



SLD Deadline 3 Submission

LIME DOWN SOLAR PROJECT

DEADLINE 3 SUBMISSION
STOP LIME DOWN

15 June 2026





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1. Introduction

1.1.1. This document comprises Stop Lime Down's (**SLD('s)**) Deadline 3 submission.

This document will address:

- SLD's responses to the ExA's first written questions for SLD (**ExQ1**);
- SLD comments on ExQ1;
- Comments on documents submitted by the Applicant at Deadline 2; and,
- Comments on documents submitted by other Interested Parties at Deadline 2.

1.1.2. This document has been produced with the input of SLD's legal and expert advisors. Unless stated otherwise, the relevant answer to or comment on a document is provided with the input of SLD's expert listed at para 1.3.1 of its Written Representation [**REP1-167**] (**the SLD WR**).

1.1.3. In comments on ExQ1, SLD has taken a proportionate approach recognising that many of the questions commented upon are not in the first instance directed to SLD. At the appropriate time, SLD will provide comments on the responses offered by the Applicant and other Interested Parties.

1.1.4. The Applicant and Wiltshire Council have both provided comments on the Written Representation produced by SLD. To avoid repetition or proliferation of comments, SLD has only provided comment in reply where there is something additional to make clear (whether by way of agreement or disagreement). In addition, SLD is progressing a Statement of Common Ground with the Applicant. SLD maintains its position as set out in the SLD WR and attached Appendices unless stated otherwise.

1.1.5. SLD also notes that the Applicant proposes in a number of topic areas to submit further Technical Notes related to SLD's submissions. SLD will comment on these



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when they become available (e.g. in respect of traffic and transport related matters).

1.1.6. This written submission uses the document reference for the tracked change version of documents where multiple versions of the document exist in the Document Library.

1.1.7. SLD welcome any questions that the ExA or any other party (including the Applicant) may have about this submission. SLD will continue to take steps to assist the ExA and advance its case throughout the remainder of the Examination.

1.1.8. This submission has not been produced with the use of AI.

2. SLD Responses to ExQ1

2.1.1. The acronym “LVIR” is used to refer to SLD’s Written Representation, Appendix B (Landscape and Visual Impact Report) [REP1-170].

Reference	Question	SLD’s Response
<p>LV1.6</p> <p>Landscape and Visual</p>	<p>Landscape Character – Assessment Methodology</p> <p>In the ES [APP-060] the applicant has assessed effects to landscape character relative to each study area (1km, 2km, 5km) as a single receptor rather than each of the separate landscape receptors (LCTs, LCAs) that make up each study area. The ExA understands that the intention of this approach is to look at the effects of the proposed development on the holistic patchwork of landscape character within each study area.</p>	<p>2.1.2. In SLD’s landscape expert’s opinion, the Applicant’s approach is acceptable for the purposes of this exercise, but it could be improved.</p> <p>2.1.3. In fact, in Ms. Tinkler’s experience, it is unusual for LVIA’s not to assess and report effects on character types / areas, as advised in the Landscape Institute’s Guidelines for Landscape and Visual Impact Assessment 3rd Edition (GLVIA3), and instead assess / report effects on all landscapes within geographical areas with arbitrary distance-related boundaries, which is what the Applicant’s LVIA has done.</p> <p>2.1.4. While this overview of the baseline situation of, and effects upon, the landscapes of the Proposed Development and wider area taken as a whole is useful, it could be helpful if effects on each NCA, LCT, and LCA were also assessed and reported, as this would add another dimension</p>



	<p>However, it is not clear to the ExA that this approach captures the impacts on the different landscape receptors and the individual characteristics identified in the relevant landscape character assessments.</p> <p><u>Wiltshire Council and SLD:</u> Wiltshire Council and SLD are asked if they consider that the applicant's approach is acceptable?</p> <p><u>The applicant:</u> The applicant is asked to either: 1) Provide further justification for its approach including reference to relevant guidance and precedent from other Nationally Significant</p>	<p>to the assessment of effects which, in the LVIA, lacks granularity – as explained in SLD's LVIR.</p> <p>2.1.5. GLVIA3 addresses the approach that should be followed: see, for example §§5.12 – 5.18, and §5.50 which explains that “The geographical area over which the landscape effects will be felt must also be considered,” and “The extent of the effects will vary widely depending on the nature of the proposal.” It goes on to list several categories of scale at which LVIA's may be carried out, but emphasises that “there can be no hard and fast rules about what categories to use” – ultimately, therefore, it is a question of professional judgement.</p> <p>2.1.6. The scales are as follows (with original emphasis):</p> <ul style="list-style-type: none">• “at the site level, within the development site itself;• at the level of the immediate setting of the site;• at the scale of the landscape type or character area within which the proposal lies;• on a larger scale, influencing several landscape types or character areas.”
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	<p>Infrastructure Project (NSIP) scale solar projects; or</p> <p>2) Provide an updated assessment defining the effects relative to the separate landscape receptors rather than to each study area as a whole</p>	<p>2.1.7. In this case, “larger” (the largest) scale is appropriate because the scale of the development is very large – see [REP1-170], §§8.2.10 – 8.2.17 (if consented, Lime Down would be one of the largest solar NSIPs in the UK). It certainly would influence (and be influenced by) several landscape types or character areas, and the Applicant’s LVIA recognises and acknowledges this.</p> <p>2.1.8. However, although only in the context of visual assessments, GLVIA3 also advises (see for example §6.21) that assessments should be “reasonable” and “proportional”, “in relation to the scale and nature of the development proposal and its likely significant effects” (emphasis added), which in Ms. Tinkler’s opinion applies to character assessment as well.</p> <p>2.1.9. Here, given the large scale and associated large extent of influence, it may be acceptable for the Applicant to assess effects within geographical areas as opposed to published character areas / types on the landscapes which lie a certain distance from the Scheme (for example beyond the</p>
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		<p>point where it is agreed that effects would cease to be “significant”), whereas closer to the sites, and on the sites themselves, it is likely that the boundaries between the areas / types, and notable localised variations within them, would be distinct, and effects upon them would be easier to discern.</p> <p>2.1.10. As set out in SLD’s LVIR, in Ms. Tinkler’s opinion, many of the significant adverse indirect effects on landscape character would a) extend further than 1km, which is what the LVIA concludes; and b) last for the duration of the operation, which the LVIA assumes would not be the case.</p> <p>2.1.11. The effects assessment should focus on the areas where the highest levels of effects would occur, factoring in that levels of effects tend to decrease gradually with distance from the development. In Ms. Tinkler’s opinion, as explained in LVIR §8.5.10, at and just beyond the 1km study area boundary there would be significant indirect adverse effects, up to Major/Moderate Adverse (significant). Beyond, gradually, the levels would decrease with distance to Neutral. At some point</p>
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		<p>between 1km and 5km from the Order Limits, the level would be as predicted in the LVIA, i.e. Moderate/Minor Adverse (not significant). This point would vary in distance depending on area-specific factors.</p> <p>2.1.12. The findings should be cross-referenced with the distance-related effects assessments. As advised in GLVIA3, assessors should check that the published assessments are suitable for the purpose, and identify and factor in any notable localised variations identified within the character areas / types (the LVIA does not identify such variations, ascribing the same levels of sensitivity to very large geographical areas).</p> <p>2.1.13. Also, the assessment would be carried out with consideration of comments made in SLD's LVIR about the LVIA's approach generally, especially method / technical matters. It is hoped that the landscape experts will be able to engage as part of the SoCG process in due course.</p> <p>2.1.14. In addition, it is important to establish the "significance" threshold that would be used for these and other exercises. As explained in SLD's LVIR at §§3.4.22- 3.4.28, whilst Ms. Tinkler agrees with the LVIA's</p>
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		<p>set threshold of Moderate, with the point scales used in the LVIA, the Moderate level is not in the middle as it should be, so judgements about whether or not an effect is significant are not properly balanced.</p> <p>2.1.15. Finally, see the point made in LV1.24 below, about considering the size of the area / type and then calculating the proportion / percentage that would be adversely affected, as well as – importantly – to what degree.</p>
<p>LV1.9 Landscape and Visual</p>	<p>Cotswold National Landscape – Setting The parties are asked to define in spatial terms the extent of the area outside of the boundary of the Cotswolds National Landscape (CNL) that is considered to form the setting of the CNL.</p>	<p>2.1.16. Ms. Tinkler’s opinion is that, from the CNL’s eastern boundary, the CNL’s setting extends eastwards to a line east of Norton and west of Hullavington, parallel to the Fosse Way, so Lime Down A, B and C lie within the setting.</p> <p>2.1.17. On balance, Lime Down D and E are not considered to lie within the CNL’s setting.</p> <p>2.1.18. Notwithstanding this, it could be argued that the western edges of Lime Down D are also within the setting, as it is the same distance</p>



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		<p>from the CNL's western boundary as the eastern parts of Lime Down B and C; however, Lime Down B is also within the setting of the CNL to the north, and relatively close to (c. 250m from) the northern boundary, albeit currently, panels are set back. The boundaries of Lime Down C are broadly c. 2km from the boundary at their furthest points. At its closest point, Lime Down D lies c. 2.5km from the CNL boundary.</p> <p>2.1.19. Ms. Tinkler's opinion is mainly due to the fact that the degree of intervisibility between the CNL and the Scheme decreases gradually with distance from west to east. Therefore, levels of adverse effects within the CNL's setting (and thus indirect effects on the CNL itself) would be "significant" adjacent to the CNL's boundary, but are unlikely to be "significant" at distances over c. 3km from it.</p> <p>2.1.20. For the purposes of the Applicant's assessments, the extent of the CNL's setting was agreed with the CNLB – or at least, that Sites Lime Down A, B, and C (or parts of them – see below) lie within the CNL's setting.</p>
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		<p>2.1.21. It is not clear what criteria the Applicant applied in determining the extent of the setting, and clarification of this would also be helpful. It may be as confirmed in [APP-197] that the CNLB defines the CNL's setting as "the area within which development and land management proposals, by virtue of their nature, size, scale, siting materials or design can be considered to have an impact, positive or negative, on the landscape, scenic beauty and special qualities of the Cotswolds AONB."</p> <p>2.1.22. Also, para. 1.7.7 of [APP-197] explains, "It is agreed with the Cotswolds National Landscape Board that parts of Sites A, B, and C are within the setting of the CNL" (emphasis added). SLD have not been able to ascertain which parts of Sites A, B, and C are considered to be within the CNL's setting. Clarity is also sought on this point. SLD are of the view that all parts lie within the setting.</p> <p>2.1.23. While Lime Down D and E are not considered to lie within the CNL's setting because of lack of intervisibility, it must be borne in mind that Lime Down D and E are physically linked to the rest of the Scheme which lies to the west (Lime Down A, B and C), which runs to the CNL</p>
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		<p>boundary. Therefore, as people travel through / in proximity to the Scheme on their way to / from the CNL, the whole Proposed Development could be experienced over a distance of several kilometres. From the Scheme’s eastern boundary, the effects would start a long distance from the CNL.</p>
<p>LV1.19 Landscape and Visual</p>	<p>Visual Impact – Residential Visual Amenity Assessment SLD explains in its Landscape and Visual Impact Report [REP1-170] that it disagrees with the applicant’s approach that a residential visual amenity assessment (RVAA) is not required and states that the level of effect that would be experienced by receptors at Grain Store Barn does cross the threshold for ‘full’ RVAA. SLD also states that may also be the case for other residential receptors.</p>	<p>2.1.24. In Ms. Tinkler’s opinion, as a minimum, the residential properties which should be subject to a “full” RVAA are those listed in [APP-191] Appendix 8-3-2-2-2: Visual Assessment Sheets of Private Receptors (Significant), Table 5.2 Private Receptor – Individual. Or, at least, those properties at which the LVIA categorises receptor value as Low in that Table. (Note Table 5.1 Private Receptor – Group should also be included but this is already identified in the ExA’s question).</p> <p>2.1.25. Ms. Tinkler disagrees with the Applicant’s RVAA’s conclusion that none of the receptors identified required a ‘full’ RVAA, as explained in SLD’s LVIR at §§10.4.14 – 10.4.31.</p>



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	<p><u>Wiltshire Council</u></p> <p>1) Do Wiltshire Council agree with the applicant's approach that a RVAA is not required? If it does not, provide reasoning and identify the residential receptors that you consider should be scoped into RVAA and why?</p> <p><u>Stop Lime Down:</u></p> <p>2) SLD are asked to identify any other receptors they consider should be subject to a full RVAA</p>	<p>2.1.26. Ms. Tinkler considers that the level of effect that would be experienced by receptors at Grain Store Barn does cross the threshold for "full" RVAA, and that that is likely also be the case for other residential receptors, especially where arrays would wrap around property boundaries, resulting in a high degree of horizontal visual encapsulation.</p> <p>2.1.27. The main reason for the difference of opinion, as explained (and queried) in the LVIR, is that the LVIA judges the level of the residential receptor's visual value to be Low, despite having concluded that the landscapes which are viewed by residents are of High value. This has led to levels of adverse visual effects having been underestimated, and therefore, effects at some properties should, properly assessed, would be above the "full" RVAA threshold.</p> <p>2.1.28. There are other residential receptors in proximity to those on the above list and elsewhere, mostly in / around Norton, and in the area between Lime Down A and the Fosse Way, but Ms. Tinkler has not visited the properties.</p>
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		<p>2.1.29. This exercise could be undertaken if required. However, as explained in Section 10.4 of the LVIR, Ms. Tinkler has concerns about the RVAA method / its interpretation which, in her opinion, need to be addressed prior to further evaluation.</p> <p>2.1.30. In Ms. Tinkler's opinion, the published RVAA guidance is not clear about certain matters which affect judgements about whether a "full" RVAA is required. For example, the guidance does not explain (nor does the Applicant's LVIA) how to establish the criteria for judgements about what constitutes the "largest" or "greatest" magnitude of effect.</p> <p>2.1.31. Also, the guidance does not state that the RVAA threshold only applies to residual effects, i.e. once proposed screening measures are assumed to have become effective (in this case, Year 15): the Applicant's RVAA has adopted this approach. However, in Ms. Tinkler's opinion, the threshold can be met between Year 1 and Year 15, because until mitigation in the form of screen planting became fully effective (assuming it did – see below), certain residential receptors would experience levels of adverse effects high enough to breach the RVAA threshold.</p>
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		<p>2.1.32. Regarding mitigation proposed to lower levels of adverse residual visual effects, as explained in Section 7.5 of SLD’s LVIR, the Applicant’s LVIA relies heavily on existing and proposed vegetation to reduce high levels of adverse effects by screening / filtering views of the Scheme (as does the glint and glare study). However, it is unlikely that all existing / proposed screening vegetation would remain in place for the lifetime of a development, as the LVIA assumes.</p> <p>2.1.33. Furthermore, and importantly, the Applicant’s RVAA does not factor in that whilst the proposed planting may screen views of the Scheme, it would also result in the total loss of view, resulting in high levels of adverse visual effect, as noted in SLD’s LVIR.</p>
<p>LV1.23 Landscape and Visual</p>	<p>Cumulative and Combined Effects - Cumulative Sequential Visual Effects Both Wiltshire Council [REP1-137] and SLD [REP1-170] raise concern</p>	<p>2.1.34. In response to Wiltshire Council’s RR [RR-4934], the Applicant had agreed to assess the cumulative sequential visual effects along the Fosse Way, the A429, and A350 routes, and at Deadline 1, submitted a Technical Note on Cumulative Sequential Visual Effects [REP1-123].</p>



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	<p>that the applicant’s assessment of cumulative landscape and visual effects does not consider sequential visual effects. Wiltshire Council identified [REP1-137] routes that the sequential assessment should include and the applicant provided a Technical Note on Cumulative Sequential Visual Effects [REP1-123].</p> <p><u>The Applicant:</u></p> <p>1) The applicant is asked to provide an assessment of the sequential visual effects from cumulative developments on users of the Wiltshire Cycleway within the 10km study area.</p> <p><u>Wiltshire Council:</u></p>	<p>2.1.35. In this question, SLD is asked by the ExA “to identify any other routes that it considers should be included in an assessment of [cumulative] sequential visual effects”.</p> <p>2.1.36. Please note that here, Ms. Tinkler is only considering inter-project cumulative effects, not intra-project, the latter occurring sequentially whilst travelling through / around the perimeter of the Proposed Development.</p> <p>2.1.37. SLD suggests two long-distance routes. The first is a main road used mainly by people in cars / on bicycles; the second follows PRowS and minor roads / lanes, used by people walking / cycling / on horseback. Both routes appear to be well-used by people visiting the region, since they run between strategic touristic locations such as the CNL and larger towns.</p> <p>2.1.38. Route 1 runs along the A429 between Chippenham (south) to Crudwell (north) (from Crudwell, the A429 continues north / north east to Cirencester). The A429 bisects Lime Down D and E. As well as Lime</p>
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	<p>2) Wiltshire Council is asked to confirm if it agrees with the applicant's methodology and conclusions in its Technical Note on Cumulative Sequential Visual Effects [REP1-123] that there would not be any additional significant adverse sequential visual effects on users of the Fosse Way or A429/A350.</p> <p><u>Stop Lime Down:</u></p> <p>3) SLD is asked to identify any other routes that it considers should be included in an assessment of sequential visual effects</p>	<p>Down, receptors could potentially experience five other solar developments.</p> <p>2.1.39. Route 2 runs south-east – north-west between Chippenham and the CNL at Sherston (the latter being a village with good facilities including accommodation for visitors, especially walkers, so a popular destination).</p> <p>2.1.40. It must be noted that there are numerous alternative routes between Chippenham and the CNL at Sherston, so travellers may not necessarily experience solar developments at multiple locations; however, during site surveys Ms. Tinkler met walkers and cyclists using this particular route who said they were travelling from Sherston to Chippenham, and knew of others who used it.</p> <p>2.1.41. Also, as explained at LVIR §8.6.47, research suggests that some or all of this route is of historic interest.</p>
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		<p>2.1.42. From Chippenham, the route runs through Kington St. Michael, passing two identified cumulative development sites along the way. There is a c. 3km gap between these sites and the southern boundary of Lime Down, where the route runs along Pig Lane, through Lime Down C. It continues north-eastwards, crossing the proposed cable corridor and the Fosse Way, running through Lime Down A for a distance of c. 2km, and crossing Foxley Lane just south of Sherston.</p>
<p>LV1.24 Landscape and Visual</p>	<p>Cumulative and Combined Effects – Cumulative Effects on Landscape Character The ES [APP-060] assesses cumulative effects to landscape character relative to study area distances offset from the boundary of Lime Down sites A to E. The ExA note from Figure 8-15-7 of the ES [APP-106] that the percentage of the area of LCA8 (Hullavington Rolling Lowlands)</p>	<p>2.1.43. Ms. Tinkler’s position on the correct scale of area to assess the cumulative effects to landscape character is that it should follow the approach set out in GLVIA3, which is considered to be the most appropriate starting point for this exercise. Ms. Tinker accepts that percentage cumulative land use change can be relevant here, as is explored below.</p> <p>2.1.44. In summary, the guidance explains that the scale of the area should be commensurate with the scale and geographical extent of the project, which, in the case of Lime Down, the guidance would categorise</p>



