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Submission to Planning Inspectorate, National Infrastructure Planning on A303 Amesbury to Berwick Down Project, Development Consent Order Application Ref. TR010025. June 2019

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with particular reference to: **Initial Assessment of Principal Issues: Section 7: Flood Risk, groundwater protection and land contamination: responses to Deadline 2, concerning *details on Rock Quality, Groundwater, and Tunnelling methods (including use of slurry/grouts*); and the *creation of an extensive "Groundwater Dam".***

Summary & Final Comments after Examination Issue Specific Hearings Sessions 4 & 5: 11–12th June 2019

Introduction

After nearly 50 years of relevant practical experience in applied geological, geotechnical and hydrogeological work, the following key aspects relevant to the proposed Stonehenge A303 tunnel are made by the writer for the attention of the Examining Authority.

This document has been prepared by Dr. GM Reeves following two written submissions for Stonehenge Alliance, a ten-minute presentation to the Panel on Tuesday 11th June 2019 (updated version appended), and involvement in questioning and discussions during Issue Specific Hearings 4 and 5 on Tuesday and Wednesday 11th and 12th June 2019.

1. **Geotechnical Properties of Chalk Bedrock along the tunnel line: Rock Strength and Stability**

A considerable amount of Site Investigation data has been obtained by the Highways Agency (now Highways England) from earlier (2000-2004) and recent ground investigations for the proposed Stonehenge tunnels and ancillary works, much of it of a high quality.
Drilling (presumably investigating the problems of rock strength and integrity especially in the Phosphatic Chalk of the Seaford and Newhaven Chalk formations) continues at the western portal end of the proposed tunnel near Borehole R7 originally drilled in 2001.
The evidence of rapid core disintegration in Phosphatic Chalk horizons (as demonstrated in Borehole R501 and others) is not due to any variances in drill bit selection or drilling methods (as stated on Tuesday 11th June 2019 by Highways England), but happens to the

recovered core as it is stored post-drilling, over the one to eight day time period, as shown on the attached core box records and core photographs in the (attached) PowerPoint images presented at the hearing.
To adequately understand the changes in rock properties (rock strength/RQD, permeability, degree of fracturing, persistence and groundwater flow potential of major fractures and faults) it is essential to adequately examine changes in all these aspects throughout the 3.3km (and possibly up to 0.5km additional distance west and east of each tunnel portal), and up to 1km or more to the north and south of the proposed tunnel line, and perhaps up to at least 100 metres in depth.
There is no possibility of thoroughly examining this 4.3 x 2 x 0.1 km block of (predominantly) Chalk rock, with very variable strengths and permeability properties, without creating a 3-Dimensional Ground Model.
No major ground engineering project such as this, in the developed world, would go ahead for approval, costing and detailed planning and design these days without this approach.
Systems for such detailed and extensive analysis have been developed in the UK over the past 10 to 15 years, largely by the British Geological Survey ground modelling group, and have been applied and adopted internationally (Entwistle et al. 2019; see attached PowerPoint presentation, as submitted on 11th June 2019 at ISH 4 of the Examination).

It is not best practice and very unfair to expect tenderers and contractors to carry out the fundamental assessments that can be readily obtained from such a 3-Dimensional Ground Model.

All relevant existing ground information (together with the continuing data being obtained from current drilling for Highways England) can thus be collated, displayed and interpreted by both the Inspectorate and the client, prior to initiating any tendering processes.
This data includes, inter alia, drilling data, core log and open hole drilling records, geophysical logging data and detailed interpretations, geological data from field mapping and trial pits, as well as surface geophysical survey and groundwater data.
It is estimated that there are at least 50 relevant deep boreholes, over 100 trial pits and numerous tests, observations, geological (especially major faults and fracture set information), hydrogeological and geophysical data sets that should and could be incorporated in such a Ground Model.
The present situation, in the opinion of this current specialist expert (GMR) is that all this data is poorly collated, investigated and interpreted, along and around (especially to the north and south) of the proposed tunnel line.
This is due to the apparent total lack of appreciation and understanding by Highways England of the breadth and depth of understanding that the application of such modern 3-D Ground Modelling techniques can bring, as is the norm now internationally, in such complex important tunnelling projects.

AGS data availability (the UK Standard format for Site Investigation data) helps with developing such models, but old, out of date software such as GINT (as quoted by Highways England in their rebuttals) is from a generation past, compared with modern 3-D Ground Modelling techniques and methodologies.

2. Hydrogeological Conditions and Consequences

It is especially evident to the present author that the proponents of the A303 Stonehenge tunnel project, Highways England and some of their consultants, do not have the necessary in-house expertise to fully assess and understand the potential hydrogeological data and the need for site specific groundwater modelling. It is likely that the Planning Inspectorate is in a similar position, which is understandable and to be expected.

Groundwater modelling for such a specific high-profile tunnelling project needs to be carried out at an appropriate scale, using the available site-specific data, set in the regional, larger scale context of the local context of Chalk Aquifer conditions.

Since much of the proposed tunnelling will now occur below the Chalk groundwater water level, a far more detailed, site specific groundwater model needs to be developed rather than the "Wessex Basin" approach currently adopted and applied by Highways England consultants and the Environment Agency. Nodes (and consequently a groundwater modelling mesh) of 20m, or at worst 50 metre spacings is more applicable and relevant to expected tunnel groundwater flow conditions than the 250 metre node spacing currently adopted.

