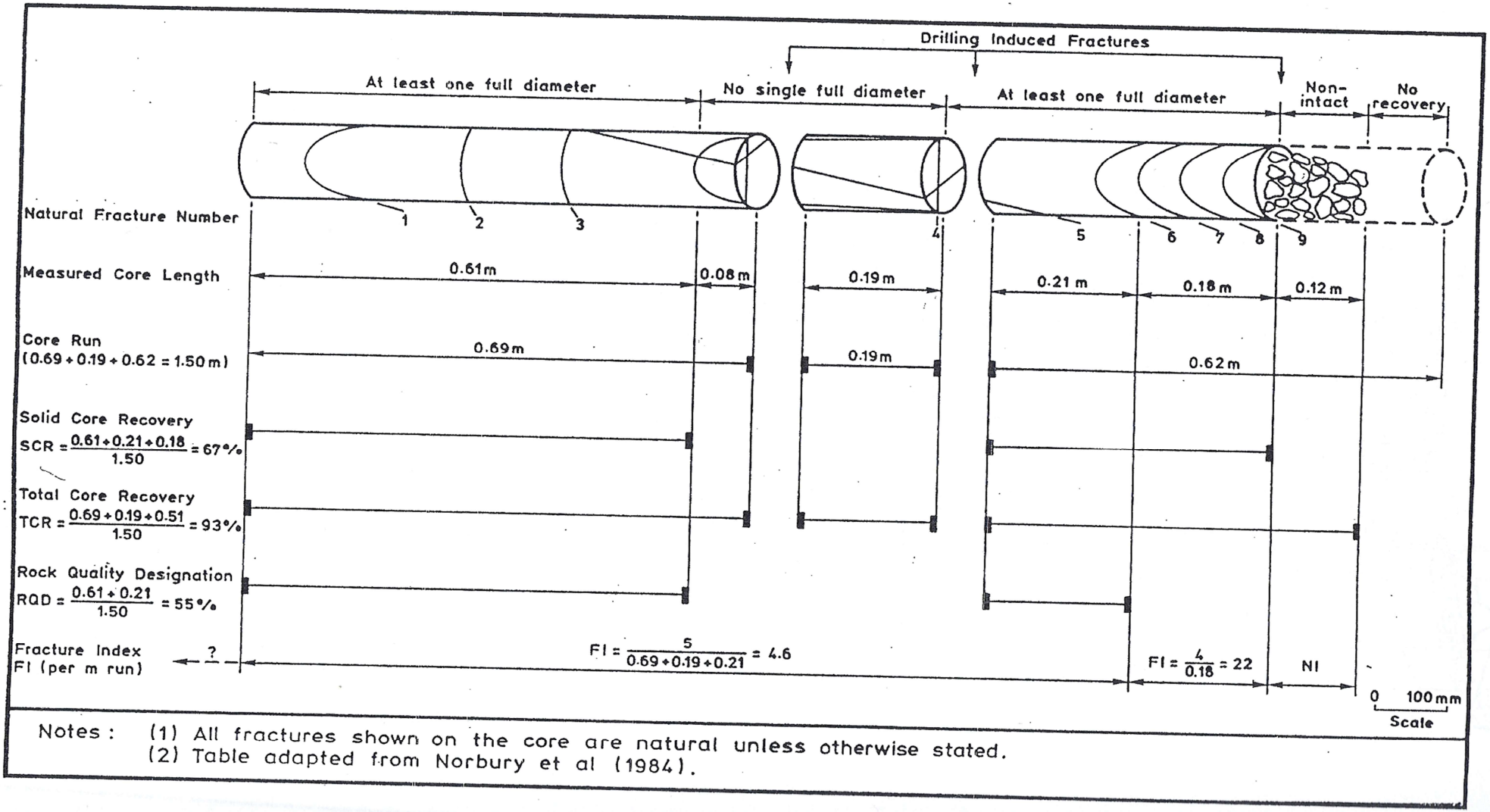
Geology, Hydrogeology, Geotechnics &

Effects of Tunnelling on Groundwater

Core Drilling, Core Logging & RQD: Wireline Logging

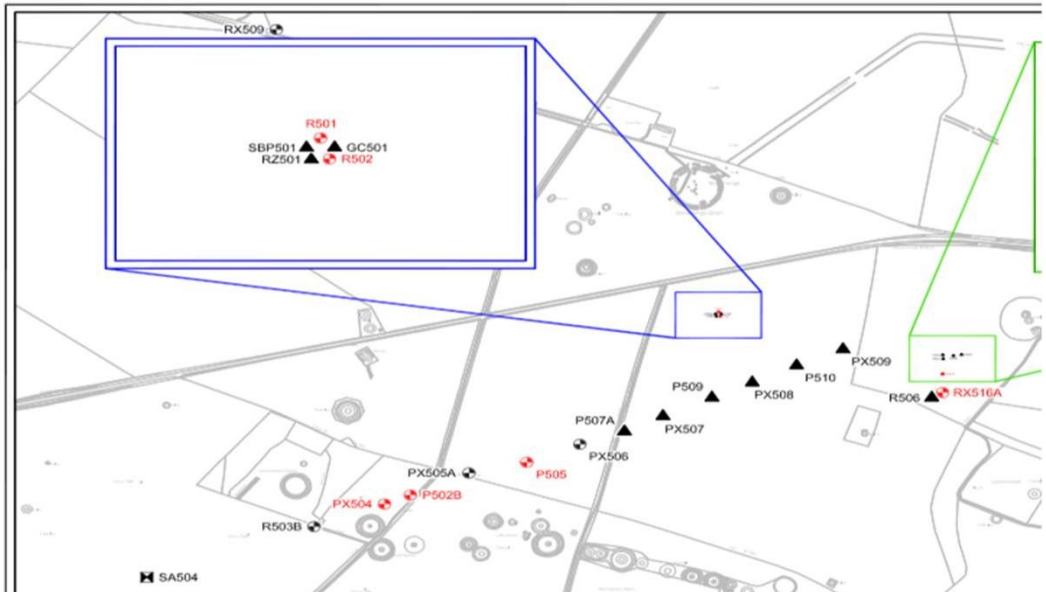
- Core Drilling & Recovery Methods
    - Wireline Recovery
    - Triple Tube core barrels
- Core Logging
- Rock Mass Classification
- TCR; SCR & RQD
    - Rock Quality Designation:
    - Rock Strength Classification Systems (CIRIA etc).
- Geophysical Logging Techniques:-
    - Caliper Logging
    - Natural Gamma
    - Optical & Acoustic Televiewers


British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Geology of Britain viewer
Try the Beta version of our 3D Geology of Britain viewer
More BGS map viewers
Surface Geology
3D Models
Borehole Scans
Earthquake Timeline
Go to Location
Switch Basemap
100%
0%
Geology Transparency
Borehole Scans
Click on a borehole to view scan.
Borehole depth
0 - 10m
10 - 30m
30m+
Unknown
Confidential or Restricted
More on boreholes
Stonehenge, Wiltshire
Borehole results
SU14SW152 — A303 Amesbury to Berwick Down R501
412291,141869 Depth: 36.5m.
Not available
May be available through GeoRecords Plus+
0
0.3
0.6km



Notes : (1) All fractures shown on the core are natural unless otherwise stated.
(2) Table adapted from Norbury et al (1984).

Schematic Illustration of Fracture Logging Terms



STRUCTURAL SOILS

FINAL

BOREHOLE LOG

Contract:		Client:		Borehole:
A303 Amesbury to Berwick Down		Highways England		R501
Contract Ref:	Start: 22.02.17	Ground Level (m AOD):	National Grid Co-ordinate:	Sheet:
731823	End: 01.03.17	93.16	E:412291.0 N:141868.9	8 of 33