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	<p>that is currently taken up with solar development is 0.57%. The proposed development and other solar applications would increase that to 5.15% with the proposed development forming the largest share at 3.41%. The ExA seek to understand the different parties views on the scale at which cumulative landscape character effects should be assessed and have the following</p> <p><u>Wiltshire Council:</u></p> <p>2) Can Wiltshire Council and SLD provide their position on the correct scale of area to assess the cumulative effects to landscape character?</p> <p><u>All Parties:</u></p>	<p>as “larger” (i.e. the largest) scale, because it would cover and influence “several landscape types or character areas”.</p> <p>2.1.45. Firstly, GLVIA3 §7.27 explains that “The approach to assessing the significance of cumulative landscape effects should be guided by the same principles as the approach to the initial project assessment”. At §7.25, GLVIA3 explains that cumulative landscape and visual effects assessments should consider effects on the same / similar receptors to those identified in the effects assessments carried out for the stand-alone scheme, i.e. i) landscape “fabric”, ii) aesthetic / perceptual / experiential landscape aspects; and iii) overall character / key characteristics.</p> <p>2.1.46. Secondly, at §7.28, GLVIA3 states that “The most significant cumulative landscape effects are likely to be those that would give rise to changes in the landscape character of the study area of such an extent as to have major effects on its key characteristics and even, in some cases, to transform it into a different landscape type”.</p>
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	<p>3) The applicant, Wiltshire Council and SLD are asked whether, and to what extent, they consider that the percentage cumulative land-use change within LCA8 should be used as an indicator of the significance of cumulative adverse effect to the landscape character of the receptor?</p>	<p>2.1.47. The Summary advice on good practice at the end of Cumulative Landscape Effects Chapter 7 is that “Cumulative landscape effects must be considered particularly in terms of consequences for the key characteristics of the landscape in question”.</p> <p>2.1.48. In summary, Ms. Tinkler’s opinion reflects her response to LV1.6 above, i.e. it would be helpful if the LVIA assessed and reported cumulative effects on each NCA, LCT, and LCA, as this would add another dimension to the more in-depth analysis of landscape effects that may be necessary, but that it should factor in comments relating to method and scope.</p> <p>2.1.49. Regarding Point 3), in Ms. Tinkler’s opinion, the percentage cumulative land-use change within LCA8 should be used as an indicator of the significance of cumulative adverse effect to the landscape character of the receptor. The extent of this as an indicator is moderate, because other factors apply.</p>
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		<p>2.1.50. The relevant factors are set out in GLVIA3 paras. 5.49 – 5.50, and are ‘distinct’ from one another. They comprise 1) Size or scale, and 2) Geographical extent.</p> <p>2.1.51. Size and scale are relevant here, as in most cumulative effects assessments, because whilst effects on landscapes / elements may not occur over a large geographical area, they may nonetheless be ‘significant’, for example if the landscapes / elements are of high value / sensitivity, and the adverse effects accrue.</p> <p>2.1.52. Geographical extent is also relevant here, as in most cumulative effects assessments, because, as GLVIA3 para. 3.50 explains, the area within which effects occur may be small or large. Theoretically, and subject to levels of sensitivity and the size and scale of effects, the larger the area affected, the higher would be the level of effect on the area overall.</p>
<p>LV1.28</p>	<p>Glint and Glare – Stop Lime Down Assessment</p>	<p>2.1.53. As part of the ongoing SoCG process the Applicant and SLD have been in contact regarding a meeting between experts, including the</p>



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Landscape and Visual	<p>SLD provided a Glint and Glare Assessment at D1 [REP1-178]. The applicant is asked to consider the conclusions and recommendations set out in SLD's assessment, and in the forthcoming SoCG between the parties, the applicant and SLD are asked to set out where agreement can be found in relation to the assessment methodology, including but not necessarily limited to:</p> <ul style="list-style-type: none">• The model output data.• The assessment of impact on local roads.• Impact significance definition.• How the cumulative footprint of the proposed development is assessed, including in relation to Badminton and Bowldown Farm Airfields.	<p>Glint and Glare experts. SLD and the Applicant will explore the items identified, and anything else thought relevant to Glint and Glare, as part of that process. It is hoped that SLD and the Applicant will be able to provide a further update on this issue at the next Deadline. At this point, SLD fully maintains the position of its expert set out in Appendix G to its Written Representation [REP1-178]. SLD also note the comments in the Applicant's Response to Written Representations [REP2-039] at §SLD-120 and from §SLD-196. SLD's Appendix G already identifies the flaws in and absence of information provided by the Applicant. Following a meeting as requested by the ExA SLD will comment further, but notes the absence of concrete information on methodology and outputs.</p>
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	<ul style="list-style-type: none">• The assessment of train driver safety	
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3. SLD Comments on ExQ1

Reference	Question	SLD's Comment
Landscape and Visual		
LV1.1	<p>Landscape Fabric – Quantifying Loss and Provision</p> <p>Wiltshire Council raises concern in its LIR [REP1-137] that effects to landscape fabric are under-assessed. SLD also raises concern in its D1 submission [REP1-170] that mitigation measures have been double counted as enhancement. Table 8-15 and 8-16 in the ES [APP-060] present the proposed planting as landscape enhancements but the same overall figures for each planting typology in Table 8-16 are identified as mitigation measures in Table 8-18. To provide clarity surrounding the effects to</p>	<p>3.1.1. In relation to quantifying losses / gains / extent of planting, and explaining which measures are mitigation / enhancement, it would be helpful if the Applicant marked the information on a plan (for example [APP-084] Landscape and Ecology Mitigation Plan), perhaps using different colours for each.</p> <p>3.1.2. It would also be helpful if the Applicant could clarify the extent of what the LVIA calls “legacy” i.e. post-decommissioning landscape benefits. SLD’s landscape expert agrees that there could be a slight positive impact for some landscape “fabric” components.</p> <p>3.1.3. Note that post-decommissioning impacts are subject to factors such whether operational mitigation and enhancement “fabric” planting measures are retained / can be secured, and if retained, whether the operational hedge heights would be reduced (to avoid the continuation</p>



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	<p>landscape fabric and the extent to which proposed planting is for the purposes of mitigation or enhancement, the applicant is asked to quantify the following by planting typology:</p> <ol style="list-style-type: none">1) Loss of landscape fabric components.2) Additional landscape fabric components, including both mitigation and enhancement measures.3) Extent of proposed planting under point 2) above that would be required for the purpose of mitigating adverse landscape or visual effects.4) Extent of proposed planting under point 2) above that would be for enhancement only.	<p>of negative operational landscape / visual impacts from the blocking of views).</p>
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<p>LV1.17</p>	<p>Visual Impact – Security Measures Work No. 6(b) in the dDCO [REP1-007] includes ‘works for the provision of security and monitoring measures including CCTV columns, lighting columns and lighting, cameras, weather stations, communication infrastructure, and perimeter fencing’. Work No. 6 appears on the Works Plans [REP1-005] to cover all the solar PV, BESS and substation areas. The applicant is asked to provide details of where CCTV columns, lighting columns and lighting, cameras, weather stations and communication infrastructure would be located and to explain how the visual impact of these components has been taken into account?</p>	<p>3.1.4. It would also be helpful to understand how the Applicant intends to ensure that security measures such as CCTV cameras / motion sensors / infra-red beams would operate effectively without visual obstruction from existing / proposed hedges and trees along / in proximity to the security fences along which much of the surveillance equipment that would be installed.</p> <p>3.1.5. Also, due to the risk of solar crime, in responses to applications for solar developments, some Police Designing Out Crime Officers (DOCOs) recommend that in order to maintain visual transparency, where potentially accessible to thieves / vandals, security fences should not be lined with hedges / trees. However, this may conflict with the need to screen views. The indicative plans for Lime Down suggest that on the whole, security fences would be separated from hedges / trees by an open buffer, but there are instances where hedges are proposed along the fencelines.</p>
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<p>LV 1.27</p>	<p>Design – Energy Storage Facility and Substations</p> <p>The applicant is asked to provide further explanation of how the energy storage facility (Work No. 2) and the onsite substations (Work No. 3) would be capable of being laid out and designed (including through use of colour and materials) in order to promote the best possible aesthetic and visual appearance and to minimise landscape and visual effects?</p>	<p>3.1.6. Ms. Tinkler notes that usually there is little potential for design flexibility for substations and associated infrastructure / elements.</p> <p>3.1.7. Substations are utilitarian industrial structures designed to perform specific functions within tightly-defined parameters, so unless enclosed / covered in some way, there is little scope for mitigation. However, it is noted that the usual substation colour palette is relatively “neutral”, comprising metallic frameworks, galvanized steel security fencing / support structures, and battleship grey transformers / circuit breakers. These colours tend to not result in high levels of contrast when seen against many landscape backdrops, but silhouetting occurs against sky.</p> <p>3.1.8. Regarding other elements, the choice of colour and materials is always important, especially for Lime Down: given the large size and scale of the Proposed Development, and its high degree of visibility, the adverse effects resulting from inappropriate, industrialising forms, colours and materials within this rural landscape would extend very widely. Combined with other design measures, the careful use of colour / materials can not</p>
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		<p>only help to camouflage / visually integrate built form into the receiving context's palette, but also to reduce the perception of scale and mass.</p> <p>3.1.9. Colour contrast is an important consideration: for example, white against a dark background can result in far higher levels of adverse visual effects than when colour and tone are integrated into the backdrop. Note that under certain light conditions, solar panels may appear black, which can usually assimilate quite well into most contexts. However, the panels' mountings are usually metal, so the eye is drawn to the geometric shapes and patterns created by the contrast in tone.</p> <p>3.1.10. For solar and BESS structures / units, usually a choice of white, grey, or green is proposed, to suit the contextual backdrop colour. However, the following should be borne in mind:</p> <ul style="list-style-type: none">• From different locations, the same built form / structures may be seen variously against woodland, grass, crops, soil, solar panels, other built form / structures, water, sky, and so on, with resulting contrast and / or silhouetting.
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		<ul style="list-style-type: none">• The majority of solar and BESS structures / units are delivered as industry standard, and are usually either white, or the manufacturer’s interpretation of green (which can be difficult to integrate successfully into a visually diverse landscape backdrop).• Tonality is just as important as hue: for example, tones of “grey” vary from almost black to almost white. <p>3.1.11. In Ms. Tinkler’s opinion, it would be helpful if the Applicant demonstrated more precisely how the adverse landscape and visual effects of colour, material, and scale would be mitigated. An Environmental Colour Assessment (ECA) would be the most appropriate form of assessment to ensure the most appropriate choices of colours and materials: this should be considered in this case.</p> <p>3.1.12. See, for example, the Landscape Institute’s Technical Information Note (TIN) 04/2018 https://www.landscapeinstitute.org/technical-resource/environmental-colour-assessment/. Provision for this should be made in the draft DCO or in the relevant Outline Plan.</p>
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Traffic and Transport		
TT1.7	<p>Construction Worker Numbers</p> <p>Paragraph 3.2.7 of the oCTMP [REP1-112] states that ‘on a peak day, assuming the build out of all areas/elements of the scheme concurrently, there is expected to be a peak of 622 workers spread across the solar PV sites. For assessment, construction workers have been spread across the solar PV sites on a proportional basis, based on the size of each area.’ Table 1 of the oCTMP provides an indicative construction programme, which shows Lime Down A, B and D all starting construction at the same time but Lime Down A and B finishing after 9 months. Lime Down C</p>	<p>3.1.13. SLD’s transport expert, Bruce Bamber of Railton TPC, notes that the Applicant has purported to spread construction workers across the solar PV sites “on a proportional basis.” However, in reality, the 400kV substation and the BESS, both in Lime Down D, are likely to attract well above the “average” for the solar sites. The 400kV substation is now predicted to be constructed in the first 6 months of the schedule and the BESS over a 19-month period commencing in month 5 (see Table 13-9 of the May 2026 TA, [REP1-058]). Connectedly, Mr. Bamber would question whether a 6-month timescale to construct a 400kV substation is realistic, particularly given that 19 months is allowed for the BESS. Even if the 400kV substation were to be constructed within 6 months, Lime Down D is still likely to be attracting proportionally more workers than other areas because of the BESS works.</p> <p>3.1.14. Mr. Bamber shares the concern raised in respect of the Applicant’s assumption that 50% of workers would arrive by shuttle bus and that average car occupancy would be 1.5. Mr. Bamber would add</p>



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	<p>and E would commence around the 8-9 month mark and would be built alongside the rest of Lime Down D. Given that workers to each of these sites would not be compelled to use the company shuttle buses (or car share) and given the different build out periods, the ExA is concerned that spreading out the assessment impact of workers on a proportional basis (and on the assumption that 50% would use shuttle buses and each car would accommodate 1.5 construction workers) is not cautious enough to capture local traffic hotspots at the worst case, and when in the construction period those worst case impacts are likely to occur. The ExA therefore requires the applicant to</p>	<p>that an average shuttle bus occupancy of 20 workers has been assumed (see Annex E of TA). This would appear to be ambitious.</p>
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	<p>provide a detailed rationale for their chosen methodology.</p> <p>The ExA also welcomes any comment from the LHA on the appropriateness of the applicant's chosen methodology.</p>	
Cultural Heritage		
CH1.2	Heritage Visualisations 1 Paragraph 4.5.1 of ES Appendix 12-1 (Heritage Statement) [APP-219] states that heritage visualisations were agreed with Wiltshire Council on January 2024 (Annex E). However, Annex E only provides a list of heritage viewpoints. Can the applicant please direct the ExA to where the visualisations for these viewpoints are	3.1.15. SLD's built heritage expert, Lucy Nicholson of Marrons, considers that it would also be helpful for visualisations to include the "wireframe" to show the height of the installed infrastructure. The height of the panels will have an obvious impact on the amount of visibility and impact.



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	<p>provided? If they have not been provided with the application material, then these are to be provided in response to this ExQ. Historic England and Wiltshire Council are also invited to suggest additional visualisations which they consider should be provided by the applicant to assist the examination, and may find the following documents helpful to inform their consideration – ES Figure 8-10 [APP-099] and ES Figure 12-1 [APP-143]. The applicant is subsequently requested to provide the additional visualisations or justification as to why not.</p>	
CH1.3	<p>Bradfield Manor Visualisations</p> <p>At D1A the applicant submitted visualisations showing the view of the</p>	<p>3.1.16. As above, any visualisations prepared should provide the “wireframe” to show the height of the installed infrastructure. The height</p>



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	<p>proposed development from Bradfield Manor [REP1A-014]. The visualisations appear to just highlight the footprint of where solar development would be located. Given the height of the solar PV panels, the applicant is asked whether, at both year 1 and year 15, the existing field pattern would be legible from these views or would the collection of fields where solar PV panels are proposed appear as a single mass of solar development?</p>	<p>of the panels will have an obvious impact on the amount of visibility and impact.</p>
<p>CH1.9</p>	<p>The applicant states that the proposed development has the potential to indirectly impact heritage assets, but any such effects would be reversible following decommissioning of the proposal. The ExA is concerned about</p>	<p>3.1.17. SLD notes also that, by way of example, the mitigation proposed to reduce visibility from the panels at Bradfield Manor may well continue to exist after decommissioning. This will have an impact on the heritage asset beyond the 60-year duration which the Applicant should assess.</p>



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	<p>the inference that because the proposal has a capped 60 year duration, the ensuing harm to heritage assets is somehow nullified. The issue around whether a 60 year use is ‘temporary’ cuts across most topic areas, however, specifically for heritage, the ExA requires a clear position from the applicant on the weight they have ascribed to a time capped DCO when assessing the level of harm to heritage assets. Historic England and Wiltshire Council may also wish to comment on this matter.</p>	
<p>Power and Generation</p>		
<p>GCT1.11</p>	<p>Land Availability and GHG Assessment</p>	<p>3.1.18. SLD will comment on the Applicants answer to this question at the appropriate Deadline. However, see below comments of SLD on the</p>



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	<p>Paragraph 5.1.2 of the SoR [APP-018] states that option agreements have been entered into with each of the owners of 8 landholdings that make up the 5 solar PV sites. The length of those option agreements was discussed briefly at Issue Specific Hearing 1, and it was identified that the applicant cannot confirm that it has secured options over all of the solar PV sites to cover the 60-year lifetime of the project.</p> <p>1) You are asked to provide a breakdown of land parcels within the solar PV sites which have not been secured in option agreements for the lifetime of the project, along with the timeframe that has been secured.</p>	<p>Applicant's response to Written Representations [REP2-039] which also raise this issue. SLD agree that such information should be provided.</p>
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	<p>2) While the ExA appreciates that you are seeking the fallback of CA over all of the solar PV land parcels, which means you could secure a 60 year operating period over them, it was made clear to the ExA at Issue Specific Hearing 1 that in circumstances where you are unable to extend the term of a lease by agreement, the relevant part of the scheme would be required to be decommissioned earlier than the maximum 60-year lifespan (because by then it would be time barred from employing CA powers). Based upon that, the ExA would like you to explain whether a reduced operating capacity on those affected land parcels has</p>	
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	<p>been factored into the lifetime GHG assessment.</p> <p>3) Please also explain what implications may arise when those affected land parcels are required to be decommissioned but contain supporting infrastructure for other parts of the project, which remain in operation.</p>	
DCO		
DCO1.5	<p>Article 2(1) (Interpretation) Q6</p> <p>The definition of “permitted preliminary works” (PPW) is a broad list. The ExA understands that PPW sit outside the scope of commencement and could be carried out prior to the discharge of the requirements contained in Schedule 2 of the DCO and the</p>	<p>3.1.19. SLD also raised concerns about the width of “permitted preliminary works” at p.126 of the SLD WR. This was particularly directed to (c) “preparation”, (d) “remedial works”, and (h) “site clearance”. The Applicant in its Response to Written Representations [REP2-039] at §SLD-420 states that these works are not expected to give rise to environmental effects requiring mitigation. SLD does not agree; clearly, all of these works have the potential for landscape harm, ecological harm, and noise-related harm (to name a few examples). While these may well</p>



