



Technical note: Ebberston to Knapton Pipeline: Review of Further Supplementary Information

1. Introduction

Amec Foster Wheeler has been commissioned by North York Moors National Park Authority ('the Authority') to undertake a review of the Further Supplementary Information (FSI) submitted by Third Energy Limited and Moorland Energy Limited (the Applicants) in June 2015 in relation to the proposed Ebberston Moor South Wellsite — Knapton Gas Pipeline (Ref NYM/2014/0587/EIA).

Amec Foster Wheeler has previously undertaken and published a review of the potential for pollution of groundwater and land stability issues in respect of the planning application (36680c007, February 2015). Whilst being satisfied that all the known likely groundwater pollution and land stability effects had been identified, assessed, and mitigated to an acceptable level, Amec Foster Wheeler still required clarifications regarding the residual induced seismicity assessment and the findings of a revised cumulative impact assessment, and the FSI is an opportunity for the Applicants to provide this information.

This technical note summarises the findings of the Amec Foster Wheeler FSI review. The initial section (Section 2) details the remaining information that Amec Foster Wheeler is seeking from the FSI. Section 3 outlines the form of the FSI, whilst the findings of the review are presented in Section 4. The review's conclusions are finally summarised in Section 5.

2. Remaining Information Being Sought

The previous Amec Foster Wheeler review (36680c007) requested the following information with respect to the Applicants EIA:

- ▶ Issue 1: The implications of the Rockflow Resources Limited work with respect to the produced water re-injection rates of any proposed new borehole at the Ebberston Moor South (EMS) Well Site, and in regard to the Helmsley-Filey Fault, given that any new borehole could potentially be used to deliver relatively high injection pressures, and that other 'area of influence' calculations (Envireau Water Technical Report, August 2014) implied that water disposal pressures effects would propagate to the fault; and
- ▶ Issue 2: The findings of a revised cumulative impact assessment, both with respect to the EMS Well Site surface works and the pipeline (Issue 2a), and the produced water disposal (Issue 2b). In terms of Issue 2a, the concern was that there had not been sufficient recognition that both Ebberston 'A' and the EMS Well Site appeared to reside over the same Corallian Group aquifer and Source Protection Zone (SPZ), and so could have cumulative impacts on the aquifer and other dependent groundwater receptors. In terms of Issue 2b, the main concern was that there could be cumulative induced seismicity impacts resulting from produced water disposal at Ebberston 'A', the EMS Well Site and possibly the York Potash proposed development, as well as from other such existing or proposed developments in the area. These Issue 2 concerns were the subject of an email from Amec Foster Wheeler's reviewer, Dr Shaun Salmon, to the



Authority dated 13th May 2015, and which appears to have been subsequently provided to the Applicants by the Authority.

The current Amec Foster Wheeler review has been undertaken with respect to these two main issues.

3. Form of the FSI

The FSI itself comprises a report and three appendices. The main report appears to have been produced by the Applicants themselves, presumably with the help (unacknowledged) of their hydrogeological consultants Envireau Water, and possibly also the induced seismicity consultants Rockflow Resources Limited. Appendix 1, addressing Issue 2a, has been generated by the Applicants hydrological consultant R. Elliott Associates Limited, whilst Appendices 2 and 3, covering the potential for induced seismicity from the Applicants Vale of Pickering and Ebberston Moor operations respectively, and therefore relevant to Issue 2b, have been issued by Rockflow Resources Limited. Shortly after Amec Foster Wheeler commenced its commission, a further Rockflow Resources report, dated 2nd July 2015 and entitled "Cumulative Effect of Multiple North York Moors Water Injection Schemes", was also made available for review.