3. Tunnelling Methods, ground vibration, settlement and subsidence

The use of a closed face bentonite slurry based tunnelling method (as finally confirmed by Highways England on 11th June 2019 at ISH Session 4) will present the opportunity for considerable penetration to, and migration into, the major north–south trending fracture zones currently identified along the proposed tunnel line (see Slides 9 and 10 on attached copy of GMR's presentation to Session 4 on 11th June 2019).

Up to 15% of the slurry mix will be bentonite, with additives (such as Long Chain Polymers as Sodium carboxymethyl cellulose, Polyanionic Cellulose, and Polyacrylamides and their derivatives, often as "Tylose") being commonly mixed into the groundwater and cut rock waste slurry mix. Groundwater salinity levels can be elevated if these additives are introduced into groundwater. They are commonly used as drilling mud additives in oil drilling.

Unless ground conditions along the proposed tunnel line (especially the existence of weak unstable, often Phosphatic, Chalk), as well as the permeability and persistence of major fracture zones (as are shown on Figures 9 and 10 on attached presentation), are properly understood, no assessment of the effects of grout migration from tunnelling can be made.

For a full analysis of potential grout migration the physical and chemical properties of the slurry grout must be known, as well as information on the "effective porosity" (or more correctly the Field Permeability) of the country rock, the fracture zones, and the altered and highly Phosphatic Chalk in-situ properties. (See Reeves, Sims and Cripps, *Clay Materials used in Construction*, 2006, Chapter 12.)

Much concern has been raised concerning the possibility of ground vibration causing detrimental effects and even damage to the ground above the proposed tunnel, and indeed known or as yet unexplored archaeological features and artefacts at surface or at depth.

If large flint nodules (some have been reported as big as 40 to 60cm) are encountered by the full face TBM, then the rotary progress of the machine could well be detrimentally affected or even stopped. Larger flint nodules could indeed cause the tunnelling process to “act as a jackhammer”, which would induce significant ground vibration to surface. Few flint bands, beds, nodules or content occurs within the Phosphatic Chalk zones, but in both the Seaford and Newhaven Formations such features are quite common. Vibration limits are discussed elsewhere (by Rupert Taylor), but adverse rock conditions, as discussed, not yet fully understood and characterised along the proposed tunnel length, could well cause problems with ground movement, settlement and even migration of subsidence and void spaces to surface in some extreme conditions.

4. **Inadequacy of Data Investigation, Interpretation, Presentation and Analysis**.

As repeatedly stated, the full potential of existing, and continuing acquired ground investigation data has not been realised, so that sufficient understanding of 3-dimensional changes in rock and groundwater conditions can inform adequate design prior to construction of the proposed tunnel.

From the experience of submitting and giving evidence both at the A303 Stonehenge Public Inquiry in 2004, and at the Examination in 2019, it is the present writer’s opinion (based on 50 years of relevant applied geological, geotechnical and groundwater-related projects), that neither Highways England, nor their hydrogeological advisors, nor the Environment Agency, have the necessary in-house expertise these days to adequately assess all geoscientific aspects of such a project.

Adequate, relevant and extensive data (and consequent advice on the same), especially in the rock property and groundwater data areas, is still significantly incomplete.

The use of the (now) commonly available, appropriate, 3-D digital ground and groundwater modelling methods of assessing the variability and potential effects of changing ground conditions using the existing extensive Site Investigation data bases, is a major remarkable omission from Highways England’s submission and documentation to the Infrastructure Planning Inspectorate for this proposed project.

5. Conclusions

Using the present state of understanding of the proposed tunnel route by Highways England, there is the potential for the creation of a massive, deep and penetrative (to up to 50m below ground level) groundwater cut off or ”Groundwater Dam” over 3.3km long, along the line of the proposed A303 Stonehenge tunnel.

This structure could cause significant long-term changes in groundwater flow, groundwater recharge and discharges, groundwater chemistry and hence quality in the area affected, as well as adversely affecting well yields and potability. In addition, there is the potential for short-term contamination from grouting (from the TBM) and possible additional detriment due to the possible need for back-up surface dewatering and grouting, with associated long term effects on local supply well yields.

With possible changes in groundwater chemistry (especially pH and dissolved oxygen levels) Chalk Rock solution may be instigated (especially in the Phosphatic Chalk zones), with potential settlement and induced subsidence.

The key component in many of these concerns is the inadequacy and incompleteness of existing Site Investigation Data (both in Drill and Well-logs), Groundwater Data and consequent G/W Modelling.

When this is coupled with total repudiation by Highways England of the necessity for modern methods of data presentation in the usage of 3-D Ground Modelling of rock property and in particular rock permeability values and changes across the A303 Stonehenge tunnel site, the effects of such lack of understanding of these variations are a major cause for concern.

Dr. GM Reeves 23.06.19

Appendices

Appendix 1: Presentation by Dr. GM Reeves to Session 4 A303 Stonehenge Examination, Tuesday 11th June 2019 (29 PowerPoint Slides)

References

Reeves, GM, Sims I and Cripps, JC (Eds) 2006. *Clay Materials used in Construction.* Geological Society of London, Engineering Geology Special Publication 21. ISBN 10: 1-86239-184-X.