Depth (m)	Samples & Testing: No	Type	Results	Mechanical Log: TCR (%)	SCR (%)	RQD (%)	If (mm)	Flush Colour & Details	Backfill	Water	Description of Strata	Fracture Log	Reduced Level	Depth (Thickness)	Material Graphic Legend
											brown chalk.				
											... at 14.30m chalk fragments are extremely weak.				
											... at 14.35m to 14.65m joint is 85° undulating rough open brown communted chalk.				
17.80	14	C		80	56	56		0% return Air+Mist			... at 14.50m to 14.70m joint is 75° undulating rough open infilled with communted chalk.				
							N 100 220				... at 14.75m phosphatic chalk becomes very weak.				
18.00-18.75 (0:05)											between 14.75m and 15.00m chalk fragments weak.				
				85	53	53		0% return Air+Mist			... at 14.85m to 15.00m heavily phosphatic.				
18.50	PS7	ES									... at 15.20m joint is 45° undulating rough open communted chalk.	268			
											... at 15.00m phosphatic chalk becomes very weak.	270			
18.75-20.25 (0:09)											between 18.50m to 18.75m joint is 80° undulating rough open black speacks and lower fracture surface between 18.20m and 18.60m.		74.41	18.75	
											from 18.60m to 18.75m becomes very weak as per nail test and fragment test.				
19.00	15	C									between 18.55m and 18.73m joint is 75° planar rough with black speaks and brown staining upper fracture surface fragmented.				
				100	0	0	N	0% return Air+Mist			... at 17.80m to 18.00m nail test (17/18/18) hard surface very weak.				
19.50	PS8	ES									... at 18.35m to 18.55m joint is 70° planar rough infilled with communted chalk (<2mm).			(1.50)	
											... at 18.55m and 18.75m joints are closely spaced.				
											... at 18.58m to 18.88m joint is 70° planar rough communted chalk.				

Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	

All dimensions in metres | Scale: 1:14

Method Used:	Plant Used:	Drilled By:	Logged By:	Checked By:
Inspection pit + Rotary Cored	Comacchio Geo 602	Ryan Pincher	RHunt + BSalmon	AZ

STRUCTURAL SOILS

FINAL

BOREHOLE LOG

Contract:		Client:		Borehole:
A303 Amesbury to Berwick Down		Highways England		R501
Contract Ref:	Start: 22.02.17	Ground Level (m AOD):	National Grid Co-ordinate:	Sheet:
731823	End: 01.03.17	93.16	E:412291.0 N:141868.9	9 of 33

Depth (m)	Samples & Testing: No	Type	Results	Mechanical Log: TCR (%)	SCR (%)	RQD (%)	If (mm)	Flush Colour & Details	Backfill	Water	Description of Strata	Fracture Log	Reduced Level	Depth (Thickness)	Material Graphic Legend
20.10	16	C		100	0	0	NI				Extremely weak and very weak brown CHALK (crumbles into multistepped fine to coarse angular fragments of chalk up to 30mm on inspection). There are weaker zones probably formed by the weathering of chalk (fragments at the centre of the core are very weak) (possible weakening/disturbance of chalk from use of multistep drilling tools). (PHOSPHATIC CHALK)				
20.25-21.00 (0:02)													72.91	20.25	
20.60	PS9	ES		100	20	20		0% return Air+Mist			Very weak to weak medium density brown phosphatic CHALK. Fractures are subhorizontal to subvertical extremely closely to closely spaced (10/100/150) undulating rough open black specks subhorizontal closely spaced subvertical to extremely to very closely spaced. (PHOSPHATIC CHALK Grade A5)	268			
20.82-20.95	17	C									... between 20.25m and 20.50m non intact recovered as fine to coarse angular gravel size fragments of phorphitic (brown chalk). Chalk is very weak medium density.			(0.75)	
21.00-22.50 (0:02) 21.00-21.30	18	C					10 100 150				... at 20.55m and 20.75m subvertical (85°) joint undulating rough black speckx.	268	72.16	21.00	
21.50	PS10	ES		50	36	36		0% return Air+Mist			... at 20.75m and 20.90m non intact recovered as fine to coarse angular fragments of chalk. Chalk is very weak to weak.	300		(0.75)	
											... at 20.80m to 21.00m nail test (6/11mm), probably weak high density.	31			
											Very weak high density brown phosphatic CHALK with occasional lenticular		71.41	21.75	AZCL
														(1.45)	

Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	

All dimensions in metres | Scale: 1:14

Method Used:	Plant Used:	Drilled By:	Logged By:	Checked By:
Inspection pit + Rotary Cored	Comacchio Geo 602	Ryan Pincher	RHunt + BSalmon	AZ

STRUCTURAL SOILS

BOREHOLE LOG

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A303 Amesbury to Berwick Down		Highways England		R501
Contract Ref:	Start: 22.02.17	Ground Level (m AOD):	National Grid Co-ordinate:	Sheet:
731823	End: 01.03.17	93.16	E:412291.0 N:141868.9	32 of 33

R501 box 20, 18.75m - 20.25m depth (Rigside)

R501 boxes 20 - 21, 18.70m - 21.00m depth (Compound)

R501 boxes 20 - 21, 18.70m - 21.00m depth (logging area)

STRUCTURAL SOILS

FINAL

BOREHOLE LOG

Contract:		Client:		Borehole:
A303 Amesbury to Berwick Down		Highways England		R501
Contract Ref:	Start: 22.02.17	Ground Level (m AOD):	National Grid Co-ordinate:	Sheet:
731823	End: 01.03.17	93.16	E:412291.0 N:141868.9	10 of 33