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	<p>approvals required therein. However, there is no associated control document(s) or DCO requirement to govern the scale and extent of PPW, or how the applicant should report any environmental impacts or potential environmental impacts encountered while carrying out PPW.</p> <p><u>The Applicant:</u></p> <p>1) The ExA refers the applicant to Requirement 4(1) of the A122 (Lower Thames Crossing) DCO 2025, which required preliminary works to be carried out in accordance with a preliminary works environment management plan. [REP9-190] in the Lower Thames Crossing DCO Examination Library provides the final</p>	<p>be open to mitigation, excluding them from the control of the Schedule 2 Requirements does not secure that mitigation.</p> <p>3.1.20. SLD agree with the ExA's suggested approach. Alternatively, SLD consider that the approach taken in recently granted Springwell DCO may manage this issue. In that DCO certain preliminary works were reinserted within the definition of commencement in specific Requirements (see Requirement 8, 9, 11, 12 and 14) so that those preliminary works were still subject to Outline Plans. For example, in Requirement 8(4) the LEMP still applied to the works of site clearance. It will be noted that the definition of "commence" in the present draft DCO already envisages certain circumstances where PPW are included in the definition of commencement (by including the words "except where stated to the contrary").</p> <p>3.1.21. SLD will comment on the remainder of §SLD-420 below. SLD may provide further comment following submissions from the Applicant and Council.</p>
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	<p>draft version of the preliminary works environment management plan that fed into Requirement 4(1). The ExA asks the applicant whether it would consider taking a similar approach to the Lower Thames Crossing DCO?</p> <p>2) If not, the applicant is required to explain and justify why PPW seem to be uncontrolled, particularly when they are able to occur anywhere within the Order limits, at any time after the DCO comes into effect, and without any reporting mechanisms to or oversight from a consenting authority, such as Wiltshire Council, the Environment Agency, Natural England or similar.</p> <p><u>Wiltshire Council:</u></p>	
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	<p>The Council is asked:</p> <ol style="list-style-type: none"> 1) If the definition of PPW is too widely drawn; 2) Whether greater control over PPW should be included within the dDCO; and if so 3) What information the Council requires to be provided and when (for example during the examination and in a dDCO Requirement or just in a dDCO Requirement for their approval post consent, but prior to any PPW taking place)? 	
<p>DCO1.37</p>	<p>Requirement 5 - Detailed design approval</p> <p><u>The Applicant:</u></p> <p>Requirement 5 is missing a ‘— (1)’. Please insert at next iteration of the dDCO.</p>	<p>3.1.22. SLD raised similar concerns regarding the scope of Works Nos 1, 2 and 3 in the SLD WR at p.130. SLD accepts that fencing and similar forms of enclosure are controlled by the fencing condition in the draft DCO (Requirement 10). However, SLD considers signs, CCTV, and lighting columns (identified by the ExA) are not so controlled and should</p>



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	<p><u>Both Parties:</u></p> <p>On the basis that Work Nos 1, 2 and 3 would include some form of fencing, gates, boundary treatment, other means of enclosure, signs, and CCTV and lighting columns, the ExA considers that this detail may need to form part of the detailed design approval, and thus may need to be included as a new sub point 5(1)(h). Both parties are asked to comment on that suggestion.</p> <p>In addition, both parties are asked to comment on whether the following tailpiece in bold text should be added to Requirement 5(2):</p>	<p>be added. As SLD explained at p.130 of the SLD WR, that mirrors other made DCOs.</p> <p>3.1.23. The Applicant's response at §SLD-429 of its Response to Written Representations [REP2-039] relies upon Requirements 7, 11, 13, 14, and 19. SLD does not consider that these currently meet the specific items identified by the ExA. It may be that these matters can be managed through the Outline Plans, but wording securing detailed design control over them should be included. Mirroring other made DCOs, however, SLD considers the proper approach would be to include these in Requirement 5.</p> <p>3.1.24. SLD may provide further comment following submissions from the Applicant and Council.</p>
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	<p>(2) <i>The details submitted must accord with Table 2-1, Table 2-2 and Table 2-3 (as applicable) of the design principles and parameters, and the relevant planning authority must be satisfied that there would be no materially new or materially different environmental effects to those identified in the environmental statement.</i></p>	
<p>DCO1.40</p>	<p>Requirement 8 - Ecological protection and mitigation strategy</p> <p>The ExA seeks comment on whether it is necessary to include reference to PPW in Requirement 8(1) as noted in bold text as follows:</p> <p><i>8.—(1) No part of the authorised development may commence, and no</i></p>	<p>3.1.25. SLD note that this raises functionally the same issue as is addressed under DCO1.5. SLD agree that some form of control is required over some or all of the PPW and this may be a further way of managing those works insofar as they relate to site clearance.</p> <p>3.1.26. SLD may provide further comment following submissions from the Applicant.</p>



	<p><i>permitted preliminary works comprising site clearance may take place until a written ecological protection and mitigation strategy has been submitted to and approved by the relevant planning authority in consultation with the relevant statutory nature conservation body.</i></p>	
<p>DCO1.43</p>	<p>Requirement 12 - Archaeology Delete the following symbols [...] around Requirement 12(1). Also, the ExA seeks comment on whether it is necessary to include reference to PPW in Requirement 12(2) as noted in bold text as follows: <i>12 (2) No part of the authorised development may be commenced and no permitted preliminary works</i></p>	<p>3.1.27. SLD note that this raises functionally the same issue as is addressed under DCO1.5. SLD agree that some form of control is required over some or all of the PPW and this may be a further way of managing those works insofar as they relate to intrusive archaeological surveys.</p> <p>3.1.28. SLD may provide further comment following submissions from the Applicant.</p>



	<p><i>comprising intrusive archaeological surveys may take place until a written scheme of investigation for that part has been submitted to and approved by the relevant planning authority.</i></p>	
DCO1.44	<p>Requirement 15 - Construction traffic management plan Should Requirement 15(3), which requires the relevant planning authority to consult with South Gloucestershire Council and the relevant highway authority before approving the Construction Traffic Management Plan, also include the requirement to consult with National Highways?</p>	<p>3.1.29. Given the relevance of the Strategic Road Network, SLD agrees that this is an appropriate addition to the DCO.</p> <p>3.1.30. SLD may provide further comment following submissions from the Applicant.</p>
DCO1.45	<p>Requirement 16 - Public rights of way and permissive paths</p>	<p>3.1.31. SLD note that this raises functionally the same issue as is addressed under DCO1.5. SLD agree that some form of control is required over some or all of the PPW and this may be a further way of</p>



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	<p>The ExA seeks comment on whether it is necessary to include reference to PPW in Requirement 16(1) as noted in bold text as follows:</p> <p><i>16.—(1) No part of the authorised development may commence and no permitted preliminary works which may affect existing public rights of way may take place until a public rights of way and permissive paths management plan for that part has been submitted to and approved by the relevant planning authority.</i></p>	<p>managing those works insofar as they relate to works affecting existing public rights of way.</p> <p>3.1.32. SLD may provide further comment following submissions from the Applicant.</p>
<p>DCO1.46</p>	<p>Requirement 17 - Soil management</p> <p>The ExA seeks comment on whether it is necessary to include reference to PPW in Requirement 17(1) as noted in bold text as follows:</p>	<p>3.1.33. SLD note that this raises functionally the same issue as is addressed under DCO1.5. SLD agree that some form of control is required over some or all of the PPW and this may be a further way of managing those works insofar as they relate to works affecting environmental surveys, geotechnical surveys, intrusive archaeological</p>



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	<p><i>17.—(1) No part of the authorised development may commence and no permitted preliminary works comprising environmental surveys, geotechnical surveys, intrusive archaeological surveys and other investigations for the purpose of assessing ground conditions, site clearance, remedial work in respect of any contamination or other adverse ground conditions, or diversion and laying of apparatus may take place until a soil resources management plan for that part has been submitted to and approved by the relevant planning authority.</i></p>	<p>surveys, other investigations for the purpose of assessing ground conditions, site clearance, remedial works, or diversion and laying of apparatus.</p> <p>3.1.34. SLD may provide further comment following submissions from the Applicant.</p>
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	<p>The ExA also seeks comment on whether the Requirement needs to be extended to add provision for the submission of a remediation strategy and verification plan prior to commencement of the development or PPW?</p>	
<p>Site Alternatives</p>		
<p>ALT 1.1</p>	<p>Site Selection Criteria The applicant's Site Selection Assessment Report [APP-185] details a range of initial sites that were considered for a solar farm with a specific search criteria. However, having not identified a suitable and available site within the parameters identified in Stages 1 - 4 the applicant widened the criteria at Stage 5 to include Grade 3 best and most</p>	<p>3.1.35. This was a concern that SLD raised in respect of the process of site selection in the SLD WR at Appendix L [REP1-186] §21 onwards. That the Applicant did not consistently apply the criteria is now reflected in the commentary in the Technical Note on Site Selection Assessment [REP2-043] (TN SSA). The Applicant's assertion that redrawing against new criteria was not proportionate is not accepted (given, among other things, the limited number of PDAs for which redrawing was required). SLD is aware that the Applicant has produced the TN SSA and this is commented upon in an Appendix to this submission below.</p>



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	<p>versatile (BMV) agricultural land and land within flood zones 2 and 3 and Stage 6 to include land with a higher gradient. However, it is not clear if these criteria were re-applied to those areas previously considered to ensure a consistent approach. You are asked to explain this apparent lack of consistency in approach to site selection. If necessary, re-apply a consistent approach to all considered sites and update the Site Selection Assessment Report [APP-185], the Planning Statement [APP-267] including Annex C – Sequential and Exception Test, and relevant parts of the ES as appropriate.</p>	
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ALT 1.2	Site Selection – Order Limits In considering the selection of the specific Order limits at Lime Down, it has not been explained how this land was determined – other than a potential landowner willingness. For example, areas of Grade 3a BMV land and land within flood zones 2 and 3 have been included but it is not clear if this is necessary considering the potential land available adjacent to the Order limits. You are asked to explain why areas identified as constraints are included within the Order limits and provide a justification. Could land elsewhere in the immediate vicinity of the Order limits have been used to avoid BMV, areas of flood risk and ecologically sensitive habitats?	3.1.36. This was a concern that SLD raised in respect of the process of site selection in the SLD WR at Appendix L [REP1-186] §35. SLD consider such further information, which is not contained in the TN SSA, is highly relevant both to understanding the process itself, but also the Applicant providing a lawful description of reasonable alternatives and an explanation of the main reasons for selecting the chosen option (as required by the EIA Regulations).
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Land Use, Soils and Food Security		
LSF1.3	<p>Permanent or Temporary Loss</p> <p>Given there is no secure commitment to return the land to agricultural use at the end of 60-year operational lifespan, should the ExA consider this land to be permanently removed from agricultural use?</p>	<p>3.1.37. SLD will comment on the Applicant's reply. However, for the moment, SLD note three things. First, SLD note that a return to agricultural use is not secured in decommissioning (it is understood that the Applicant considers such a return cannot be secured). This is pertinent when assessing the likely significant effects of the Proposed Development now in EIA terms. Second, SLD consider the answer to EB1.1 to be pertinent here, as the Environmental Impact Assessment (Agricultural) (England) (No.2) Regulations 2006 (SI 2006/2522) may (practically or legally) weigh against such a return. Third, SLD consider that its analysis of the planning policy in favour of extension of and repowering of PV generating installations to be pertinent here. As is explained by SLD's experts in Appendix A to the SLD WR [REP1-169] from §5.2, there is a strong policy weight in favour of extensions and repowering. This weighs against the loss being temporary, and/or means less weight should be given to the consideration of the Proposed Development being temporary.</p>



4. Comments on Applicant’s Deadline 2 Documents

Reference	Document	SLD’s Comment
Landscape		
REP2-046 Section 2	Wiltshire Comments on WRs	4.1.1. SLD welcome comments from the Council on its submissions. SLD would note that some of the concerns identified (e.g. at §2.1, which suggests SLD has taken a simplistic approach at §3.5.5 of SLD’s Written Representation) are answered by referring to the full report produced by SLD’s expert (e.g. at §5.1.43 of Appendix B [REP1-169] , to which §3.5.5 of SLD’s Written Representation cross-referenced).
REP2-048 §25.2	Wiltshire Comments on D1 and D1A Documents	4.1.2. SLD notes and agrees with the Council’s comments at §25.2 concerning the Technical Note on Landscape Fabric and Landscape Character [REP1-121] which is an important new point. 4.1.3. These comments relate to the LVIA’s definition of “fabric”, which, in the Council’s landscape expert’s opinion (with which SLD’s landscape expert agrees) should include hard / built elements as well as “soft” elements such as vegetation and water (as GLVIA3 indicates it should) – see for example the Council’s §25.4.



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		<p>4.1.4. This is an important and relevant matter because – along with having double-counted landscape / visual mitigation as landscape / visual enhancement, and not having factored in the adverse effects of mitigation measures – the omission is a reason for the LVIA having incorrectly concluded that the Proposed Development would result in Moderate Beneficial (Significant) effects on the character of sites Lime Down A – E, and thus concluded there would be “beneficial landscape effects within the setting of the CNL in the long term which would further the purposes of the designation.”</p>
<p>Traffic and Transport</p>		
<p>REP 2-039, §WC-011</p>	<p>Applicant’s Response to Written Representations</p>	<p>4.1.5. The applicant seeks to justify the decision not to widen roads outside of the Highway Improvement Areas on the basis of average levels of HGV movements are lower than the “peak” levels originally identified, the temporary nature of the construction period, the desire to avoid impacts on vegetation and landscape character and “over-engineering”. Reference is made to the additional information (Annex K in [REP1-057] and [REP1-</p>



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		<p>059] that show the places where two HGVs are considered capable of passing each other.</p>
<p>REP 2-039, §SLD-195</p>	<p>Applicant's Response to Written Representations</p>	<p>4.1.6. The following comment is made: "Once the Final CTMP is produced the final construction numbers will be known. At this point a check will be done to see if any of these numbers exceed the AADT's included on the links in the ES assessment. If it is exceeded then a further ES assessment will be required". This appears to suggest that if the estimates of HGVs are incorrect, the numbers will be revised and the ES amended. The implication is that the current assessments may not represent a "worst case" assessment and relevant consultees and the Examiners may not be currently presented with the correct information on which to base reliable judgements.</p>
<p>Ecology</p>		
<p>REP 2-039, §WC-005, §WC-050-054</p>	<p>Applicant's Response to Written Representations</p>	<p>4.1.7. Mr. Valori of Betts Ecology notes the recurring point regarding the uncertainty of the extent of hedgerow removal permitted under the DCO. The Applicant refers several times to their Outline EPMS [REP1-106] and the DCO as detailing the extent to which hedgerow removal powers can</p>



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		<p>be exercised, as well as confirming that Wiltshire Council will be required to approve the detailed EPMS. As a consequence, there remains continued uncertainty regarding the extent of hedgerow clearances which are anticipated as being necessary, and a “worst case” assessment should be made.</p>
REP 2-039, SWC-007	Applicant’s Response to Written Representations	<p>4.1.8. Mr. Valori generally agrees with the Applicant that solar panels do not, necessarily, prevent skylark foraging along the solar fields’ buffers or among the panels, provided suitably extensive patches of nesting habitat surround them as well. In this case, a sufficiently wide grassland strip is indeed more likely to provide a more stable source of food than an arable field without any leys.</p> <p>4.1.9. That being said, these boundary buffers are no replacement for actual, open grassland nesting habitat.</p> <p>4.1.10. In Mr. Valori’s opinion, the Applicant should monitor skylark numbers as a long-term measure, to confirm that proposed mitigation and</p>



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		enhancement is working. There should be an escalation process if it is established that it is not effective.
REP 2-039, §WC-062	Applicant's Response to Written Representations	4.1.11. Mr. Valori agrees with Wiltshire Council. While the Applicant would be securing a District-Level Licence for the Cable Route Corridors, the Applicant has not provided good justification for not doing so for the Solar PV Sites and further information is needed in relation to the proposed GCN mitigation strategy.
REP 2-048, §5.2, §6.1	Wiltshire Council's comments on Deadline 1 and 1A Submissions	4.1.12. Mr. Valori strongly agrees with the points raised by Wiltshire Council. It is noted that given proposed culverted crossings across wet ditches have not been subject to any in-depth ecological analysis. As a consequence, there is a risk that impacts to white-clawed crayfish are being underestimated.
REP 2-049 , §EA-021	Environment Agency response to D1 and D1A submissions	4.1.13. Mr. Valori agrees with the Environment Agency's recommendation that stream buffers be extended from 8m to 10m.
Noise		



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REP2-039 §SLD-223	Applicant's Response to Written Representations	4.1.14. SLD does not repeat the existing points of disagreement between the parties. However, SLD's expert (Mr Ian MacArthur) notes that the Applicant asserts a "sustainable balance" of mitigation versus reducing towards LOAEL without evidencing or explaining balance. It is unclear what investigation has been done to demonstrate these diminishing returns.
REP2-039 §SLD-225	Applicant's Response to Written Representations	4.1.15. It remains the case that the Applicant has selected figures at or close to the modal value as appropriate. That judgment should be clarified to explain why it dismissed significant periods of time where background levels are significantly lower. 4.1.16. SLD's expert selected the value of 30dB because, in his professional judgement, it would be an appropriate level to select (it is not the lowest level, but representative of the range of lower levels which commonly occur), given the range of background levels, and the relative short term monitoring dataset, including to reduce the uncertainty of the assessment outcome and conclusions. The Applicants selection



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		introduces significant uncertainty, as for 50% of the time, the impact would be greater than indicated.
REP 2-039, §SLD-227	Applicant's Response to Written Representations	<p>4.1.17. The Applicant's response suggests that the Applicant did not have a dedicated weather station in place for the operational noise surveys, nor did they undertake a review to identify periods of adverse/unsuitable weather conditions. Their quote regarding their review of one specific period was: "Based on the information from local weather stations".</p> <p>4.1.18. This is contrary to the Environmental Statement Volume 3, Appendix 14-3 Baseline Noise Survey [APP-236], which states at para 1.3.2 "A weather station was set up to capture the weather data for the Solar PV Sites allowing for any periods of adverse weather conditions to be identified and omitted from further analysis."</p>
REP 2-039, §SLD-229	Applicant's Response to Written Representations	<p>4.1.19. The Applicant's acceptance is noted. Thus, the evidence collected is wholly unrepresentative of locations away from local roads (as SLD identified in its submission).</p>



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REP 2-039 §SLD-230	Applicant's Response to Written Representations	4.1.20. The value for moderate annoyance is not applicable as it fails to take into account the existing natural soundscape compared to the higher level of industrial noise to be introduced. It fails sufficiently to take into account the use of such routes, and while it may not make the routes unusable, there should be proper assessment of the effects. ExAQ NV1.9 is also noted in this respect.
REP 2-039 §SLD-234	Applicant's Response to Written Representations	4.1.21. SLD's expert considers a comparison to a whisper or refrigerator is inapposite because it fails to reflect the fact that the sound is constant. Someone whispering in a person's ear constantly, however quietly, would be considered highly intrusive and annoying. SLD's view remains that the level set is not appropriate. The approach adopted by the Applicant does not properly reflect the standard and fails in both avoidance but also mitigating to a proper LOAEL level.
REP 2-039 §SLD-235	Applicant's Response to Written Representations	4.1.22. SLD's expert notes that the fixed threshold noise level is not relied on during the daytime, as the Applicants selected value is not reflective of the lower background levels which regularly occur. This supports rather than detracts from the point made by SLD.