The main report makes no specific reference to Issue 1, and is clearly focussed towards addressing the cumulative impact issue (Issue 2). For example, in the Introduction it is referred to as "*This Further Supplementary Information of Cumulative Effects...*", and in the Background section it makes reference to Dr Salmon's email of 13th May 2015. However, whilst the Elliott Associates appendix (Appendix 1) was issued on 2nd June 2015 and was clearly commissioned specifically to address the Amec Foster Wheeler Issue 2a, the Rockflow Resources Vale of Pickering and Ebberston Moor reports are of earlier dates (2nd April 2015 and 20th November 2014 respectively) and appear to be of more general application, and so some effort is required to draw out information from them that relates to the Amec Foster Wheeler Issue 2b. The Applicants (most probably Envireau Water) attempt to help undertake this work in Section 2 of the main report, but much of this text is by way of introduction, and the Rockflow Resources reports still need to be consulted to substantiate the main report's brief cumulative effects and conclusions sections.

The cumulative induced seismicity impacts related to the York Potash proposed development are referred to in Section 3 of the main report, although which of the Applicants consultants authored the work is unclear. However, this part of the assessment makes no specific reference to any Rockflow Resources report, and does not appear to be as authoritative as previous Rockflow Resources work. The July 2015 Rockflow Resources report can be seen to be an attempt to address the deficiencies of this section of the main report.

4. Findings of the Amec Foster Wheeler Review

4.1 Issue 1: Implications of Rockflow Resources work with respect to produced water re-injection rates of any proposed new borehole at EMS Well Site, and in regard to the Helmsley-Filey Fault

In its original review, Amec Foster Wheeler was complementary about the work of Rockflow Resources with respect to induced seismicity risk due to the proposed disposal of produced water at the EMS Well Site, variously referring to it as "*authoritative*", "*detailed and technical*" and "*well documented and reasoned*". It is therefore disappointing that the request by Amec Foster Wheeler for the Applicants (and therefore, by implication, given the highly technical nature of the work, Rockflow Resources) to discuss the implications of the risk assessment with respect to any new borehole on the EMS Well Site, and how its assessment of residual effects is reconciled with the Envireau Water '*area of influence*' calculations (Technical Report, Section 5.3), seems to have been overlooked.

With no new information provided in the FSI in regard to these matters, Amec Foster Wheeler proposes to the following:

- ▶ To avoid the risk of breaching the fracture gradient and potentially causing a seismic event, the previous (July 2014) advice of Rockflow Resources with respect to the existing borehole at the EMS Well Site should also be adopted (indeed, conditioned) for any new borehole, or any combination of old and new boreholes. This advocates that water would be injected at a bottom-hole pressure (BHP) no more than 1000 pounds per square inch absolute (psia) above



the initial formation pressure, no booster pump would be used to supplement the efforts of the electric submersible pump(s) (ESP(s)), and that an acceptable monitoring scheme design of formation pressures and trigger levels would be implemented; and

- ▶ The Envireau Water 'area of influence' calculations are considered overly simplistic and precautionary, and discounted in favour of the more comprehensive and informed Rockflow Resources calculations, and which imply a 'Negligible' 'Not Significant' residual risk of induced seismicity with respect to the EMS re-injection alone.

4.2 Issue 2: Findings of revised cumulative impact assessment

Issue 2a: With respect to the EMS Well Site surface works and the pipeline

The Appendix 1 Elliott Associates letter observes that Ebberston 'A' sits beyond the Scarborough (what Elliott Associates refer to as the Troutsdale) SPZ that underlies the EMS Well Site. This is important, because it implies that the two well site surface works (Ebberston 'A' and EMS) would not result in cumulative impacts on the underlying groundwater.

With respect to pipeline effects, Elliott Associates is of the view that the potential effects of the pipelines (Ebberston 'A' - Knapton and EMS - Knapton) would be similar to each other, and together would not be sufficient to increase the significance of residual effects above 'Negligible' and 'Not Significant'. Amec Foster Wheeler is accepting of this position.

Based on the above considerations, Amec Foster Wheeler agrees with the Elliott Associates summary of residual cumulative effects and evaluation of significance in its revised assessment table i.e. that the cumulative residual effects are 'Negligible' and 'Not Significant'. However, as an aside, as with the previous Elliott Associates residual effects assessment table provided in February 2015, the potential (pre-mitigation) magnitude and significance scores are not using the correct terminology e.g. for the pipelines in the SPZ, the magnitude score should be 'Moderate/Minor' and the significance level 'Major/Moderate to Moderate/Minor'.