Depth (m)	Samples & Testing: No	Type	Results	Mechanical Log: TCR (%)	SCR (%)	RQD (%)	If (mm)	Flush Returns & Details	Backfill	Water	Description of Strata	Fracture Log	Reduced Level	Depth (Thickness)	Material Graphic Legend
22.50-23.20 (0:01)											or patches of chalk and brown phosphatic sandy matrix. Fractures are subvertical very closely spaced undulating rough to planar rough open/closed infilled with cemented chalk and black specks. (PHOSPHATIC CHALK Grade B4) . . . at 21.00m to 21.75m percentage of phosphate content comparatively less. . . . at 21.30m to 21.40m joint is 85° undulating rough open black specks and another joint 85° cuts across previous one (conjugate joints). . . . at 21.43m to 21.52m joint is 50° undulating rough open with black specks. . . . at 21.50m to 21.60m midpoint joint (85°) planar rough closed.				AZCL
				1				0% return Air+Mist							
23.20-24.00 (0:01)												320	69.96	23.20	
23.30	19	C													
				100	77	41	70 150 250	0% return Air+Mist						(0.80)	
23.70	PS11	ES									Assumed zone of core loss.				
24.00-25.00 (0:01)												330	69.16	24.00	
							60 190				Very weak medium density brown phosphatic CHALK containing patches/lenticular shaped chalk and brown phosphatic irregular randomly disturbed brown sandy matrix. Fractures are subhorizontal to subvertical very closely to medium spaced undulating rough planar rough infilled with brown sandy chalk upto 4mm. (PHOSPHATIC CHALK Grade C3) . . . between 23.20m and 24.00m chalk dark brown and highly polished. . . . at 23.30m to 23.42m joint is 75° undulating rough open black specks. . . . at 23.90m fracture is subhorizontal open undulating rough brown sand upto 2mm.			(1.00)	
24.50	PS12	ES		55	44	39		0% return Air+Mist							
													68.16	25.00	

Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	

All dimensions in metres — Scale: 1:14

Method Used:	Plant Used:	Drilled By:	Logged By:	Checked By:
Inspection pit + Rotary Cored	Comacchio Geo 602	Ryan Pincher	RHunt + BSalmen	AP AGS

STRUCTURAL SOILS

FINAL

BOREHOLE LOG

Contract:		Client:		Borehole:
A303 Amesbury to Berwick Down		Highways England		R501
Contract Ref:	Start: 22.02.17	Ground Level (m AOD):	National Grid Co-ordinate:	Sheet:
731823	End: 01.03.17	93.16	E:412291.0 N:141868.9	11 of 33

Depth (m)	Samples & Testing: No	Type	Results	Mechanical Log: TCR (%)	SCR (%)	RQD (%)	If (mm)	Flush Returns & Details	Backfill	Water	Description of Strata	Fracture Log	Reduced Level	Depth (Thickness)	Material Graphic Legend
25.00-26.00 (0:01)											. . . between 23.87m and 23.97m joint is 50° planar rough infilled with brown sand.				
25.12-25.12	20	C									Extremely weak low density brown phosphatic CHALK with patches/lenses of white chalk and disturbed in brown phosphatic sandy matrix. Fractures are randomly orientated extremely closely to very closely spaced undulating rough open to moderately wide infilled with brown sandy phosphatic and fine gravel sized fragments more than 4cm. (PHOSPHATIC CHALK Grade C4) . . . at 24.00m and 25.00m chalk becomes lower end of very weak.			(1.00)	
				90	82	79	80 190	0% return Air+Mist							
25.80	PS13	ES													
25.93	21	C											67.16	26.00	
26.00-27.50 (0:02)											at 24.00m to 25.00m only 55mm recovery loss of recovery due to possible intense fracturing. . . . between 24.00m to 26.00m highly phosphatic. . . . at 24.90m and 25.00m nail test grains 27mm of penetration (extremely weak low density) at rig site.	340			
26.13-26.40	22	C										350			
26.48-26.70	23	C									Very weak medium density brown phosphatic CHALK with patches/lenses of white chalk disturbed in brown phosphatic sandy matrix (possible burrow infilled). Fractures are subhorizontal closely spaced undulating rough open infilled brown sand up to 2mm. (PHOSPHATIC CHALK Grade B4) . . . at 25.00m and 26.00m phosphatic chalk becomes very weak medium density. . . . at 25.33m, 25.56m and 25.92m fractures are				
				100	98	87	70 300 520	0% return Air+Mist							
26.80	PS14	ES													

Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	

All dimensions in metres — Scale: 1:14

Method Used:	Plant Used:	Drilled By:	Logged By:	Checked By:
Inspection pit + Rotary Cored	Comacchio Geo 602	Ryan Pincher	RHunt + BSalmen	AP AGS

R501 boxes 25 - 27, 24.00m - 27.50m depth (Logging area)

R501 boxes 25 - 27, 24.00m - 27.50m depth (Compound)

R501 boxes 25 - 26, 24.00m - 26.00m depth (Riside)

Groundwater Data, Modelling and Groundwater Barriers

- Drill Log Data
- Groundwater Observations & Monitoring.
- Multi-Seasonal Records
- Fracture Flow
- Chalk Hydrogeology

Simplified Conceptual Groundwater Flow Regime

(From Mortimore et al; 2017)