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REP 2-039 §SLD-237	Applicant's Response to Written Representations	4.1.23. This clarifies that the Applicant's approach has dissociated the likely significant effects of annoyance due to audibility and change to the existing sound climate as determined by BS4142. That is a departure from the British Standard for the reasons Mr MacArthur identified in his report. BS8233 relates to anonymous traffic/transportation noise, not industrial noise, and is not appropriate for comparison in any event.
REP 2-039 §SLD-242	Applicant's Response to Written Representations	4.1.24. SLD's expert remains of the view that the assessment is not robust. Among other things, large uncertainty remains in background noise levels due to the approach adopted. That an approach that is not robust has been accepted elsewhere does not justify the flaws that are identified.
Flooding		
REP 2-039, §SLD-251	Applicant's Response to Written Representations	4.1.25. SLD note that the Applicant has used the Exception Test. The suggestion that the Sequential Test has not been failed where the Applicant has moved on to the Exception Test is not understood; the Exception Test is only applicable where the Sequential Test cannot deliver an acceptable site.



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REP 2-039, §SLD-255	Applicant's Response to Written Representations	4.1.26. Without repeating all of the disagreement, among other things the Applicant fails to engage with the points that (a) the EA notes many episodes of fluvial flooding in the area, while the FRA ignores these and claims that there is no fluvial flooding in the vicinity of the sites and (b) that the Applicant's own modelling shows extreme flow rates in response to a heavy rainfall event, whereas their assessed flood risk is "low".
REP 2-039, §SLD-256	Applicant's Response to Written Representation	4.1.27. The Applicant fails to engage with the criticisms of the FRA methodology. Further, the Applicant notes that Appendix F3 provides "qualitative photographic evidence of flooding within the known Gauze Brook floodplain during Storm Bert", and claims that it is consistent with their assessment. Professor Skeffington disagrees. 4.1.28. It is acknowledged that "the photographs do not provide surveyed levels, measured depths, velocity data or hazard ratings. The water is turbid, the ground surface cannot be seen, and the views are oblique". The purpose of the photograph was to illustrate that the extent of flooding was



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		greater than the Applicant would have predicted, and that this should generate concerns about depths and velocities.
REP 2-039, §SLD-257	Applicant's Response to Written Representation	4.1.29. The Applicant recognises in general terms many of the risks associated with issues like soil compaction due to construction. But it has undertaken no assessment of the magnitude of those risks. Though SLD agrees that the purpose of the FRA is not to resolve existing flooding, a study of the present response to rainfall of the catchment, as expressed in the hydrographs from the Gauze Brook, shows that the area is surprisingly sensitive to heavy rainfall. That should be taken into account in the FRA, rather than assuming that an unspecified amount of runoff management would be sufficient for mitigation.
REP 2-039, §SLD-258	Applicant's Response to Written Representation	4.1.30. In its response, the Applicant purports to explain their assessment of fluvial flood risk as "low". However, it is not explained how the range of factors allegedly considered leads to this conclusion. It is stated that "the Manning's/open-channel calculations have been mischaracterised. They are local level and conveyance checks for minor watercourses, not predictions of downstream flood hydrographs at Corston, Malmesbury or



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		<p>other settlements.” SLD’s criticism is based on the quality of the Mannings modelling for minor watercourses, pointing out that it is (a) not credible, and (b) would lead to the conclusion that flood risk is far from low. There is no suggestion that the aim is to generate flood hydrographs downstream, though this is something the Applicant should also be doing.</p>
<p>REP 2-039, §§SLD-261 and SLD-262</p>	<p>Applicant’s Response to Written Representation</p>	<p>4.1.31. SLD has never suggested the land should be treated as impermeable hard standing. The issue is whether the soil can cope with the concentrated runoff even if vegetated. The Applicant still has not demonstrated this, nor properly engaged with the literature on run-off effects. The Applicant notes correctly that this “does not demonstrate a material increase in storm runoff, peak discharge, flood depth or flood hazard”. To do this would require access to a sophisticated flood model. It is notable that the Applicant has not investigated storm runoff and peak discharge either. The Applicant details the major factors affecting flood risk during storm events – of these it is “antecedent conditions” that provide the mechanism which drives increased flood risk. Wetter soils, or soils that are saturated for longer, will increase runoff through the saturation excess overland flow mechanism. The Applicant has failed to assess this.</p>



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REP 2-039, §SLD-269	Applicant's Response to Written Representation	4.1.32. SLD would welcome clarity on how the discussion of panel heights in Flood Zones 2 and 3 interact with the maximum parameters for the Proposed Development. At [REP1-048] §2.3.13 it is explained that “for both fixed and tracker panels, all sensitive and electrical equipment mounted on the Solar PV Panels will be elevated by the supporting legs or frame so that it is no less than 0.6 meters above the design flood level, including the appropriate climate change allowance”. Upstream of Corston the Gause Book shows flood depths of up to 0.3m and Rodbourne Brook of 0.6m. It is unclear how the Applicant accounts for these flood depths and elevations within the existing maximum parameters for the solar panels (of 4.5m for tracker panels and 3.5m for fixed panels), or whether in fact this would call for maximum heights apparently in excess of the parameters.
REP2-039 §§SLD-266 and 267	Applicant's Response to Written Representation	4.1.33. SLD notes that the Applicant does not challenge the basic premise of the position set out, which is that reduced evaporation will lead to an increase in water runoff from the site. That would be contrary to the requirement in NPS EN-1 not to increase the flood risk off site. The



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		<p>Applicant notes correctly that this “does not demonstrate a material increase in storm runoff, peak discharge, flood depth or flood hazard”. To do this would require access to a sophisticated flood model. It is notable that the Applicant has not investigated storm runoff and peak discharge either. The Applicant details the major factors affecting flood risk during storm events – of these it is “antecedent conditions” that provide the mechanism which drives increased flood risk. Wetter soils, or soils that are saturated for longer, will increase runoff through the saturation excess overland flow mechanism. The Applicant has failed to assess this.</p>
REP 2-045, Introduction	Applicant’s Response to LLFA on Hydraulic Modelling Requirements	<p>4.1.34. SLD agrees with the LLFA that full field-scale hydrological modelling is necessary for the panel areas at Lime Down. SLD disagrees with the Applicant’s expert, Arthian, who considers that such modelling is unnecessary and disproportionate.</p> <p>4.1.35. SLD’s considers that as a high-risk, large scale development in a flood-sensitive area, Lime Down requires a detailed, quantitative FRA.</p>



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<p>REP 2-045, §2.2</p>	<p>Applicant's Response to LLFA on Hydraulic Modelling Requirements</p>	<p>4.1.36. Arthian point out several times that EN-1 paragraph 5.8.15 requires the FRA to be “proportionate to the risk and appropriate to the scale, nature and location of the project.” They claim that their approach meets these criteria. However:</p> <ul style="list-style-type: none">• this is a very large-scale project involving extensive engineering on 748 ha of panel areas plus large amounts of associated infrastructure in a scheme envelope of about 46 km² plus a 22 km cable route;• the nature of the project is that it will increase runoff rates and amounts and thus increase flood risk; and• the project is proposed in an area of high flood risk with significant implications for communities both on-site and downstream. This is thus a high risk, large-scale project in a sensitive area and a proportionate FRA would therefore need to be detailed, quantitative and consider all aspects of flood generation. <p>4.1.37. The Applicant states (§2.2.4) that “EN-1 Section 5.8 does not prescribe any specific assessment methodology” (such as hydraulic modelling), which is correct. However, it also states (at §5.8.15) that “as a minimum” the FRA should “consider and quantify the different types of</p>
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		<p>flooding (whether from natural and human sources and including joint and cumulative effects) and include information on flood likelihood, speed-of-onset, depth, velocity, hazard and duration”. The Applicant has considered the different types of flooding and quantified them to some extent, and provided information on likelihood and depth, though mostly round their own assets. But there is nothing on speed-of-onset, velocity and duration, and no way to produce this information without doing some dynamic modelling. Thus, dynamic modelling is required for Lime Down.</p>
<p>REP 2-045, §2.2</p>	<p>Applicant’s Response to LLFA on Hydraulic Modelling Requirements</p>	<p>4.1.38. SLD considers that the Applicant has failed to justify why it does not need to undertake further modelling in respect of solar panel runoff. It is noted that paragraph 2.10.84 of EN-3 provides that “in general”, this will not be necessary. However, the Applicant has not addressed why the case is a general one. As described in Appendix F2 of SLD’s Written Representation, the nature of the soils and geology at Lime Down leads to low infiltration rates and rapid runoff under flood conditions, producing the flood proneness that so concerns members of the public.</p>



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<p>REP 2-045, §3.2</p>	<p>Applicant's Response to LLFA on Hydraulic Modelling Requirements</p>	<p>4.1.39. In Sections 3.2 and 3.3, Arthian provide for the first time a rationale for their assessment of runoff from panel areas.</p> <p>4.1.40. The paper identifies four factors that determine whether redistributed rainfall will generate increased runoff. The following comment is provided in respect of each:</p> <p>4.1.40.1. <u>Ground Cover Condition</u>: This is indeed vital and generally agreed. But it still needs to be demonstrated that (a) the vegetation established under the panels will be sufficient to absorb the drip-line energy and (b) whether the vegetation will survive under the panels, given that it is a stressed environment, short of water and sunlight. It would also rule out grazing as a management option unless the under-panel areas could be fenced off. At Lime Down, drip-line energy needs to be assessed given the large size of the panels proposed to be used.</p> <p>4.1.40.2. <u>Soil Structure and Compaction</u>: This is agreed, though the intrinsic characteristics of the soil are also important here. Some soils have</p>
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		<p>low infiltration capacity even before compaction due to construction. Resistance to compaction and recovery potential from compaction are important factors which vary widely across soil types. For this reason, a soil assessment is needed before designing mitigation measures – which has not been performed at Lime Down.</p> <p>4.1.40.3. <u>Flow Connectivity</u>: This is agreed.</p> <p>4.1.40.4. <u>Existing Baseline Conditions</u>: This is a description of the known runoff problems due to arable agriculture. However, not all land to be replaced by panels is arable. The Baseline Habitats Maps (Figures 9.1.8 to 9.1.12, [APP-113]) for the solar PV sites give the current land use on a field basis. Of the fields, 65% are arable, 24% grassland and 11% mixed. Additionally, farmers are aware of these problems and take action to alleviate them, for instance by planting a cover crop if bare ground would otherwise last a significant time, using low pressure tyres to reduce compaction etc. Farmers have a long-term interest in stewardship of their land, and ignoring these problems risks economic damage.</p>
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		<p>4.1.41. It is noted that even though these factors are “management-dependent variables” they can still (and should) be modelled.</p> <p>4.1.42. Additionally, Professor Skeffington notes that there are factors affecting runoff other than those discussed. They include:</p> <ul style="list-style-type: none">• <u>Slope angle</u>: Slopes of $<5^\circ$ are generally required to avoid having to institute further measures (see Yavari, R., et al., <i>Minimizing environmental impacts of solar farms: a review of current science on landscape hydrology and guidance on stormwater management</i>. Environmental Research: Infrastructure and Sustainability, 2022. 2(3): p. 032002 – included at Appendix 2 at the end of this submission). Most if not all areas at Lime Down meet this criterion.• <u>Orientation of the panels with respect to the slope</u>: Orienting the panels parallel to the slope should maximise percolation opportunities and reduce runoff. The tracking panels at Lime Down have a fixed N-S orientation irrespective of the slope, and the fixed panels have a fixed E-W orientation irrespective of the slope. This means in most
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		<p>cases that the orientation is sub-optimal, though it is unclear how large an effect this will have.</p> <ul style="list-style-type: none">• <u>Distance between panel rows</u>: A close distance implies that there is less land available for infiltration. According to Yavari, the US states of Maryland, Rhode Island, North Carolina, Pennsylvania and Ohio require the area between panels to be at least equal to the area covered by panels. This is more stringent than Lime Down, where the distance covered by the panels (4.85 m) is almost twice as large as the distance between the panels (2.5m) at minimum spacing. This will reduce the potential for infiltration and increase the shading of the under-panel areas relative to the recommended 1:1 ratio.
REP 2-045, §3.2.4	Applicant's Response to LLFA on Hydraulic Modelling Requirements	<p>4.1.43. Professor Skeffington does not consider it clear that the proposed mitigation will be effective. For example:</p> <p>4.1.44. <u>Use of "light plant"</u>: These specifications are welcome, but "light plant" is a relative term. Equipment capable of carrying large quantities of panels and driving 4 m piles is necessarily going to be heavy enough to</p>



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		<p>induce some soil compaction. Some areas of the site are vulnerable to compaction and difficult to remediate, but there has been no assessment of this.</p> <p>4.1.45. <u>Planting vegetation</u>: Planting vegetation is necessary but it is not clear whether it will be sufficient given the sensitivity of most of the soils. The issue also is whether this vegetation will survive the stressed environment under the panels, especially in view of the large panel sizes and high panel density which will increase shading and reduce water input under the panels.</p>
REP 2-045, §3.2.4	Applicant's Response to LLFA on Hydraulic Modelling Requirements	<p>4.1.46. Professor Skeffington considers that field-scale modelling is both necessary and would be proportionate to the significance of Lime Down:</p> <ul style="list-style-type: none">• A hydraulic model would allow the exploration of the effectiveness of the mitigation measures. The variables do not need to be fixed parameters of the development.• It is right that model outputs are very often sensitive to model assumptions. However, analysis of this can tell the modeller which



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		<p>variables are important and require more investigation, and which can take assumed values without affecting the accuracy of the result.</p> <ul style="list-style-type: none">• The Manning’s calculations for minor streams are not credible, as shown in SLD WR, Appendix F1, and in any case show that an extreme rainfall event would lead to devastating consequences even in the absence of solar panels. The whole analysis relies on an assumption that planting vegetation under the panels would be sufficient to prevent excess runoff and erosion, with no investigation or evidence supplied that this will be the case.
REP 2-045, §5.7	Applicant’s Response to LLFA on Hydraulic Modelling Requirements	4.1.47. Arthian note they are unable to find the quoted reference “Burch, T., Armstrong, A. & Maslen, S. (2014) <i>Impact of Solar Parks on Runoff Generation and Associated Land Drainage/Flood Risk Consequences</i> . British Hydrological Society” (included at Appendix 2 at the end of this submission). This was a presentation given to a joint meeting of the British Hydrological Society (BHS) and the Chartered Institution of Water and Environmental Management (CIWEM). The meeting was entitled “ <i>Hydrological Impacts of Energy Projects</i> ” and was held at CIWEM in



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		<p>London on June 5th 2014. The presentation is well-known for being the first to consider systematically the effects of solar panels on runoff in the UK, and for suggestions as to how to mitigate them. There are also photographs of drip from panel edges, rivulet production, and the effects of badly-managed solar farm construction on an unsuitable site. Until recently, the presentation was available on the BHS website in their series covering past meetings, but unfortunately all but the most recent of these have now been removed.</p>
Power and Generation		
REP2-042, §2.15; REP1-110, §2.1.22	Applicant's Detailed Response to Stop Lime Down Deadline 1 Submission on BESS Fire Emissions Outline Battery Safety Management Plan May 2026 Revision 2	4.1.48. SLD note the Technical Note produced at Deadline 2. Reflecting on the detailed response, SLD will review further and provide comment at the next deadline and/or consider whether any matters can be addressed as part of the SoCG process.
Soils and Agriculture		
REP2-039, §SLD-287	Applicant's response to the Written Representations	4.1.49. Appendix K1 points out that experience shows that grass does not grow well under panels due to heavy shading, shelter from rain and