Issue 2b: With respect to the produced water disposal

The Rockflow Resources Ebberston Moor report (November 2014) uses the same form of approach previously adopted for the EMS Well Site to assess induced seismicity risks for both Ebberston 'A' alone and for the entire Ebberston Complex (Ebberston Moor and Ebberston South/Wykeham gas fields). The latter assessment provides information on the cumulative effects of the EMS and Ebberston 'A' re-injection schemes, and therefore addresses part of Issue 2b. The two re-injection schemes are essentially as understood by Amec Foster Wheeler in its February 2015 ES review report, with some 3500 barrels per day (bpd, 556 m³/d) injected into the deep Sherwood Sandstone at EMS, and about 8500 bpd (1351 m³/d) injected into the same aquifer at Ebberston 'A' (via a recompleted EM-1 well or a new nearby EM-A well). Rockflow Resources Table 4-2 details the maximum pressure rise after ten years that can be expected for different injection volumes across a number of effective thickness-hydraulic property-area scenarios. For the expected base case injection volume (4.4 million barrels, MMbbl, equivalent to 700000 m³), the combined re-injection is shown to be extremely unlikely to trigger a seismic event, with the formation pressure rise classed as 'safe' (0-450 psi) or 'monitor' (450-900 psi) for all scenarios except that for the thin (76 m), low net pore fraction (5%) sandstone over a 69 km² area defined rather artificially with respect to the extent of the seismic 3D coverage. The table shows that the risk of an event increases further if higher injection volumes into relatively small hydraulically connected areas (pressure compartments) are required, but even in these circumstances the monitoring of formation and injection pressures and the adoption of a low injection pressure strategy would lessen the risk. Indeed, by assigning probabilities to the various elements of the injection system, Rockflow Resources has estimated that with the additional mitigation, the likelihood that combined EMS and EMA re-injection would cause a seismic event with a magnitude greater than 0.0 is less than 1 in 50,000 (Table 5-1), which Amec Foster Wheeler considers is equivalent, in EIA terms, to a 'Negligible', 'Not Significant' cumulative effect.

This assessment is taken on further by the Rockflow Resources Vale of Pickering report (April 2015), which has a Section 4.4.1 addendum that considers the cumulative impact of the Vale of Pickering and Ebberston Moor (combined Ebberston 'A' and EMS) re-injection schemes. This notes that the Vale of Pickering and Ebberston Moor fields are some 10 km apart and are effectively separated by the Pickering Fault. As a

result, the pressure compartment scenarios for the two schemes generally do not overlap, and as such the re-injections would have no cumulative impacts. The only exception to this is with respect to the so-called 'Regional aquifer' scenario, which comprises the entire >3800 km² onshore extent of the Sherwood Sandstone Formation, and includes both gas fields. However, even for the 'worst case' 'Regional aquifer' scenario, the combined injection of 42.7 MMbbl (comprising 19.6 MMbbl for the Vale of Pickering and 23.1 MMbbl for Ebberston Moor, and equivalent to 6.8 Mm³) formation pressure would rise by only 188 pounds per square inch (psi), which is less than half the minimum trap integrity in the shallower Vale of Pickering area of 500 psi, and hence the cumulative re-injection would fall into the 'safe' category, and is extremely unlikely to trigger a seismic event. Monitoring of formation and injection pressures and the adoption of a low injection pressure strategy would again further minimise the risk. The residual impact is considered by Amec Foster Wheeler to again be equivalent, in EIA terms, to a 'Negligible', 'Not Significant' cumulative effect.