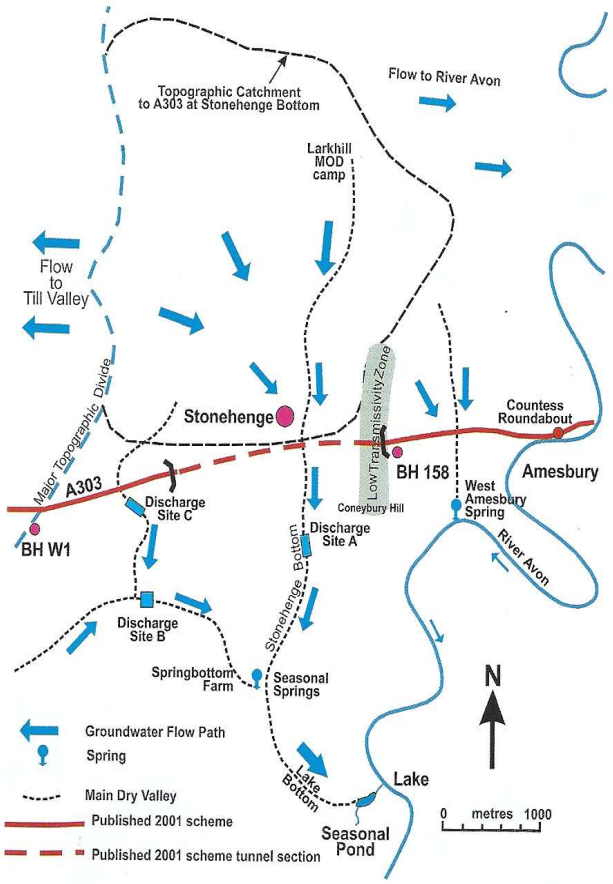
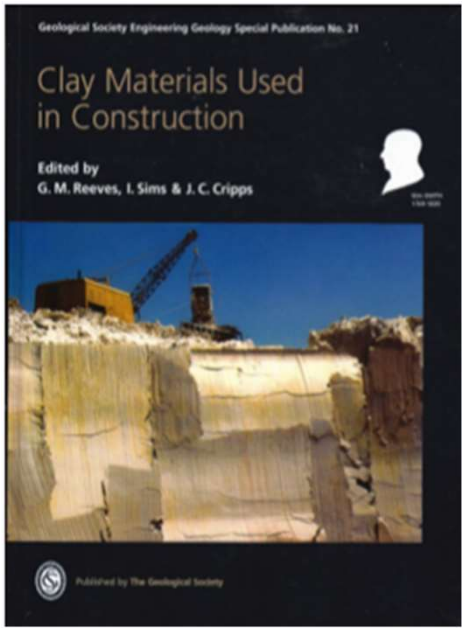


Fig. 28. A303 Stonehenge tunnel area conceptual groundwater flow regime. Stonehenge Bottom acts as a drain to the area with a spring located downstream at Springbottom Farm and a seasonal pond in Lake Bottom close to the River Avon. During the rapid rise in groundwater levels in 2002 the floor of Stonehenge bottom became flooded up to the A303 crossing and Trial Pits on the west side partly filled with water.

Bentonite Shield Tunnelling Methods, Grouting, :Poor Quality Rock and Grout Invasion.