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		<p>patchy wetness. The Applicant claims that this issue is dealt with in the outline Landscape and Ecological Management Plan (LEMP) [APP-283], in §§1.3.86 to 1.3.101. This merely says that diversity will be reduced under the panels due to shading. The large size and proposed close spacing of the panels will make this problem particularly acute. A good vegetation cover is essential to prevent soil erosion and enhanced runoff (see discussion under SLD-261 and SLD-262). The Applicant does not have a credible plan for establishing vegetation in this demanding environment.</p>
<p>REP2-039, §SLD-291</p>	<p>Applicant's response to the Written Representations</p>	<p>4.1.50. Appendix K1 points out that Field Capacity Days (i.e. when the soil is predicted to be saturated) are stated in the Applicant's ALC report ([APP-243] §1.2.11) to be higher than the average for lowland England (between 188 and 171 days per year as opposed to the average of 150 days). Around half the year is thus unsuitable for construction and trafficking on the field sites, and Appendix K1 questions whether construction is likely to be restricted to these times, given the cost and practicality of doing so. The Applicant responds only to say that Field Capacity Days is a "broad climatic parameter". The Applicant states that</p>



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		<p>soil handling will be restricted by the provisions of the Soil Resources Management Plan. The Applicant's Outline Soil Resources Management Plan ([APP-280] at §1.8.5) sets out the criteria for determining whether soil is suitable to be stripped or moved. For the Lime Down soils, which have a generally high clay content, the acceptable window will be similar, being 5 or 6 months from May or June onwards. But soil stripping and storage is a much more restricted operation than general construction. The nature of the soils on site means that the Applicant should be committing to no construction on field sites during the November to end April period. It would be acceptable to work on sites where the soil will be destroyed (e.g. the substations and BESS) during this period, provided the soil was stripped and stored in the summer.</p>
REP2-039, §SLD-292	Applicant' s response to the Written Representations	4.1.51. Appendix K1 points out that the Outline Soil Resources Management Plan fails to consider damage to the existing field drainage system, particularly by piling and trenching. The Applicant states that "Where existing land drainage is encountered or affected during construction, it would be reinstated or otherwise managed so that drainage function is maintained". This is possibly reassuring, but the absence of any



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		consideration in the outline SRMP suggests that the Applicant is unaware that this is potentially a very significant issue which will consume time and resources.
Alternatives and Site Selection		
REP2-043	Technical Note on Site Selection Assessment	See Appendix 1 below.
Climate Change		
REP2-039, §§SLD-362 and SLD-363	Applicant's response to the Written Representations	4.1.52. It is noted that a technical note on climate change and GHG emissions is to be provided by the Applicant. Detailed comment by SLD will be provided once it has had sight of this document. However, at this stage SLD does not accept the approach adopted is a cautious one. In the first place, changes in emissions related to future operational emissions are speculative and should be evidenced. Second, the approach adopted by the Applicant where grid emissions intensity is fixed in 2029 has the effect of overestimating the savings over the lifetime of the Proposed Development – it is far from a cautious approach and assumes that grid emissions intensity will not continue to improve (which is contrary to the Government's policy). On that basis, it is not understood how the 2029 figure can represent a "realistic but low grid" average for the life of the



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		Scheme. Given the obligation to assess likely significant effects, neither fixing a figure nor using an inapposite comparison (to CCGT) is appropriate.
REP2-039, §SLD-372	Applicant' s response to the Written Representations	4.1.53. SLD disagrees. Cirencester does have temperature minimum and maximum date, and that site (and other stations closer than Yeovilton) are chosen by the Met Office as suitable for climate change assessments.
Draft DCO		
REP2-039, §SLD-418	Applicant' s response to the Written Representations	4.1.54. SLD repeat the point made from para 2.1.3 of its Deadline 1A submission [REP1A-022] (SLD D1A Submission).
REP2-039, §SLD-419	Applicant' s response to the Written Representations	4.1.55. SLD repeat the point made from para 2.1.6 of the SLD D1A Submission.
REP2-039, §SLD-420	Applicant' s response to the Written Representations	4.1.56. SLD have addressed the scope of some PPW above as part of the ExAQs. In respect of the “apparatus”, SLD consider that the DCO still requires further clarification. The words “(not including those cables comprising part of the authorised development)” should be included in the definition of “apparatus” to make express what the Applicant considers to be implied in the draft.



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REP2-039, §SLD-421	Applicant' s response to the Written Representations	4.1.57. The Applicant's response is noted. SLD consider that the word "only" should be introduced in Article 40(4) after the word "remove" to make express in the DCO the Applicant's interpretation of these provisions.
REP2-039, §SLD-422	Applicant' s response to the Written Representations	4.1.58. SLD will review the Explanatory Memorandum when it becomes available (on this and other matters where relevant) and respond as appropriate.
REP2-039, §SLD-423	Applicant' s response to the Written Representations	4.1.59. It is noted that the Applicant accepts there is overlap between Article 17 and s.106 WIA 1991. SLD remain of the view that s.106 should be excluded to the extent it overlaps with Article 17. While the dispute resolution mechanisms under s.106 apply to Article 17 (see Article 17(2)), Article 17 permits (among other things) the application of terms and conditions to discharge. Section 106 does not permit this. As such, to preserve the distinct controls in Article 17, s.106 should be disapplied to that extent.



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		<p>4.1.60. If the Applicant considers that Article 17(2) means not merely the dispute resolution conditions under s.106 apply, but all of the provisions of s.106, SLD consider this (1) should be examined; and, (2) Article 17(2) requires clarification. In particular, such examination related to Article 17 should concern the power in that provision to impose terms and conditions. SLD are of the view that the power to impose terms and conditions is appropriate for inclusion.</p> <p>4.1.61. The position related to s.116 is noted; while SLD note that the Applicant does not propose to use s.116 it is accepted that that is not a reason in itself to disapply the provision.</p>
REP2-039, §SLD-424	Applicant' s response to the Written Representations	4.1.62. The explanation for Article 44 is accepted.
REP2-039, §SLD-425	Applicant' s response to the Written Representations	4.1.63. SLD consider the extension of time a move in the right direction, but note the concern of the Council that more time was requested [REP2-048] . That request should be acceded to.
REP2-039, §SLD-426	Applicant' s response to the Written Representations	4.1.64. SLD maintains its position and considers this change is appropriate in the circumstances given the effects of the Proposed



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		Development, the extensive mitigation proposed, and importance of these issues to the community. Direct engagement is different to raising matters with the Council for it to consider enforcing. SLD remain of the view that this change is proportionate.
REP2-039, §SLD-427	Applicant' s response to the Written Representations	4.1.65. That such a Community Liaison Manager is provided for during decommissioning is welcome.
REP2-039, §SLD-428	Applicant' s response to the Written Representations	4.1.66. SLD do not accept that all other works are addressed by other Requirements. The Applicant should provide (either by way of technical note, or in the Explanatory Memorandum) an explanation of how it understands all other Works to be controlled outside of Requirement 5. SLD maintains its position.
REP2-039, §SLD-429	Applicant' s response to the Written Representations	4.1.67. This matter is already addressed above as it was also raised by the ExA as part of the ExAQs.
REP2-039, §SLD-430	Applicant' s response to the Written Representations	4.1.68. SLD disagree. If a matter requires confidentiality (e.g. location of badger setts), that is a matter which can be raised with the arbitrator. A



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		<p>presumption of confidentiality is a departure from the normal principles of open justice, and also would allow one party to maintain confidentiality against the wishes of another. The approach taken in the cited DCOs should be adopted.</p>
REP2-039, §SLD-431	Applicant' s response to the Written Representations	4.1.69. SLD consider the extension of time a move in the right direction, but note the concern of the Council that more time was requested [REP2-048]. That request should be acceded to.
REP2-039, §SLD-434	Applicant' s response to the Written Representations	4.1.70. As a preliminary point, SLD query the words “not so substantive” in relation to the height of fixed panels, and remain of the view that the Design Principles and Parameters can be used to avoid effects through the use of smaller panels. SLD consider that this issue has to be considered alongside the mitigation proposed, so as to understand whether more substantial mitigation is required in relation to 4.5m panels (to thereby mitigate those panels at the height of their elevation). SLD consider that the analysis provided should take into account whether mitigation measures are reduced by 3.5m panels. As appropriate, SLD will



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		address this as part of discussions related to Landscape and Visual Amenity at the relevant ISH.
REP2-039, §SLD-437	Applicant' s response to the Written Representations	4.1.71. SLD repeat the point made from para 4.1.2 onwards of the SLD D1A Submission concerning confidentiality.
REP2-039, §§SLD-439 and SLD-440	Applicant' s response to the Written Representations	<p>4.1.72. As above, SLD repeat the point made from para 4.1.2 onwards of the SLD D1A Submission concerning confidentiality. As identified, the issue is not merely the benefits of the Proposed Development and the relevant GHG emissions concerning the scheme, but also the harms of the Proposed Development and securing mitigation.</p> <p>4.1.73. SLD disagree with the Applicant's view in SLD-440 that the DCO manages this issue. In the first place, the obligation on the Applicant is to assess the likely significant effects in EIA terms. Given the information currently available (including about the length of agreements) that has not been done. Drafting in the DCO does not change this position. In any event, the DCO provides for partial decommissioning. If the Applicant is now of the view that it could not use the partial decommissioning powers</p>



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		without amendments to the Outline Plans (or other modifications to the DCO) or similar, there is no requirement for partial decommissioning powers and they should be removed. Rather, the Applicant should make an amendment application when the underlying position changes.
REP2-039, §SLD-443	Applicant' s response to the Written Representations	4.1.74. SLD do not agree with the Applicant. The Applicant does not assess the likely significant effects of the Scheme, and were it to assess a reasonable worst case it would assess one which properly reflected the evidence on entitlement to the land now. It is incumbent on the Applicant to furnish the ExA with the requisite information.
REP2-039, §SLD-444	Applicant' s response to the Written Representations	4.1.75. SLD does not repeat its submissions, but this neither responds to the fact that the Applicant freely entered those agreements, and the Applicant is under the duty to furnish the ExA with the relevant information. The requests in respect of this issue made by the ExA in the ExAQ are particularly pertinent.
REP2-039,	Applicant' s response to the Written Representations	4.1.76. It is noted that ExA has asked questions relevant to this issue (e.g. GCT1.7). SLD will comment on the further information provided at the



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§§SLD-446 and 449		appropriate time. However, it is noted that the Applicant does not actually explain how the test in NPS EN-1 para 4.11.12 can be met by a Gate 1 connection agreement. That certain policies are not to be understood to impose limits on new infrastructure does not change that the Applicant cannot apparently provide sufficient assurance to meet the para 4.11.12 test.
REP2-039, §§SLD-452 and 453	Applicant' s response to the Written Representations	4.1.77. The Applicant's submission does not address the specific point about the interaction between the Gate offers for connection and the relationship between the PV and the BESS. It is noted that the ExA has asked questions related to this issue (e.g. GCT1.7) and SLD will comment at the appropriate time.
REP2-040 §SLD-019	Applicant's Response to Deadline 1A Submission	4.1.78. SLD draws attention to the submissions already made above in this section. The obligation in EIA terms is to assess what the likely significant effects are considered on a reasonable worst case basis. SLD remains of the view that this is not done. As a first step, SLD consider it key that a proper and full answer to GCT1.11 is provided. SLD will comment on this issue further.



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SLD Deadline 3 Submission

5. Conclusion

5.1.1. This submission has reviewed the documents submitted by the Applicant at other parties at Deadline 2.

5.1.2. SLD's review of that material confirms that the additional information has not resolved the concerns raised by SLD at preceding deadlines. For all the reasons set out in this submission, and the documents prepared by SLD so far, SLD maintains that development consent should not be granted for the Scheme.

6. Appendix 1: Comment on Technical Note on Site Selection [REP2-043]

Introduction

6.1.1. In Appendix L to its Written Representation submitted at Deadline 1 [REP1-186] (**Appendix L**), SLD provided an analysis of the Applicant's original Site Selection Assessment Report [APP-185] (**SSAR**). Appendix L argued there were various methodological and substantive flaws in the assessment conducted by the Applicant in identifying and considering Potential Development Areas (**PDA**s). That included an assessment which concluded that the Applicant was overly generous when assessing the site for the Proposed Development (PDA 10). Appendix L also explained why, from a legal perspective, a proper approach to assessment of alternatives and site selection was required. Such a proper approach goes to the question of whether the Environmental Statement is adequate in law.

6.1.2. At Deadline 2 the Applicant submitted its Technical Note on Site Selection [REP2-043] (**TNSS**). The TNSS approach is a departure from the original SSAR. SLD has reviewed the TNSS and considers it to both maintain a number of existing methodological and substantive flaws in the SSAR, but also to introduce further flaws. SLD maintain the view that PDA 10 is either the most, or one of the most, harmful sites for a proposal to be advanced.

6.1.3. SLD notes the other submissions in the Applicant's Response to Written Representations [REP2-039] (**ARWR**). At §SLD-046 it provides a superficial response to SLD's reassessment against the Annex A which suggests a disproportionately brief review of PDA 10 was conducted compared to the other PDAs as part of the site selection process. This bolsters rather than undermines SLD's position. SLD is not (contrary to the Applicant's apparent suggestion) stating that almost a 'mini-EIA' should be conducted; but for a Proposed Development of this size and significance more than a cursory assessment should be taken. That was the approach adopted in Appendix L.



6.1.4. The remainder of this short paper proceeds by reference to paragraphs in the TNSS. Paragraph references are to that document unless stated otherwise.

Policy

6.1.5. SLD note the discussion of policy from §1.1.3 to §1.1.6. However, the position in policy and law remains as described in Appendix L from §5. SLD disagree with the Applicant (including at ARWR §§SLD-036 and SLD-037) that the Applicant has met the requirements of law and policy. SLD note that the Applicant accepts that site selection could be a reason to refuse when considered in combination with other aspects of law and policy. SLD agrees with this; SLD disagrees with the Applicant that there are no reasons to refuse here (ARWR §SLD-039).

6.1.6. The Environmental Statement is still required in law to be adequate, and there are various reasons (at §14) why the Applicant's reliance on NPS EN-1 §4.3.24 does not capture the obligations weighing upon it to assess alternatives. That is heightened in the context of the s.85 of the Countryside and Rights of Way Act 2000 requirement in respect of the Cotswolds National Landscape (which SLD explores at §16). Ultimately, SLD remains of the view that the Applicant's approach is not adequate, is not in proportion to the size and nature of the Proposed Development, and is flawed methodologically and substantively.

6.1.7. SLD generally disagree with the analysis of significant effects at §2.3.1 in respect of the Cotswolds National Landscape. These points from its Written Representation are not repeated. However, the Applicant takes a simplistic view of SLD's submissions on s.85 (ARWR §SLD-040) seemingly suggesting that SLD's submission was that s.85 requires all harm to be avoided. That clearly misunderstands the submission, which is that the requirement to "avoid" harms must be seen in the context of the s.85 duty to further the purposes of the CNL. Put another way, what is required by avoidance must extend to effects which conflict with the s.85 duty.



The 25km Approach

6.1.8. In section 2 of the TNSS the Applicant begins by conducting an assessment against a 25km rather than 20km search radius. SLD note that this would further extend the 400kV cable; for the reasons it addressed in its Written Representation this is inherently disadvantageous and problematic in environmental terms. It also ignores those sites which SLD consider (from its re-evaluation of the 12 PDAs) to be superior in environmental terms to PDA 10.

6.1.9. However, given the Applicant has conducted this assessment, SLD comment upon it here. At §2.3.2 of the TNSS the Applicant considers a 25km radius from Melksham Substation. The Applicant asserts that no suitable PDAs were identified as a result of that analysis. SLD disagree and, among other things, note the land to the north of Malmsbury (bullet point 2) and land south of Royal Wootton Bassett (bullet point 4). While the Applicant asserts constraints are present, a consistent approach would be to follow the process adopted in SSAR. A PDA should have been identified and a test against the Annex A criteria conducted. The drawing of the PDA is key, because that drawing permits the Applicant to consider the extent of the available land and the degree to which exclusions from the PDA can avoid environmental effects. This was a persistent error in the original SSAR as well (e.g. in the failure to combine PDAs addressed at Appendix L from §28).

6.1.10. A similar point arises in respect of §3.1.5 of the TNSS. Again, the Applicant fails to adopt the same process as set out in its original SSAR, and therefore cannot properly consider these alternatives for inclusion because no PDAs (or additions to PDAs) were drawn. In that regard SLD note, among other things, the land to the west of Trowbridge (bullet point 3) and to the west of Melksham (bullet point 4).

Combining PDAs and Using the Least Constrained Areas

6.1.11. The Applicant then turns to consider Appendix L. It is pertinent first to note that the list of constraints at §4.1.2 is one which conflicts with the process of



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identifying PDA 10 and the Proposed Development itself. In Appendix L, SLD identified that the Applicant had adopted an inconsistent approach to the application of criteria to different PDAs. Here the position is even more problematic, as it is inconsistent application of criteria to just PDA 10.

- 6.1.12. SLD address these matters in summary only here, but the ExA will be aware that the underpinning evidence from SLD is available in its Written Representation and its Appendices. Among other things:
- 6.1.12.1. (bullet point 3) SLD consider there are 5 listed buildings at this range in respect of PDA 10 and the Proposed Development. In addition, SLD considers that the Fosse Way is pertinent here.
 - 6.1.12.2. (bullet point 5) SLD accept that, while PDA 10 and the Proposed Development include Grade 3a and 2 agricultural land, most of that information was not available at the site selection stage. That is with the exception of Grade 2 predicted to the far east side of Area E south of Cleeve House (predicted in Natural England's Provisional ALC maps)
 - 6.1.12.3. (bullet point 6) Flood Zones 2 and 3 are present along the Gauze Brook and Rodbourne Brook (and Norton Brook as well, albeit panels are proposed nearby rather than in the Norton Brook Flood Zone). This information was available in advance. In addition, surface water flooding is scattered across the whole of the site, and available on the relevant mapping (that mapping having been used as part of the SSAR).
 - 6.1.12.4. (bullet point 7) as is immediately apparent from **[APP-079]** areas of ancient and other woodland are either abutting the Proposed Development or enveloped by it. That includes Bincombe Wood, Lords Wood, Surrendell Wood, Bradfield Wood, Rodbourne Plantation and Seagry Wood. It is unclear from the TNSS whether the Applicant's assessment has simply drawn the redline area around such woods to exclude them, or has provided wider buffer areas.