A consideration of the final component of the cumulative impact assessment is presented in the FSI Section 3, which looks at the combined effects of the Vale of Pickering, Ebberston Moor and York Potash re-injections. Adding what the Applicants (and/or Envireau Water) consider to be a maximum cumulative (over ten years) injection volume of 16 MMbbl for York Potash Limited's (YPL) 'worst case' scenario to the Vale of Pickering-Ebberston Moor 42.7 MMbbl, and using 'worst case' subsurface parameters (which Amec Foster Wheeler has deduced to be an effective thickness of 76 m and a net pore fraction of 5%), would result in a total re-injection volume of 58.7 MMbbl (9.3 Mm³) and raise the regional aquifer pressure by up to about 260 psi, half the minimum trap integrity, and at the upper end of the 'safe' category and the lower end of the 'monitor' category. Amec Foster Wheeler considers that with monitoring of formation and injection pressures and the adoption of a low injection pressure strategy, the residual impact would again reduce to a 'Negligible', 'Not Significant' effect.

However, the FSI Section 3 also considers a more worrying 'worst case' scenario. If the Pickering Fault is 'sealing', the ~40 MMbbl (6.4 Mm³) combined Ebberston Moor-York Potash re-injections into the remaining smaller (300 km²) area of aquifer (the mapped onshore extent of the Sherwood Sandstone Formation that is not crossed by significant faults and lies more than 914 metres below ground level (mbgl); Figure 4.17, Rockflow Resources, November 2014) is reported to result in aquifer pressures rising into the 'Unsafe' or 'Very Risky' categories. Indeed, in undertaking the calculations itself, Amec Foster Wheeler has identified instances where the pressures rise into the 'dangerous' (> 1500 psi) category, and in these circumstances the suggestion in the FSI that reliance is simply put on regular pressure monitoring and a feedback mechanism where injection pressures reduce over time as they come into equilibrium with aquifer pressures is considered by Amec Foster Wheeler to be insufficient, and more assessment is required. Without this information, Amec Foster Wheeler maintains that there is a case for assessing the cumulative re-injection effect as being of at least 'Moderate' in magnitude, which would imply a 'Major-Moderate' and 'Significant' effect on the overlying 'High' sensitivity infrastructure and local population.

Amec Foster Wheeler considers that the focus by the Applicants in its main report on the 'worst case' scenario has led to an overstating of the overall risk, and for a better appreciation of the Ebberston Moor-York Potash re-injection cumulative effects, some calculations for a wider range of scenarios are required, in a similar way to that undertaken by Rockflow Resources for its Ebberston Moor assessment (November 2014). This would involve retaining the relatively small (~300 km²) assessment area, but looking at different sandstone thicknesses, net pore fractions, and injection volumes.

This concern was expressed by Amec Foster Wheeler to the Authority in an email dated 1st July 2015, but appears to have been anticipated by the Applicants, because the Rockflow Resources report published the following day presents a more detailed and comprehensive assessment of the cumulative induced seismicity impact of the three re-injection schemes. Adopting a similar form of approach as adopted in its previous work, Rockflow Resources has calculated the maximum pressure rise after ten years that can be expected for different injection volumes across a number of effective thickness-hydraulic property scenarios and for both the regional aquifer (Vale of Pickering, Ebberston Moor and York Potash) and 'sealed Pickering Fault' (Ebberston Moor and York Potash) pressure compartments.

Whilst acknowledging the lack of detailed published information regarding YPLs proposed re-injection rates, Rockflow Resources has indeed looked at a wide range of scenarios, and as a result has provided a more balanced and authoritative view of the likely pressure increases compared to the main report 'worst case' only assessment. The findings of the 'Regional aquifer' assessment is similar to that in the main report, with pressure rises of ~200 psi, less than half the Vale of Pickering minimum trap intensity and at the upper end of the 'safe' category. However, it is especially with respect to the 'sealed Pickering Fault' that the pressure

increases have been put into better context, with pressure increases all in the 'safe' or 'monitor' categories except for the larger re-injection volumes for thin (76 m) and low net pore fraction (7%) scenarios. Although unexplained changes to some of the input parameter values compared to those used in the main report work in favour of the Applicants case, e.g. the change in the 'sealed Pickering Fault' area from 300 to 400 km² and the net pore fraction from 5 to 7 %, Amec Foster Wheeler can anticipate Rockflow Resources justification for some of these changes. Amec Foster Wheeler therefore considers that with monitoring of formation and injection pressures and the adoption of a low injection pressure strategy, the residual impact would reduce to a 'Negligible', 'Not Significant' effect.