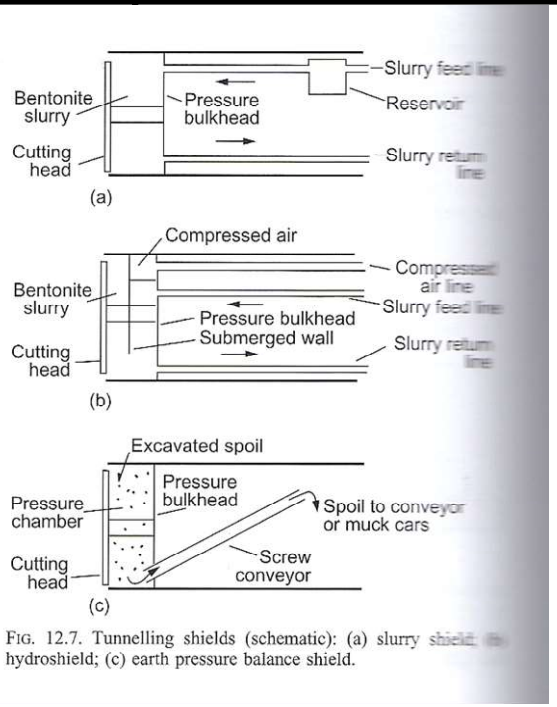
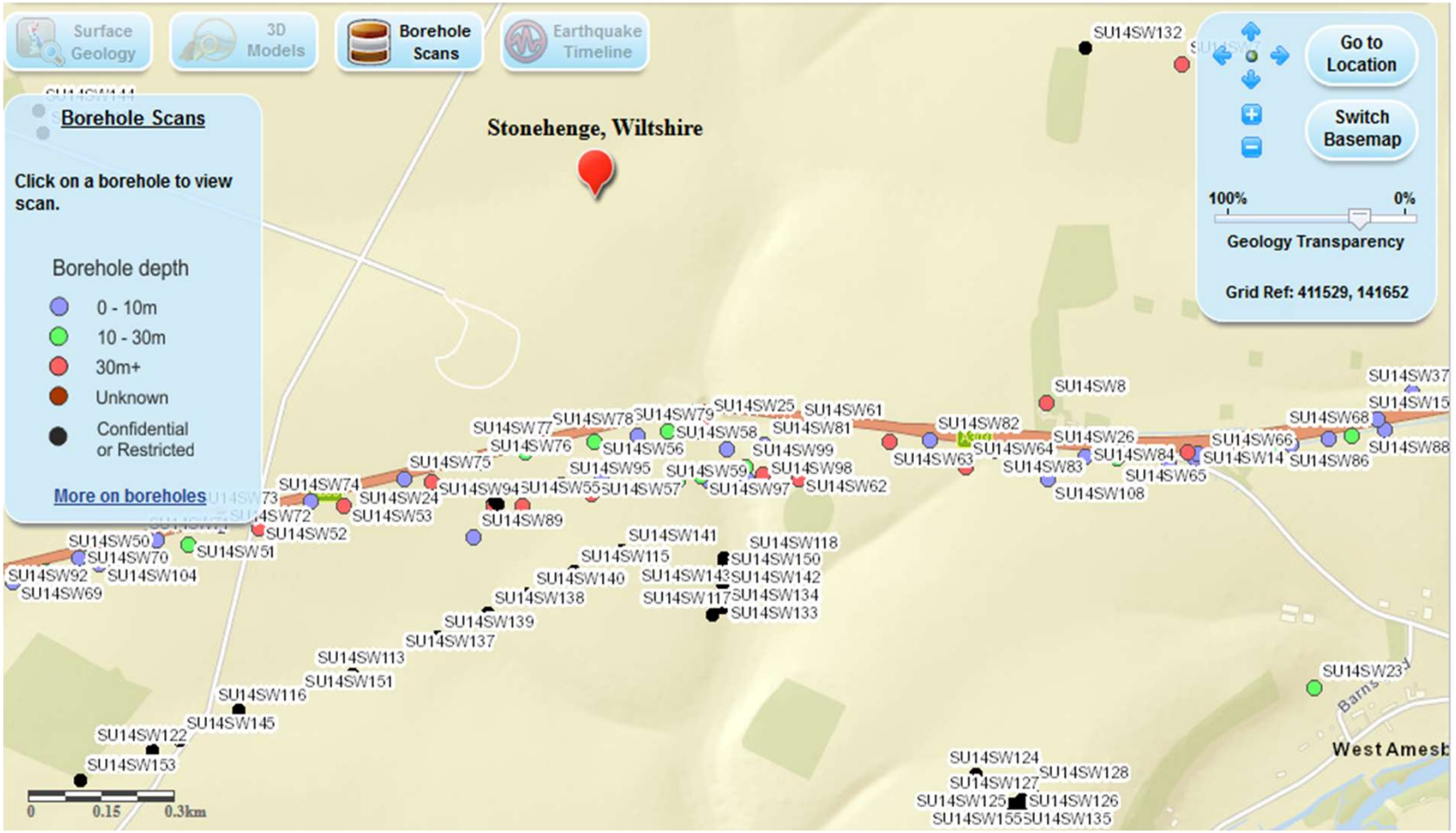