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- 6.1.12.5. (bullet point 8) as is apparent from Table 9-6 of the Ecology Chapter of the ES [REP1-016], two additional Local Wildlife Sites are abutting or enveloped by the Proposed Development. That is in addition to Harries Ground SSSI abutting Area E. Again, how the Applicant draws the redline area is unclear.
- 6.1.12.6. (bullet point 9) a large number of PRowS abut or envelope the Proposed Development. SLD has provided more detail on this in its Written Representation.
- 6.1.12.7. (bullet point 10) the cable route passes through the impact zone for the Bradford on Avon Bat SAC.
- 6.1.13. The reality is that the process described at §4.1.2 to §4.1.4 is a process which uniquely privileges PDA 10 (the Proposed Development site) by not assessing it against the same criteria as the remaining PDAs. SLD thus firmly refutes the suggestion that “Area remaining when constraints removed” in Table 4-1 for PDA 10 is “not applicable”. It is *entirely* applicable. In the SSAR process PDAs 1-9 and 11-12 would not have been compared against the Proposed Development but rather PDA 10. SLD consider that the Applicant should either produce a figure for PDA 10 applying those criteria identified in §4.1.2, or the Applicant should narrow the criteria in §4.1.2 to reflect the process which resulted in the selection of PDA 10 and the Proposed Development site.
- 6.1.14. This is not an arid technicality. The Applicant’s position is that it selected PDA 10 via a forward-looking site selection process; not the backwards looking one described here. A lawful and acceptable in planning terms SSAR would apply a consistent approach and come to properly described, explained, and defensible outcomes. The analysis provided does not do this, and is a flaw which affects the remainder of Section 4 of the Technical Note.
- 6.1.15. From §4.1.5 the Applicant has engaged in a clustering approach. Of course, this approach is impacted upon by the error in the approach already identified above. However, this section is flawed as well. In the first place, given



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the acceptable range of PDA3 and PDA4 as appears in the original SSAR, it remains entirely unclear why the Applicant excludes the eastern parts of PDA 4, and PDA 9. Second, even on the Applicant's own process in its SSAR (§2.4.7) its narrowed PDA 7 is well in excess of the 40ha minimum the Applicant otherwise chose to apply. Third, SLD remain of the view that the Applicant's approach fails to meet the size and scale of the Proposed Development. The inconsistent approach to assessment (not applying Appendix A) is again repeated at §4.1.7.

6.1.16. The Applicant then combines some PDAs into three clusters. Each is primarily rejected on the basis of cultural heritage constraints. However, this approach by the Applicant fails to consider how PDAs can be appropriately drawn to avoid these effects. Also, given the cultural heritage assets involved, SLD notes that similar concerns arise in respect of PDA 10 anyway (such as in respect of Bradfield Manor). This raises real concerns about the consistency of the assessment. SLD consider that this approach does not demonstrate the forward-looking approach to assessment of alternatives required properly to avoid effects and select a site, and also does not properly engage in the analysis contained in the Annex A criteria.

6.1.17. In conclusion, the above process not only maintains flaws from the SSAR, but also introduces new flaws as part of a backwards-looking process which appears to attempt to justify PDA 10 (and the Proposed Development) in retrospect rather than present what the Applicant asserts was a lawful, proportionate, and consistent approach to selection prospectively.

Redrawing PDAs to Apply Criteria Consistently

6.1.18. In section 5 the Applicant addresses the redrawing of PDAs against (what it calls) the Stage 6 criteria. The Applicant admits and accepts (at §5.1.5) that a consistent approach would identify further areas for development. Looking at Figure 7 in Annex A, the substantial addition to PDA 2 is readily apparent (being 391.1 hectares). It is noted that the Applicant excludes additions around PDA 1, 3 and 4 using the same flawed criteria already considered above.



- 6.1.19. At §5.1.10 the Applicant applies the defective constraints identified above to PDA 2 and the new addition to calculate the total PDA size as 511.8ha. The same points made in the preceding paragraph address this (i.e. the inconsistent approach to the application of criteria for identification of the more constrained PDAs).
- 6.1.20. The Applicant then considers the extended PDA 2 included in Cluster 1. It is not assessed against the Annex A criteria. The Cluster would be approximately 1198.1 hectares. That is a significant size as it approaches the Proposed Development at 1,237 hectares *without* the Proposed Development meeting the criteria against which all of Cluster 1 has been assessed. The rejection of this Cluster essentially boils down to a heritage concern regards Broughton Gifford Conservation Area without a recognition that inclusion of the additional PDA 2 area provides an opportunity for further exclusions to manage the effects on that heritage asset.
- 6.1.21. The Applicant also considers the extended PDA 2 included in Cluster 2. It is not assessed against the Annex A criteria. This Cluster would be approximately 1184.8 hectares. Again, that approaches the Proposed Development notwithstanding it has never been assessed against the criteria that Cluster 2 was assessed against. Again, the rejection of this Cluster essentially boils down to a heritage concern regards Sneed Conservation Areas without a recognition that inclusion of the additional PDA 2 area provides an opportunity for further exclusions to manage the effects on that heritage asset.
- 6.1.22. The Applicant's approach above is not only flawed, but if applied correctly would clearly identify combined PDAs of at least similar size to the Proposed Development (and that is before PDA 10 was assessed against the new criteria). The TNSS reinforces rather than rebuffs the criticisms advanced by SLD in Appendix L on this point.



Conclusion

6.1.23. As will be apparent from the above, SLD does not accept the analysis in the Technical Note. Not only does it retain existing flaws, but also introduces new ones by assessing the PDAs and Clusters against *more* onerous criteria than PDA 10 and the Proposed Development. For that reason, SLD respectfully suggest that the Applicant should be directed to either (1) produce a figure for PDA 10 to be included in Table 4-1 of the Technical note; and/or (2) PDA1-9 and 11-12 be reassessed to produce figures for Table 4-1 which applies the same criteria as those which apply to PDA 10 and the Proposed Development.

6.1.24. As a final summary point, the obligation in the EIA Regulations is to describe the site selection process that took place. While SLD do not consider this new Technical Note remedies the errors that it identified anyway, if and insofar as the ExA consider there are flaws in the original SSAR, a retrospective and backwards looking addendum to the SSAR which does not reflect analysis at the time cannot remedy those flaws (nor can it render what is an inadequate and disproportionate process, adequate and proportionate). That goes back to a key flaw (identified, among other things, in respect of the criteria applied to the other PDAs in the Technical note but not to PDA 10) that the Applicant still fails to identify an adequate, proportionate, and consistent approach which would prefer PDA 10 on a forward-looking basis. At no point in the Technical Note is PDA 10 (and the Proposed Development) assessed against the same criteria as are applied to all other PDAs.



7. Appendix 2: Hydrology Papers

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Minimizing environmental impacts of solar farms: a review of current science on landscape hydrology and guidance on stormwater management

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Minimizing environmental impacts of solar farms: a review of current science on landscape hydrology and guidance on stormwater management

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Abstract

As solar energy becomes an increasingly cheap source of renewable energy, major utility-scale ground solar panel installations, often called ‘solar farms’, are rapidly growing. With these solar farms often covering hundreds of acres, there is the potential for impacts on natural hydrologic processes, including runoff generation and erosion. Here we review the current state of scientific research on the hydrology and water quality impacts of solar farms, as well as management recommendations for minimizing any impacts. The limited field measurements indicate the redistribution of soil moisture around solar farms, but the net impacts on runoff and erosion are less clear. Research focused on coupling solar farms with agriculture as ‘agrivoltaics’ demonstrates reduced evaporative water losses and associated crop stress, particularly in more arid regions. With regards to land and the stormwater management associated with solar farms, most US states currently do not have solar farm-specific recommendations and instead defer to standard stormwater management permits and guidance. In states with solar farm-specific guidance, typical recommendations include minimizing construction-related compaction, ensuring a high cover of perennial vegetation with minimal maintenance, and designing with pervious space between solar panel rows to promote infiltration of any runoff; in some cases, structural stormwater management like infiltration basins may be required. In general, solar farms can be designed to minimize the impact on landscape ecohydrological processes, but more research is needed to determine whether current recommendations are adequate. In particular, there is a need for more field research on less ideal sites such as those with higher slopes.

1. Introduction

The advancement of human civilization depends on energy. Societies are growing, and the standard of living is rising, resulting in a growing demand for energy. The use of fossil fuels as a major energy source has led to environmental pollution and global warming. In addition, fossil fuels are not renewable. In recent decades, there has been a search for cheaper, affordable and more environmentally friendly and sustainable energy sources (Gunerhan *et al* 2008, Shorabeh *et al* 2019).

Amongst sustainable energy sources, solar energy is favored, owing to its plentitude and increasing affordability. It is more abundantly distributed in nature than any other renewable energy source. Solar energy has widely and exponentially grown in the last couple of decades (US Energy Information Administration (EIA) 2020). Solar photovoltaic (PV) technology converts the Sun’s energy to environment-friendly electricity (Solangi *et al* 2011). This has been one of the most booming forms of renewable energy in recent years, due to technological advancements and favorable government policies that have made it increasingly affordable and accessible (Gunerhan *et al* 2008, Hassanpour Adeg *et al* 2018, Shorabeh *et al* 2019). PV development can also

be beneficial in terms of potentially supporting the reclamation of degraded land, economic opportunities, and rural electricity access. (Ravi *et al* 2016). It also avoids the greenhouse gas impacts, air quality concerns, and other sources of pollution caused by fossil fuels (Aman *et al* 2015, Hernandez *et al* 2014, Grigorescu *et al* 2019, Lambert *et al* 2021, Shorabeh *et al* 2019, Taha 2013, Vrinceanu *et al* 2019).

PV technology is deployed in various ways. One popular approach leverages the rooftops of residential or commercial buildings for solar panel installation, where solar panels are impervious panels of PV cells. Solar panel arrays mounted on the ground are another way of harvesting solar energy, particularly at a larger scale compared to residential rooftop solar. Utility-scale ground solar panel installations used for electricity generation of 1 MW or greater are commonly referred to as ‘solar farms’ (US Energy Information Administration (EIA) 2020). On solar farms, solar panels are mounted on metal supports, with panels arranged in long rows. The area under and between the panels could be paved, covered with gravel, bare soil, or vegetated. The interspace between the rows, as well as access paths or roads between clusters of rows, allows for maintenance as well as possible infiltration of water (Barnard *et al* 2017a, Gunerhan *et al* 2008, Zhu *et al* 2019).

Utility-scale solar energy development needs a lot of space, and its large-scale installation could potentially have some negative impacts on the environment, but this depends on the way that the solar farm is built and maintained (Hernandez *et al* 2019, 2014, Moore-O’Leary *et al* 2017). The area covered by solar farms can vary between 1 acre (0.40 ha) to several hundred acres, depending on the power generation capacity. The construction process of solar farms can require extensive landscape modification that could result in the modification of soil properties and vegetation (Aman *et al* 2015, Jacobson and Delucchi 2011). The addition of an impervious surface, as solar panels, could alter the site’s hydrology and impact erosion. Changes in vegetation and ongoing maintenance of the site can also impact soil carbon dynamics and habitat provision (Barnard *et al* 2017a, Choi *et al* 2020a, Gunerhan *et al* 2008, Moore-O’Leary *et al* 2017, Walston *et al* 2021). There is increasing interest in leveraging solar farms for the provision of additional ecosystem services or benefits beyond solar power generation. This could include planting of certain vegetation to create pollinator habitats (Blaydes *et al* 2021, Graham *et al* 2021, Walston *et al* 2021, 2018). The concept of ‘agrivoltaics’ involves leveraging the solar farm for agriculture, such as sheep grazing or crop cultivation (Weselek *et al* 2019).

As solar energy becomes an increasingly cheap source of renewable energy, the number of solar farms is rapidly growing. As of 2022, there are approximately 5500 major solar projects across the US, with existing installations generating 55 GW, and projects under construction or in development generating 110 GW (Solar Energy Industries Association 2020). Thus, it is critical to ensure that these projects are implemented in the most sustainable way.

There is a small but growing body of scientific research seeking to understand the impacts of solar farms, specifically on landscape ecohydrology in a range of environmental and land conditions. Similarly, there are rapidly evolving guidance and/or regulations on best land development practices related to solar farm implementation. Thus, we seek to synthesize the current state of scientific knowledge and management recommendations, as well as to identify gaps. We review the current science on how solar farms impact landscape hydrology and related soil and vegetation characteristics, as well as review the current state of land and stormwater management guidance in US states with respect to solar farms.

2. Methods

In order to review the current science on solar farm hydrology, in mid-2022 we sought relevant scientific literature using Google Scholar and Web of Science to perform searches with the following key words: (solar farm, PV, or agrivoltaic) and (hydrology, stormwater management, soil moisture, runoff, or evapotranspiration). We have also followed references cited in these articles to identify additional relevant articles. This yielded 18 usable articles which are reviewed.

In addition, we reviewed available information on land and stormwater management recommendations from US states. In the US, most states have authority delegated from the US Environmental Protection Agency to oversee permitting processes related to land development under the National Pollutant Discharge Elimination System (NPDES). States may also choose to enact their own regulations relating to solar farm development and/or stormwater management. We searched the websites of US state agencies with jurisdiction over stormwater management regulations, in order to summarize the available rules and guidelines specific to stormwater management on solar farms. If we could not find stormwater management information specific to solar farms for a given state, we also attempted to contact the agency directly for information.

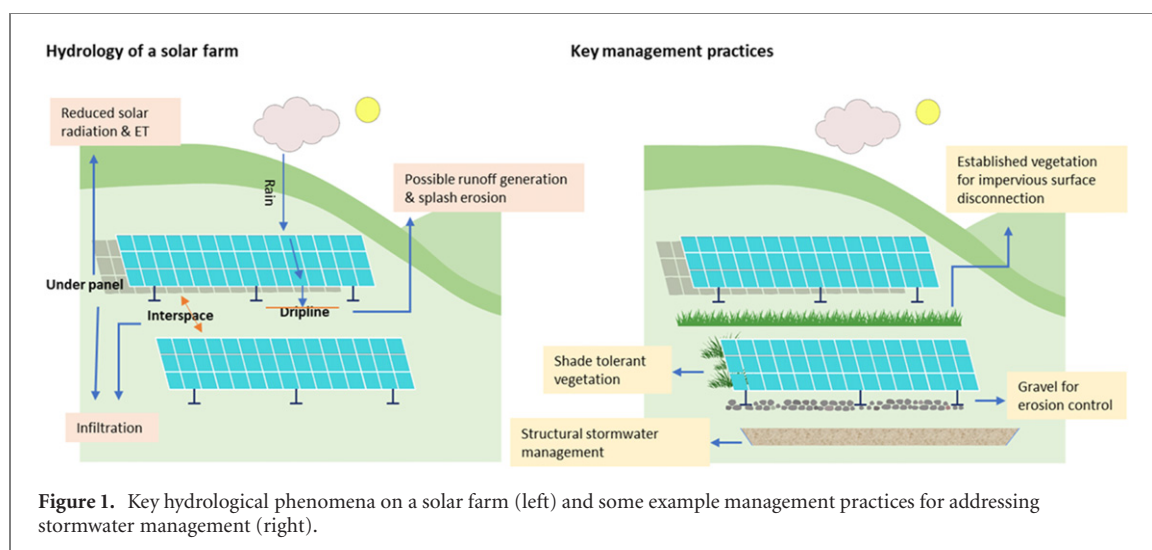


Figure 1. Key hydrological phenomena on a solar farm (left) and some example management practices for addressing stormwater management (right).

3. Review of scientific research on solar farm hydrology

Research on the landscape hydrology of solar farms is comprised of field-based and computational modeling studies. Field-based studies primarily address hydrologic components and landscape biophysical attributes, including soil moisture patterns, evapotranspiration, soil properties, and vegetation characteristics (table 1). Field studies span multiple continents and climatic zones, including Asia, North America and Europe. Modeling studies focus on simulating soil moisture, runoff generation, and erosion (table 2).

3.1. Solar farms and soil properties

Given that solar farms involve major construction activities during the site development process, there is potential for them to have impacts on soil properties and vegetation. Soil physical and chemical properties directly impact hydrologic processes, and thus we begin our review with understanding these impacts.

Some physical, chemical, and biological soil indicators can be lower on solar farms compared to semi-natural land cover types, depending on solar farm management strategies. Research on a solar farm in southern France with silty clay soils did not find differences in soil bulk density on solar farms as compared to semi-natural pinelands and shrublands, but did find a reduced water holding capacity (Lambert *et al* 2021). Research on a solar farm in Colorado, USA observed a greater coarse particle fraction on the solar farm as compared to an adjacent native grassland reference. The reason for the difference in particle size is likely the soil disturbance and vegetation removal during the construction phase of the solar farm, which causes erosion of the fine particles (Choi *et al* 2020a).

Some studies have found the carbon and nitrogen content to be lower in the soil on solar farms than in reference soils (Choi *et al* 2020a, Lambert *et al* 2021). Basal respiration and microbial biomass have also been measured at lower quantities on solar farms compared to reference land covers (Lambert *et al* 2021). However, at a solar farm on reclaimed cropland with meadow grasses, there were no significant differences in soil physical and chemical properties, as compared to a reference site (Armstrong *et al* 2016). There were some differences in soil biological indicators such as respiration, but the differences were not consistent throughout the year.

Some soil properties may also vary within the solar farm. Unsaturated hydraulic conductivity was found to be higher beneath solar panels on a solar farm in Colorado than at the edge or interspace area between panels (see the schematic of example solar farm in figure 1). The reason for this difference may be the reduced exposure to maintenance activities beneath the panel, which could induce compaction and reduce hydraulic conductivity (Choi *et al* 2020a). This in turn can impact patterns of soil moisture distribution, which is discussed later in section 3.4.