5. Conclusions

Amec Foster Wheeler has completed a review of the Applicants FSI with respect to the proposed Ebberston Moor South Wellsite — Knapton Gas Pipeline.

The FSI has unfortunately provided no new information with respect to the implications of the Rockflow Resources Limited work in terms of the produced water re-injection rates of any proposed new borehole at the EMS Well Site, and in regard to the Helmsley-Filey Fault (Issue 1). Amec Foster Wheeler therefore firstly proposes that the previous (July 2014) advice of Rockflow Resources with respect to the existing borehole at the EMS Well Site should be adopted (indeed, conditioned) for any new borehole, or any combination of old and new boreholes. This advocates that water would be injected at a BHP no more than 1000 psia above the initial formation pressure, no booster pump would be used to supplement the efforts of the ESP(s), and that an acceptable monitoring scheme design of formation pressures and trigger levels is implemented. Secondly, reliance is placed on the Rockflow Resources calculations, rather than those of Envireau Water, with respect to the residual risk with respect to the EMS re-injection alone, and on that basis Amec Foster Wheeler advises that the risk is 'Negligible' and 'Not Significant'.

With respect to the findings of a revised cumulative impact assessment, both with respect to the EMS Well Site surface works and the pipeline (Issue 2a), and the produced water disposal (Issue 2b), Amec Foster Wheeler firstly (Issue 2a) accepts the findings of Elliott Associates that the Ebberston 'A' and EMS surface works do not both reside in the Troutsdale SPZ, and so would not have cumulative impacts on the underlying groundwater, and also that the two pipelines would not together be sufficient to increase the significance of residual effects above 'Negligible' and 'Not Significant'. Secondly, in terms of Issue 2b, the newly provided Rockflow Resources reports (November 2014, April 2015 and July 2015) present quantitative assessments that suggest that the cumulative produced water disposal effects of EMS and Ebberston 'A', then the entire Ebberston Moor re-injection with that of the Vale of Pickering, and finally the Vale of Pickering, Ebberston Moor and York Potash re-injections, are also both 'Negligible' and 'Not Significant'.

On this basis, Amec Foster Wheeler considers that its outstanding concerns regarding the residual induced seismicity assessment and the findings of a revised cumulative impact assessment have been satisfactorily addressed.

Author



Dr Shaun Salmon

Reviewer



Dr Mike Carey

Copyright and non-disclosure notice

The contents and layout of this report are subject to copyright owned by Amec Foster Wheeler (© Amec Foster Wheeler Environment & Infrastructure UK Limited 2015), save to the extent that copyright has been legally assigned by us to another party or is used by Amec Foster Wheeler under licence. To the extent that we own the copyright in this report, it may not be copied or used without our prior written agreement for any purpose other than the purpose indicated in this report. The methodology (if any) contained in this report is provided to you in confidence and must not be disclosed or copied to third parties without the prior written agreement of Amec Foster Wheeler. Disclosure of that information may constitute an actionable breach of confidence or may otherwise prejudice our commercial interests. Any third party who obtains access to this report by any means will, in any event, be subject to the Third Party Disclaimer set out below.



Third party disclaimer

Any disclosure of this report to a third party is subject to this disclaimer. The report was prepared by Amec Foster Wheeler at the instruction of, and for use by, our client named on the front of the report. It does not in any way constitute advice to any third party who is able to access it by any means. Amec Foster Wheeler excludes to the fullest extent lawfully permitted all liability whatsoever for any loss or damage howsoever arising from reliance on the contents of this report. We do not however exclude our liability (if any) for personal injury or death resulting from our negligence, for fraud or any other matter in relation to which we cannot legally exclude liability.

Management systems

This document has been produced by Amec Foster Wheeler Environment & Infrastructure UK Limited in full compliance with the management systems, which have been certified to ISO 9001, ISO 14001 and OHSAS 18001 by LRQA.