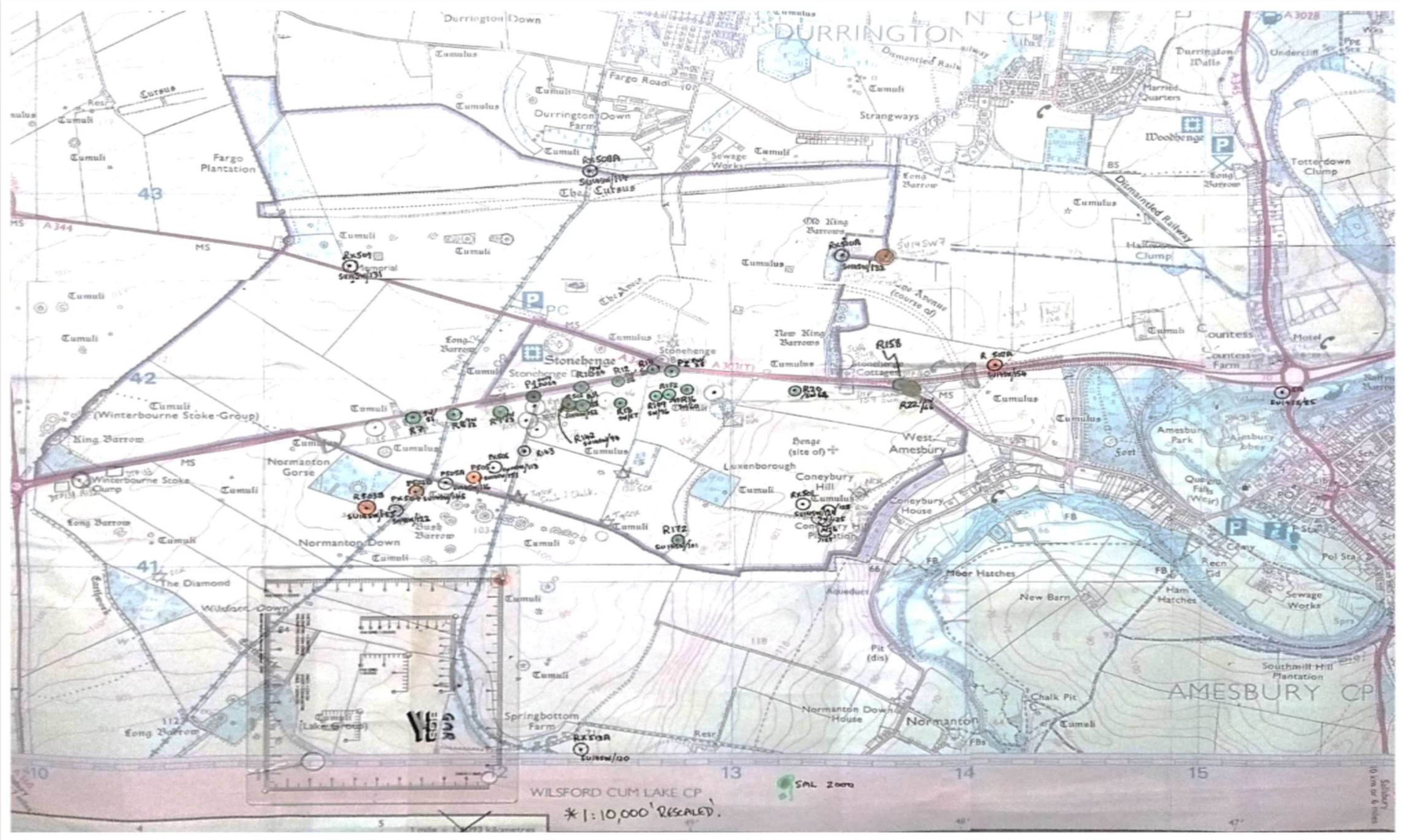
FIG. 12.7. Tunnelling shields (schematic): (a) slurry shield; (b) hydroshield; (c) earth pressure balance shield.

Slurry (Bentonite Based) Tunnelling:

- **Up to 12 to 15% Bentonite**
- **Additives to aid filter cake formation (eg. Long Chain Polymers such as …**
  - **Sodium carboxy methyl cellulose,**
  - **Polyanionic cellulose (PAC),**
  - **Polyacrylamides & derivitives.**
- **High degree of Penetration into formation in:-**
  - **Fracture Zones**
  - **Poor quality fractured rock**
  - **High Permeability rock.**
- **Maximum Penetration of Latents into high K zones.**

BGS GeoIndex Database:





Durrington Down
DURRINGTON
Cursus
Fargo Plantation
Fargo Road
Durrington Down Farm
The Cursus
Sewage Works
Strangways
Woodhenge
Durrington Walls
Married Quarters
Totterdown Clump
Long Barrow
Dismantled Railway
Old King Barrows
New King Barrows
Stonehenge
Stonehenge Cottages
The Avenue
Countess
Countess Farm
Cumuli (Winterbourne Stoke Group)
King Barrow
Normanton Gorse
Winterbourne Stoke Clump
Long Barrow
Normanton Down
Bush Barrow
Luxenborough
Coneybury Hill
Coneybury House
West Amesbury
Henge (site of)
Amesbury Park
Amesbury Abbey
Queens Falls (Weir)
Moor Hatches
New Barn
Ham Hatches
Sewage Works
The Diamond
Wilsford Down
Springbottom Farm
Normanton Down House
Normanton
Chalk Pit
Southmill Hill Plantation
AMESBURY CP
WILSFORD CUM LAKE CP
SAL 2000
*1:10,000' RESCALED'.