3.2. Solar farms, micrometeorology, and evapotranspiration

The presence of solar panels has the potential to alter multiple meteorological properties. They may change the balance of incoming solar radiation and emitted radiation, in turn altering soil temperature and evapotranspiration. The fact that they are typically mounted some distance above the ground and inclined may also affect wind dynamics. Additionally, the type and health of vegetation affects actual evapotranspiration (AET) rates, where vegetation may be influenced by the solar panels as well as by human management decisions.

Reduced solar radiation from shading has been documented beneath solar panels on solar farms in France, the United Kingdom, and Oregon and Nevada, USA. This results in lower mean daily soil and air temperatures

Table 1. Summary of the reviewed field-based studies on solar farm hydrologic phenomena, highlighting the basic study location and types of measurements made on hydrologic and related variables. An 'x' indicates that measurements were made for variables in the given category.

Source	Site characteristics			Types of measurements				
	Location	Climate zone	Solar farm info	Micro-meteorology	Soil Phys/Chem/Bio properties	Veg- etation	Soil moisture	Runoff
AL-agele <i>et al</i> 2021	Corvallis, Oregon USA	Mediterranean warm, cool summer climates	0.8 ha agrivoltaic vegetable farm with 18 degree panel tilt. Silty clay loam soil	x	—	x	x	—
Armstrong <i>et al</i> 2016	Swindon, United Kingdom	Oceanic climate	Land cover prior to construction: the field site was arable cropland and was sown with a species-rich meadow mixture After construction: the control and interspace of the solar farm were re-seeded with species-rich meadow mixture	x	x	x		
Barron-Gafford <i>et al</i> 2019	Tucson, Arizona, USA	Arid climate, hot desert	Agrivoltaic site with crops (tomatoes, jalapenos, and chiltepin plants). Native soil was replaced with an organic garden blend (organic compost and an organic garden blend (organic compost and sandy soil) Age of the solar site: less than one year	x	—	x	x	—
Choi <i>et al</i> 2020a	Northern Jefferson County, Colorado, USA	Cold semi arid	The treatment site is revegetated with native grasses similar to the undisturbed condition (control point) Surficial soils at the solar site are paleosols with clay-enriched subsoil Age of the solar site: 8 years	x	x	—	x	—
Elamri <i>et al</i> 2018a, 2018b	Montpellier, France	Mediterranean hot summer	Agrivoltaic system (lettuce) with varying panel density and tilt. oil type is loamy clay deep alluvial soil (same site as Marrou <i>et al.</i> with updated ability for variable panel tilt)	x	—	—	x	—
Hassanpour Akeh <i>et al</i> 2018	Corvallis, Oregon USA	Mediterranean warm, Oregon USA	Agrivoltaic site with pasture. The soil classification for both the control and agrivoltaic systems is Woodburn silt clay Age of the solar site: 2 years	x	—	x	x	—
Lambert <i>et al</i> 2021	Southern France	Mediterranean hot summer climates	Soil type of solar farms are carbonatic pedofeatures Different control points with a land cover of pinewood, shrubland and abandoned vineyards were selected	—	x	x	x	—

(continued on next page)

Table 1. Continued Summary of the reviewed field-based studies on solar farm hydrologic phenomena, highlighting the basic study location and types of measurements made on hydrologic and related variables. An ‘x’ indicates that measurements were made for variables in the given category.

Source	Site characteristics			Types of measurements				
	Location	Climate zone	Solar farm info	Micro-meteorology	Soil Phys/Chem/Bio properties	Veg-etation	Soil moisture	Runoff
Marrou 2013b <i>et al 2013a</i> ,	Montpellier, France	Mediterranean hot summer climates	Agrivoltaic system (lettuce and cucumber) with varying panel density and a fixed 25 degree tilt. The soil type is loamy clay deep alluvial soil (same site as Elamri <i>et al 2018a</i>)	x	—	x	x	—
Uldrijan <i>et al 2021</i>	South Moravian Region, Czech Republic	Oceanic climate	The soil has textures of loamy-sand to clay-loam, vegetated with perennial grass mixture Age of the solar site: 7 years	—	—	x	—	—
Wu <i>et al 2022</i>	Northwestern China	Arid climate, cold desert	Solar farm with a panel tilt of 37.5 degrees, where a panel row is comprised of two adjoining sub panels with a 3 cm gap. Mixed gravel and sand soil substrate	—	—	—	x	—
Yue <i>et al 2021</i>	Western China	Arid climate, cold desert	The soil material is loess or gravel, soil texture is mainly sandy loam and light silt loam The main plant species are shallow-rooted plants Some of panels are fixed and some are rotating	x	—	—	x	—

Table 2. Summary of reviewed studies performing hydrological modeling of solar farms.

Source	Solar farm info	Modeling approach	Target variable(s)
Barnard <i>et al</i> 2017a	Three solar farm sites in west Texas and one solar site in Georgia USA (humid subtropical climate)	Flo-2D/HEC-HMS maps of maximum flow depth and velocity	The final products are
Cook and McCuen 2013	No specific geographic location Different scenarios: <ul style="list-style-type: none"> • Slope 1%–5% • Soil type B and C • Panel angle 30, 45 and 70 • Vegetation type: bare ground 	Custom model in MATLAB (Water balance, Manning's Eqn)	Runoff depth, peak flow, erosion potential
Edalat 2017	Two solar farms in Nevada USA (arid climate) <ul style="list-style-type: none"> • Urban • Outside urban area 	HEC-HMS	Runoff depth/peak flow
Elamri <i>et al</i> 2018b	Agrivoltaic solar farm in Montpellier, France (mediterranean hot summer)	Hydrus 2D with custom AVrain module to simulate rain redistribution of panels	Solar panel rain redistribution /runoff, soil moisture
Pisinaras <i>et al</i> 2014	Low, medium, and high intensity solar farm scenarios for sub-basins in 1%–5% of Vosvozis River watershed in northern Greece (Mediterranean hot summer climate) Solar farm scenarios replaced existing agricultural land use	SWAT	Surface runoff, infiltration, evapotranspiration
Walston <i>et al</i> 2021	Midwest United States (hot summer, continental climate) land use scenarios: <ul style="list-style-type: none"> • Agriculture scenario • Solar-turfgrass scenario • Solar-native grassland scenario 	InVEST ecosystem services model	Sediment retention, water retention
Wu <i>et al</i> 2022	Solar farm in northwestern China (arid, cold desert climate)	Custom model using energy balance, AVrain and single bucket water balance	Soil moisture and temperature

below the panels in comparison to full sun reference sites during the spring and summer (AL-agele *et al* 2021, Armstrong *et al* 2016, Hassanpour Adeh *et al* 2018, Marrou *et al* 2013b, Yue *et al* 2021). Remote sensing of land surface temperature at a solar farm has also indicated overall reductions in soil temperature across the site as compared to pre-development data, though this approach could not explicitly evaluate changes below the panels (Edalat 2017). Wind and humidity changes were not as consistent. Wind speed and vapor pressure deficit did not change relative to solar panels at a solar farm in France (Marrou *et al* 2013b). However, wind speed, direction, and relative humidity were all altered around solar panels, as compared to the reference site at a solar farm in Oregon (Hassanpour Adeh *et al* 2018), and vapor pressure deficit decreased under solar panels on solar farms located in the United Kingdom and Arizona USA (Armstrong *et al* 2016, Barron-Gafford *et al* 2019).

There can be temporal variability in how solar farms affect meteorological properties and resulting soil dynamics. For example, solar panels decreased the soil temperature beneath the panels compared to reference sites, but these differences were more substantial in spring versus summer (Lambert *et al* 2021). Increases in soil temperature beneath solar panels relative to reference sites have also been observed during autumn and winter periods at solar farms located in the United Kingdom and western China, when solar panels may help prevent loss of longwave radiation (Armstrong *et al* 2016, Yue *et al* 2021). Remote sensing observations of the land surface temperature in Nevada found temperature differences to be greatest in winter when the Sun was lower and the shadows from solar panels were larger (Edalat 2017).

Reductions in solar radiation generally translate into reduced potential evapotranspiration (PET) under solar panels (Elamri *et al* 2018a, Hassanpour Adeh *et al* 2018). Solar farm impacts on evapotranspiration dynamics have been investigated in depth on prototypes of agrivoltaic systems in France, testing two crops (cucumber and lettuce) and two solar panel configurations (full panel density vs half density (Marrou *et al* 2013a). Results show that PET and AET were higher in the full Sun reference locations compared to the solar farm agrivoltaic sites. The reduction in AET was slightly more at the full density solar farm as opposed to the half density site, and differences also varied by crop type. For the lettuce agrivoltaics site, AET over the measured growing period was 103 mm at the full Sun reference, but reduced to 81 and 79 mm for the half density and full

density solar farm sites, respectively. Similarly, at the cucumber agrivoltaics site, AET was 178 mm at the full Sun reference, but reduced to 153 and 145 mm at the half density and full density solar farm sites, respectively. In general, ET fluxes were more affected in spring than in summer, indicating temporal variability in the solar panel influence (Marrou *et al* 2013a). The ratio of transpiration to evaporation also changed, increasing 3 – 4 times in the shaded area of the solar farm sites.

Additional research at this same agrivoltaic site explored the impact of variable panel tilting/tracking on solar radiation and ET (Elamri *et al* 2018a). While there was still a net reduction in solar radiation and ET under panels with panel tracking, it led to much less heterogeneity than at the sites with a fixed panel orientation.

3.3. Solar farms and vegetation

As with soil properties, vegetation on solar farms is a function of both initial human management decisions regarding the initial solar farm development, and ongoing operations and maintenance decisions on the solar farm. It is also affected by interactions with site soil properties and hydrology. Vegetation is explicitly leveraged as a stormwater management practice, as described later in this review, and is a critical managed element of agrivoltaics operations where solar farms are leveraged for the additional co-benefits of crop production. Thus we feel it is important to review what is known about changes in vegetation on solar farms.

Existing field research has focused on the assessment of vegetation coverage, biomass, and diversity, as well as on interactions with hydrologic processes via water use efficiency or water productivity. Findings are quite variable in these limited studies. Surveys of a solar farm (non-agrivoltaic site) in France largely found no major differences in plant community composition and coverage, relative to nearby reference shrubland and pineland sites. There was a slight increase in the relative abundance of shadow-tolerant plant types under solar panels (Lambert *et al* 2021). At a reclaimed brownfield site in the Czech Republic, where the land was sown with a meadow grass mixture during solar farm development, differences in plant composition within the solar farm were observed in a survey eight years after the initial development (Uldrijan *et al* 2021). A greater abundance of taller native perennial grasses was documented in the interspace between panel rows, where more shade-tolerant species and sometimes invasive grasses were observed beneath panels. At a solar farm in the United Kingdom, reduced plant species diversity was observed under solar panels, with reference and panel interspace areas dominated by forbs and legumes (Armstrong *et al* 2016).

Both increases and decreases in vegetation biomass have been documented under solar panels, depending on the climatic zone. In the areas with lower solar radiation (solar farms in the United Kingdom and the Czech Republic), reduced vegetation coverage and reduced biomass (up to four times lower) have been documented beneath solar panels, relative to panel interspace or reference areas (Armstrong *et al* 2016, Uldrijan *et al* 2021). However, the results of research in the solar farm located in Oregon show 126% more dry biomass beneath solar panels relative to the interspace zone and 90% more dry biomass relative to the reference site (Hassanpour Adeb *et al* 2018). This site is less energy-limited. Thus, the shading of solar panels helps to reduce ET losses and in turn to maximize the water use efficiency of plants, as well as to increase biomass. At crop agrivoltaic sites in Oregon and France, some reduction in crop yield and biomass has been observed under panels relative to nearby reference sites (AL-agele *et al* 2021, Elamri *et al* 2018a). At sites with solar panel tracking, biomass was only 16% less than the reference, compared to 30% or greater reductions at fixed panel sites (Elamri *et al* 2018a).

More efficient water use has been observed under solar panels in multiple cases, mainly because of the shading and reduced solar radiation and PET under the panels. This is particularly evident in locations abundant in solar radiation. In an agrivoltaics solar farm in Arizona, USA, the shade of the solar panels reduced plant drought stress and led to greater crop and food production (Barron-Gafford *et al* 2019). More efficient water use was also observed for lettuce crops in an agrivoltaics solar farm in France. Coverage of soil by crops was found to be important in reducing soil evaporation and maximizing the availability of water for transpiration and biomass production (Marrou *et al* 2013a). Water productivity also improved in the shade of panels at a tomato agrivoltaic site located in Oregon (AL-agele *et al* 2021). Modeling of water and vegetation dynamics at agrivoltaic sites in France successfully reproduced field data on rain and soil water redistribution, and allowed for the additional scenario exploration of plant-water interactions and optimization. The modeled scenarios indicated that the tilting of solar panels could help to minimize water interception and the associated redistribution of water. The scenarios also indicated that agrivoltaics could improve water productivity relative to more traditional agriculture, with only small reductions in crop yield (Elamri *et al* 2018a, 2018b).

3.4. Impact of solar panels on soil moisture distribution

On solar farms, the impervious surface of solar panels intercepts precipitation and drains the water into the interspace between panels. Previously discussed changes in evapotranspiration and soil physical and chemical properties can interact with this altered surface hydrology to cause some heterogeneity in the soil moisture content on solar farms.

Field measurements of the soil moisture on solar farms have often been focused on key locations relative to the solar panels. These have included the interspace area fully open to the sun between panels, under the lower front edge of the panel or ‘dripline’, underneath the center of the panels, and at the back (higher) edge of the panels where there is partial Sun (figure 1). Sometimes measurements may also be made at a control or reference area outside the main array of panels. At a solar farm in western Oregon, USA on silt clay soils, the soil beneath the center of solar panels was consistently wettest, followed by soil under the back edge of solar panels, and nearby reference soils, with the interspace soils being driest. At a 0.6 m depth, soil under the center of the panels remained near saturation ($\sim 30\%$ volumetric water content (VWC)), whereas the interspace area depleted from $\sim 30\%$ to $\sim 20\%$ VWC by the end of the growing season (Hassanpour Adeg *et al* 2018). Similar patterns have been observed at solar farms in China (Wu *et al* 2022, Yue *et al* 2021). Soil moisture at a northwest China site was wettest (10%–20% VWC) at the main dripline at the front of panels as well as under the center of the panel row where a small gap in panels was located; soils at the back edge of panels and nearby reference soils were driest (5%–10% VWC; Wu *et al* 2022). At an arid western China solar farm, soil moisture was consistently higher under panels—14.7% higher under fixed tilt panels compared to 11% higher under variable tilt panels (Yue *et al* 2021). Soil moisture was also consistently higher under solar panels at an agrivoltaics site located at Arizona, USA, as compared to an agricultural control site (Barron-Gafford *et al* 2019). At a solar farm in Colorado, USA (cold semi-arid climate) with paleosols and clay subsoil, some soil moisture variability was observed. Dripline soils were consistently higher (up to 20% – 30% VWC), especially following rain events (Choi *et al* 2020a). However, substantial variability in soil moisture at all locations relative to solar panels led to a lack of statistically significant differences. The reference site at nearby native grassland was consistently lower in moisture ($\sim 5\%$). At an agrivoltaic site in France, higher soil moisture was observed at panel driplines, while soil moisture was lower under the panels and in the interspace (Elamri *et al* 2018b). Another solar farm in France did not demonstrate differences in soil moisture under solar panels compared to the interspace, but did observe overall reduced soil moisture at the solar farm sites as compared to a shrubland reference (Lambert *et al* 2021). Overall, the main panel dripline at the front of solar panel rows is consistently wetter, and interspace zones tend to be drier. However, under panel soil moisture may vary depending on the balance of evapotranspiration and runoff contributions, due to the climate and panel design.

There have also been some efforts to model soil moisture dynamics on solar farms. These studies have created or leveraged models of rain redistribution from solar panels, and then combined this with various approaches of water and energy balance representation to simulate soil moisture (Elamri *et al* 2018b, Wu *et al* 2022). In both cases, there was reasonable agreement between observed and simulated soil moisture. Suspected causes of inaccuracy included challenges in representing the complex energy dynamics under solar panels that influence evapotranspiration (Wu *et al* 2022) as well as challenges in the accurate representation of water redistribution (Elamri *et al* 2018b).

3.5. Solar farms and runoff

To our knowledge, at the time of the writing of this review, the evaluation of runoff generation has occurred only in published modeling-based studies. Many of these studies leverage existing modeling programs, with certain modifications used to represent the unique land cover type of the solar panels. None of these published studies, to our knowledge, have validated their models with field data specific to solar farms.

HEC-HMS (US Army Corps of Engineers 2021) has been leveraged in multiple studies. In one study, the runoff on a solar farm was simulated using a linked model which used a combination of Flo-2D and HEC-HMS (which uses a one-dimensional approach). To simulate the flow from upgradient catchments to the solar farm catchment, HEC-HMS was used. USDA Natural Resource Conservation Service Curve Number methods and shallow water equations were used to predict and route stormwater runoff across FLO-2D grids. The results were reported as maps of maximum flow depths and velocities (Barnard *et al* 2017a). HEC-HMS has also been used to study hydrologic dynamics in a Nevada, USA (arid climate) solar farm (Edalat 2017). It is shown that regardless of the orientation and tilt angles, runoff volume increases after solar panel installation. Impacts on peak flow are more variable, with the orientation of panels either increasing or decreasing peak flow rates. The results indicate that the panels also noticeably change the rain distribution onto the land surface. Therefore, panel orientation and tilt angles are important factors that need to be considered in stormwater channel design to carry runoff peak flow. One major limitation of this study was that solar panels were represented as an impervious surface on the ground, and infiltration could not be permitted under the panels, as would occur at an actual site; thus this approach likely overestimates runoff (Edalat 2017).

SWAT has also been leveraged for assessing the impact of solar farms on watershed hydrology (Pisinaras *et al* 2014). For a watershed in northern Greece, scenarios were implemented that induced land use change from agriculture to solar farms in 1 or 5% of the watershed area. Solar farm implementation was represented using soil physical property changes, curve number increase associated with imperviousness, ground cover change from cultivated to bare soil, and reduced solar radiation. The model demonstrated increased surface runoff

and percolation, and decreased ET due to solar panel implementation, but these changes were not significant at the watershed scale. However, there is the potential for local-scale impacts. For example, there were increases of ~100 mm in surface runoff for a given sub-basin, even for a low impact scenario of solar farm implementation (Pisinaras *et al* 2014).