Modern Methods of Ground Data Presentation: 3-D Ground Modelling

- 2 Dimensional :-
  - Maps
  - Sections
  - Fence Diagrams

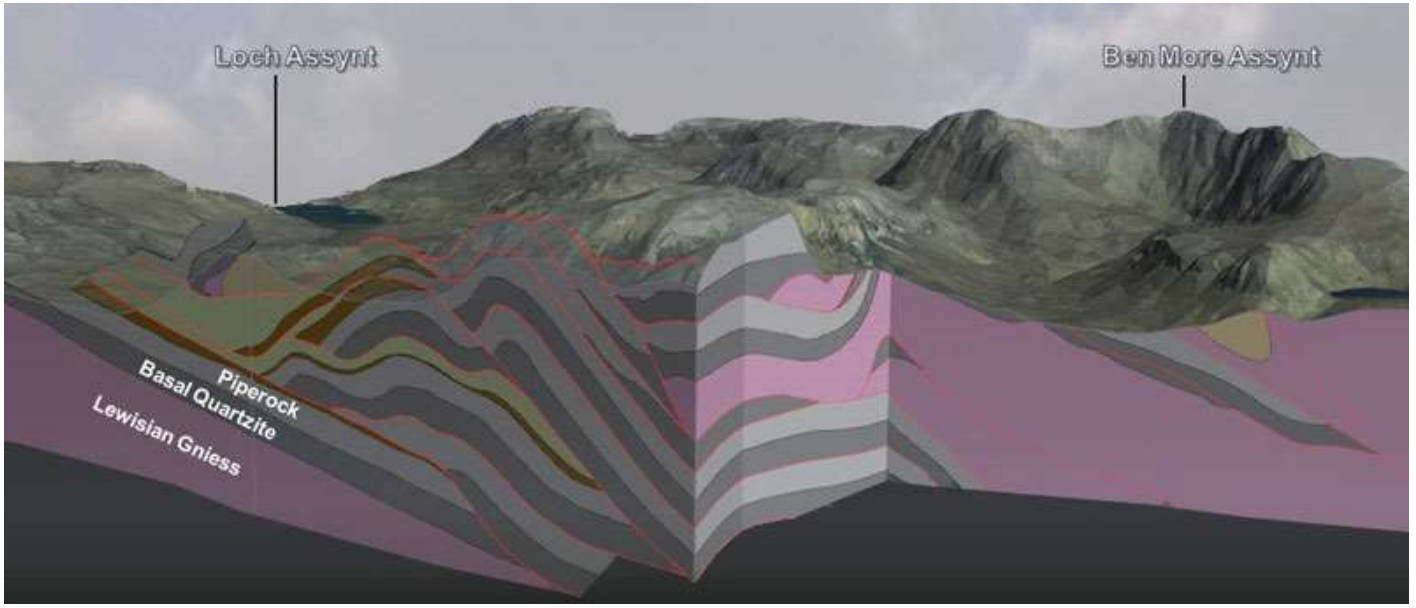
- 3-D Modelling:-
  - Borehole Logs and Data
  - Rock Properties- Strength/Lithology/Degree of Fracturing/Fault Zones
  - Alteration Zones (e.g. Phosphatic Chalk)
  - Groundwater Levels, Zones; Aquifers; Aquicludes; Recharge & Discharge
  - 3-D Geophysics- Methods; Combined Interpretations; Exponential Data Gains.

3-D Geological Ground Modelling-5

- Lithoframe Examples (See.... https://www.bgs.ac.uk/services/3Dgeology/lithoframe.html)
- Assynt Culmination Geological 3D Model (©BGS)

Assynt Culmination 3D geological model | UK geology ...
bgs.ac.uk 800 × 342 jpeg Image may be subject to copyright.

- https://youtu.be/WkOWUzvAxq4



Conclusions:

- **Potential Creation of massive, deep & penetrative (to up to 50m BGL)**
  GROUNDWATER CUT-OFF/"Groundwater Dam"- 3.3km+long.
- **Significant long-term changes in :- Groundwater Flow, G/W recharge,**
  G/W discharges, G/W chemistry and quality, Well yields and
  Chalk Rock solution (especially in Phosphatic zones).
- **Potential for short-term contamination from grouting (ex-TBM) and possible need for back-up surface dewatering and grouting, with associated effects**
- **Inadequate (inc. interpretation of existing)- Site Investigation Data (Drill & Well-logs)**
  - **Groundwater Data and consequent G/W Modelling**
  - **Data presentation (3-D Ground Modelling)**
  - **Rock Permeability values,changes and effects.**

gmr 01.06.19