Other research has relied on custom-built models for representing solar farms (Cook and McCuen 2013). A model written in MATLAB was based on the creation of NRCS type II storms for precipitation (hyetograph) inputs. A simple water balance for each land surface cell was used to allocate precipitation to storage or loss (runoff). Manning's equation was used to estimate runoff velocity and the associated kinetic energy relating to splash erosion. Model scenarios were constructed for a 30 cell grid solar farm, where each cell could have a portion allocated as wet, dry, or interspace. A variety of characteristics were manipulated to simulate changes in soil types, solar panel spacing, vegetation roughness, etc. The results indicated that the addition of solar panels over a grassy field does not change the volume of runoff, the peak discharge, nor time to peak. In general, it was not anticipated that structural stormwater management would be required to prevent adverse impacts (Cook and McCuen 2013).

Some US states, such as Minnesota, have recommended a simple modification to the calculation of impervious surface used in typical runoff modeling approaches for stormwater management planning. Minnesota's recommendation for the modification of runoff calculations leverages the ratio of impervious to pervious surface, where the pervious surface considers both the interspace area as well as the area directly below the panels. Runoff depth associated with this impervious to pervious ratio, as well as soil type, is determined using an Excel tool that leverages the output of an extensive series of models generated in XP-SWMM (Minnesota Pollution Control Agency 2019).

3.6. Solar farms and erosion

Research on the impacts of solar farms on erosion is quite limited. Some modeling results suggest solar panels can increase erosion. The energy and velocity of water draining from the panels is higher, which could cause erosion in soil below the base of the panels, especially if the interspace is bare. Increases (up to 10 times) of kinetic energy were simulated, which could lead to erosion and the need for erosion control measures, but this modeling effort was not validated by field measurements (Cook and McCuen and 2013).

A larger-scale modeling assessment has quantified changes in erosion and associated sediment loss, along with multiple other ecosystem services for hypothetical solar farms in the Midwestern US. These solar farm scenarios focused on vegetation, comparing hypothetical solar farms with native grassland or turfgrass with baseline agricultural land use. Modeling with InVEST, which leverages the revised universal soil loss equation, estimated sediment export under the solar-native grassland scenario to be 0.007 tons/ha/year, which was a reduction of over 95% and 77% compared to the agriculture and solar-turfgrass scenarios, respectively (Walston *et al* 2021). However, erosion estimates were based largely on landscape characteristics such as vegetated cover or slope and did not explicitly represent the fact that solar panels are elevated off the ground.

This existing work largely focuses on the potential for erosion on solar farms after initial construction. However, construction of solar farms can require substantial land manipulation. Thus, it is also important to consider this in erosion estimates, and manage this impact appropriately (see discussion in section 4). In addition to erosion associated with runoff, aeolian erosion is a concern in more arid environments, particularly when presence of vegetation is limited (Ravi *et al* 2016).

4. Review of guidance from US states on solar farm development and stormwater management

In our review of the guidelines and rules of different US states regarding stormwater management on solar farms, a major finding was that most states (close to 30) do not have any guidance for stormwater management specific to solar farms. For ten states, no definitive information was found online and no answer was received to email inquiries, and it is assumed that there is no solar farm specific guidance. In general, these states without specific guidelines defer to their standard rules regarding construction and stormwater management. This typically means that for construction that disturbs a certain area of land (often specified as 1 acre), the solar farm developer would need to follow requirements under the construction general permit for stormwater management. There also may be post-construction stormwater management requirements. The management of construction-related stormwater impacts is required to be managed by states or the US Environmental Protection Agency (US EPA) under the EPA's National Pollution Discharge Elimination System (NPDES) (US EPA 2015).

Twelve US states currently have solar farm-specific guidance relating to managing stormwater (table 3). These states are largely located in the north-central, eastern, and northwestern US. Guidelines from these states rely heavily on 'low impact development' practices (Davis 2005). This involves minimizing initial impacts on

the site during the construction process, as well as strategically planned development and site operations that maintain the natural characteristics of the land to mitigate stormwater. The stormwater management functions desired involve runoff volume reduction via infiltration and, to a lesser degree, evapotranspiration; these processes are in turn dependent on soil properties and vegetation. The reduction of erosion and/or retention of sediment relies on reducing the velocity of runoff through infiltration and enhanced surface roughness, particularly from vegetation (Davis *et al* 2012).

Some guidance relates to the initial site selection process for the solar farm. It is recommended to avoid soils with a slip potential, and well-draining soil types are ideal. Lesser sloped sites are ideal, though there is substantial variability in the recommended slope thresholds (e.g. Maryland recommends 5% or less, while other states recommend less than 10%). With considerations such as the slope or soil hydrologic class, certain categories (e.g. poorly draining soils or higher slopes) are generally permissible for solar farms, but would require additional structural stormwater management to be added (discussed further below).

During the construction process, it is recommended that soil compaction and disturbance be minimized, in order to maintain the soil's natural ability to infiltrate runoff. It is also critical to implement temporary erosion and sediment controls to prevent any impacts during the construction process. This may include erosion control socks, temporary sedimentation basins, or mulching the bare soil surface.

Another group of recommendations relates to how the solar farm site is designed. A key stormwater management practice mentioned by most states with specific guidance is to maintain a certain interspace distance between rows of solar panels. This leverages the 'low impact development' principle of disconnecting impervious surfaces. The pervious interspace between solar panel rows serves to promote infiltration of any runoff and the retention of eroded sediment. In this interspace, as well as under the panels, it is often recommended to maintain a certain proportion of vegetation cover on the site, at least 85% – 90%. A deep-rooted perennial vegetation cover, typically grasses, forbs, or legumes is recommended to facilitate infiltration and assist with erosion control. This may be satisfied by minimizing the impact to existing vegetation, or may be facilitated by seeding. Crop production may also occur, but additional considerations may be needed to ensure that harvesting does not facilitate increased runoff or erosion. It is also important to promote the establishment of more shade-tolerant vegetation under the panels. Minimal mowing, pesticide, or herbicide application is recommended.

The additional practice recommended in some cases is structural stormwater management. As noted above, these sorts of structural practices may be required for specific cases where a site has a high slope or poorly draining soils. Some structural practices are focused on runoff volume reduction via enhanced infiltration, and include features like infiltration basins or infiltration trenches. Other structural practices may be focused on erosion prevention and sediment control and involve stone drip or splash pads near the dripline area under solar panel rows.

5. Discussion and conclusions

5.1. Insights from ecohydrologic research on solar farms

There is a small but growing body of work characterizing how solar farm development changes soil properties, vegetation, and hydrologic processes. Most existing work focuses on soil properties, vegetation, soil water, and micrometeorological characteristics or evapotranspiration; there is no published work yet in the academic literature, to our knowledge, documenting the direct measurement of runoff on solar farms.

The results of scientific research vary from findings of no net impact of solar farms on these ecohydrological properties to detection of some impacts. Field soil moisture measurements often demonstrated variability with respect to the solar panels. These changes in soil moisture relative to panels demonstrate the impact of panels on solar radiation, runoff redistribution, and the corresponding evapotranspiration. Particularly in regions where evapotranspiration is not energy-limited (e.g. warm arid regions), there is a climatic sweet spot where the shading of solar panels can help reduce evapotranspiration and maximize water efficiency and facilitate enhanced crop production in association with solar farms (Barron-Gafford *et al* 2019, Hassanpour Adeg *et al* 2018). Results from agrivoltaic systems indicate that crops can still achieve high yield under the fluctuating shade of these systems (Marrou *et al* 2013a). However, more extensive research is merited in agrivoltaic systems across a range of climate settings and crop types.

In wetter climates, there is an interest in keeping soils from reaching sustained levels of saturation and the associated runoff generation. Solar panels introduce heterogeneity in the soil moisture distribution, with precipitation accumulating along the dripline at the lower edge of the panels. It is essential that appropriate management practices are implemented to prevent this heterogeneity from manifesting in increased runoff and erosion generation. Variable panel tilting may also be considered to reduce the redistribution of water.

Table 3. Example guidelines from US states regarding stormwater management on solar farms. The table is not comprehensive of every guideline for all listed states, but provides examples of the range of guidelines currently available.

Category	Recommendation	Source of example
Site conditions		
Site slope	Ideally <5%; >5% requires various additional management considerations. For slopes >8%, additional management needed to maintain sheet flow and prevent erosion. <10% is favorable; additional management considerations if >10%.	Maryland (MA DOE 2021) North Carolina (NC DEQ 2018), Rhode Island (RI DEM 2021) Pennsylvania (PA DEP, 2019)
Soils	For soils with a depth to bedrock of 12" or less, plans must show that soil will be enhanced by the addition of at least 4" of top soil. Sites with soils having a slip potential should be more closely evaluated for any geotechnical issues—especially in areas with moderate to steep slopes. 2. Soil compaction should be avoided.	New Hampshire (NH DES 2020) Pennsylvania
Considerations during construction		
Considerations during construction	To minimize disturbance and compaction, construction vehicles and equipment should avoid interspace areas during installation of the solar panels to effectively use interspace later for impervious disconnection/infiltration. Erosion and sediment control practices are needed. Temporary erosion control, such as mulch, must be put on exposed soil at the site to prevent erosion during rain events until vegetation is established. Avoid soil compaction and/or topsoil removal. If the soil is compacted or removed, it should be amended to return to its pre-development condition.	Maryland Massachusetts (Mass DEP 2017), Minnesota (MN PCA, 2021), New Hampshire Massachusetts, New Hampshire, North Carolina
Post-construction stormwater management		
Modeling runoff from impervious area	The calculation of water quality volume depends on the slope (if >15%, then panels are an effective impervious area, if not then the evaluation of vegetated areas is emphasized). For water quality and water quantity calculations, solar panels are considered disconnected impervious surfaces. Curve number adjustment is permitted to account for infiltration under impervious panels. With certain steeper slope + soil drainage classes, there cannot be the assumption that infiltration will occur under panels. Solar panels are not considered impervious surfaces, so they do not need to be considered in the calculation of impervious cover at a site.	Connecticut (CT DEEP 2020) Minnesota, Virginia (VA DEQ 2022) New Hampshire New Jersey (New Jersey Legislature 2021)
Panel orientation	Parallel orientation of the solar panels is recommended with respect to slope, in order to prevent flow concentration. If not, runoff should be directed to infiltration practices. The orientation of panels should be considered with respect to drainage pattern, flow concentration, drainage area, and velocity.	Rhode Island Connecticut
Vertical clearance of panels	< 10 feet in order to minimize erosion at the dripline.	Connecticut, Massachusetts, North Carolina, Ohio (OH EPA 2019), Pennsylvania
Impervious disconnection	In general, all states with solar-specific stormwater guidance leverage the disconnection of the impervious surface (i.e., solar panel rows) with well-established vegetation as a key stormwater management strategy, under certain site conditions. More details are noted in the examples below. The vegetated interspace area receiving runoff must be equal to or greater in length than the disconnected surface (e.g., the width of the row of solar panels). Runoff must sheet flow onto and across vegetated areas to maintain the disconnection. Solar panel rows are spaced in a manner to allow sunlight penetration sufficient to support vegetation between the solar panel rows. Pervious space is required between rows of panels. This allows for the use of the 'disconnected impervious credit method', which often results in a reduction in the water treatment volume required. Under some conditions such as the existence of an uncompacted soil profile, dense and healthy vegetation maintenance, it is possible to easily manage the runoff from panels by disconnection. The disconnection length depends on the soil type, where well-draining soils require a shorter interspace (e.g. 1:1 solar panel to interspace distance along the slope) compared to more poorly draining soils.	Maryland, North Carolina, Pennsylvania, Rhode Island Massachusetts, Rhode Island Minnesota Ohio

(continued on next page)

Table 3. Continued Example guidelines from US states regarding stormwater management on solar farms. The table is not comprehensive of every guideline for all listed states, but provides examples of the range of guidelines currently available.

Category	Recommendation	Source of example
Site conditions		
Vegetation	In areas receiving disconnected runoff, groundcover vegetation must be maintained in good condition and should be protected from future compaction (e.g., by planting shrubs or trees along the perimeter). Include cool-season, warm-season, shade-resistant, and legumes as necessary to develop a dense, year-round groundcover that accounts for differences in the temperature and shading from panels.	Maryland North Carolina, Ohio, Rhode Island
	Utilize low- and slow-growing grass varieties to reduce compaction and damage from frequent mowing. Low maintenance grass mixture recommended. The use of fertilizers, pesticides, and herbicides should be minimized.	North Carolina, Ohio, Rhode Island
	>90% deep-rooted perennial vegetative cover with a density capable of resisting accelerated erosion and sedimentation is required. If mowed, do not cut to < 4 in. In agrivoltaic applications, this may include hand-harvested or small machine-harvested crops.	Pennsylvania
	There should be at least 85% coverage. Maintain the vegetation height that maximizes sheet flow - no shorter than 4" and not taller than 12" (grass) or 18" (meadow).	Rhode Island
Post-construction structural stormwater management	When the slope >5%, spreaders, terraces, or berms may be used to prevent concentrated flow and promote infiltration. When the slope >10%, more extensive stormwater management is required.	Maryland
	If the disconnected interspace is not adequate for the volume reduction of runoff or other site conditions merit it, other types of permanent stormwater management for non-erosive conveyance of runoff must be constructed, such as infiltration trenches or berms, wet sedimentation basins, or sand filters.	Connecticut, Massachusetts, Minnesota, Pennsylvania
	A stone drip pad to prevent erosion at the dripline, if panels have a fixed inclination.	Ohio
	Where panels are not oriented generally parallel with the slope and/or where slopes are >8%, runoff needs to be either intercepted by stone trenches for infiltration and/or directed non-erosively to an infiltration practice. Add scour control if instances of erosion/scour develop. Regular inspection and maintenance of infiltration practices is required, and to look for erosion	Rhode Island
	For a solar array in an open field, it is expected that the designer will show compliance with flow control related requirements by using infiltration and/or dispersion type management practices	Washington (Washington State Department of Ecology 2021)

At the time of this review, we were unable to find any study that directly evaluated runoff generation on solar farms through field measurement. Thus, we are still lacking critical insight into whether solar farms change runoff generation, and whether existing site and stormwater management practices are adequate to prevent adverse impacts. As a result, existing hydrologic models of solar farms are largely uncalibrated. There is also a bias in the sort of sites being evaluated. In general, existing environmental research on solar farms has focused on more ideal sites, i.e. those on sites with lower slopes and well-draining soils. Thus, we are neglecting sites that could be more vulnerable to changes in hydrologic processes with solar farm development.

In general, there is still also a need for simultaneous evaluation of multiple environmental co-benefits from solar farm land management, considering how certain vegetation or crop choices could help manage runoff, but also provide habitat or food.

5.2. Connecting observed phenomena to management decisions

While there are some environmental conditions that are linked to the inherent characteristics of ground-mounted solar panels (e.g. that there will be at least some level of shading and interception of water from an inclined panel above the ground), many phenomena can be influenced strongly by specific decisions in how the solar farm is constructed and managed.

Changes in certain soil properties (e.g. the reduction in soil organic matter) between solar farms and reference sites indicate the impacts of initial solar farm development, such as some removal of soil and/or vegetation and regrading of soil. This is something that can be changed by a more careful development process. Other soil property changes in different parts of the solar farm (under panel versus interspace) indicate the impacts of continued maintenance between the panels, such as mowing, that may induce some compaction. Thus, these observed detrimental impacts should be addressed as solar farm development guidance is developed. There are opportunities to select management practices that minimize adverse impacts (e.g. soil compaction) and maximize additional benefits- for example, leveraging sheep grazing for vegetation management in lieu of frequent mowing.

5.3. Key gaps in regulatory/management approaches and scientific knowledge

Most states in the US currently rely on construction general permits for guiding solar farm development, which may not be adequate for the unique design of solar farms (Great Plains Institute 2021). Only 12 of 50 US states had solar-specific stormwater management guidance, as of the writing of this review. The management practices currently recommended largely leverage low impact development practices of disconnection of the solar panel impervious surface, well-developed shade-tolerant vegetation, and minimal impact of construction practices on soil properties. Where necessary, given site conditions or solar panel configuration, structural stormwater practices such as infiltration practices are recommended. These recommendations are an important start, but validation is needed to confirm that these current practices are adequate, and appropriately tailored to the site conditions. There is a particular lack of guidance relating to appropriate stormwater management practices for solar farms in arid environments (table 3).

Given that runoff volume and quality are key metrics in the stormwater regulatory realm, it is a major gap that there is a lack of field research studying runoff on solar farms. It is also critical that hydrologic modeling approaches be improved to appropriately represent the unique design of solar panels, in that there is an impervious surface with the ability to infiltrate water underneath. In particular, approaches are needed that are simple enough to be widely implemented by those personnel preparing runoff calculations and associated permits for proposed solar farm development.

Though this review focused on hydrology and stormwater management, it is critical that future research and management consider simultaneous evaluation of some of the many other ecosystem services (or dis-services) that could be provided by solar farms (Moore-O'Leary *et al* 2017). The role of solar farms (and how precisely they are developed) can also be explored further within the food-energy-water nexus (Lee *et al* 2021). Hernandez *et al* recently proposed a framework of 'techno-ecological synergy' which pushes us to think more broadly about how to implement renewable energy technologies where they will minimize ecological impact and maximize additional co-benefits (Hernandez *et al* 2019). Thus, instead of simply considering how to minimize the environmental impacts for an already proposed solar farm, we need to also think more broadly about what are the most optimal sites for this type of development. This includes considering how to leverage existing impervious surface for the implementation of utility-scale solar energy, such as parking lots or warehouses. With these multi-criteria and system frameworks, we can ensure that solar farms are developed in the most sustainable manner.

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Data availability statement

No new data were created or analysed in this study.

ORCID iDs



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Impact of solar parks on runoff generation and associated land drainage/flood risk consequences.

BHS - 5th June 2014

retired)

strong

JBA)

(JBA)



Large-scale solar PV deployment in the UK - 2011 to Feb 2014

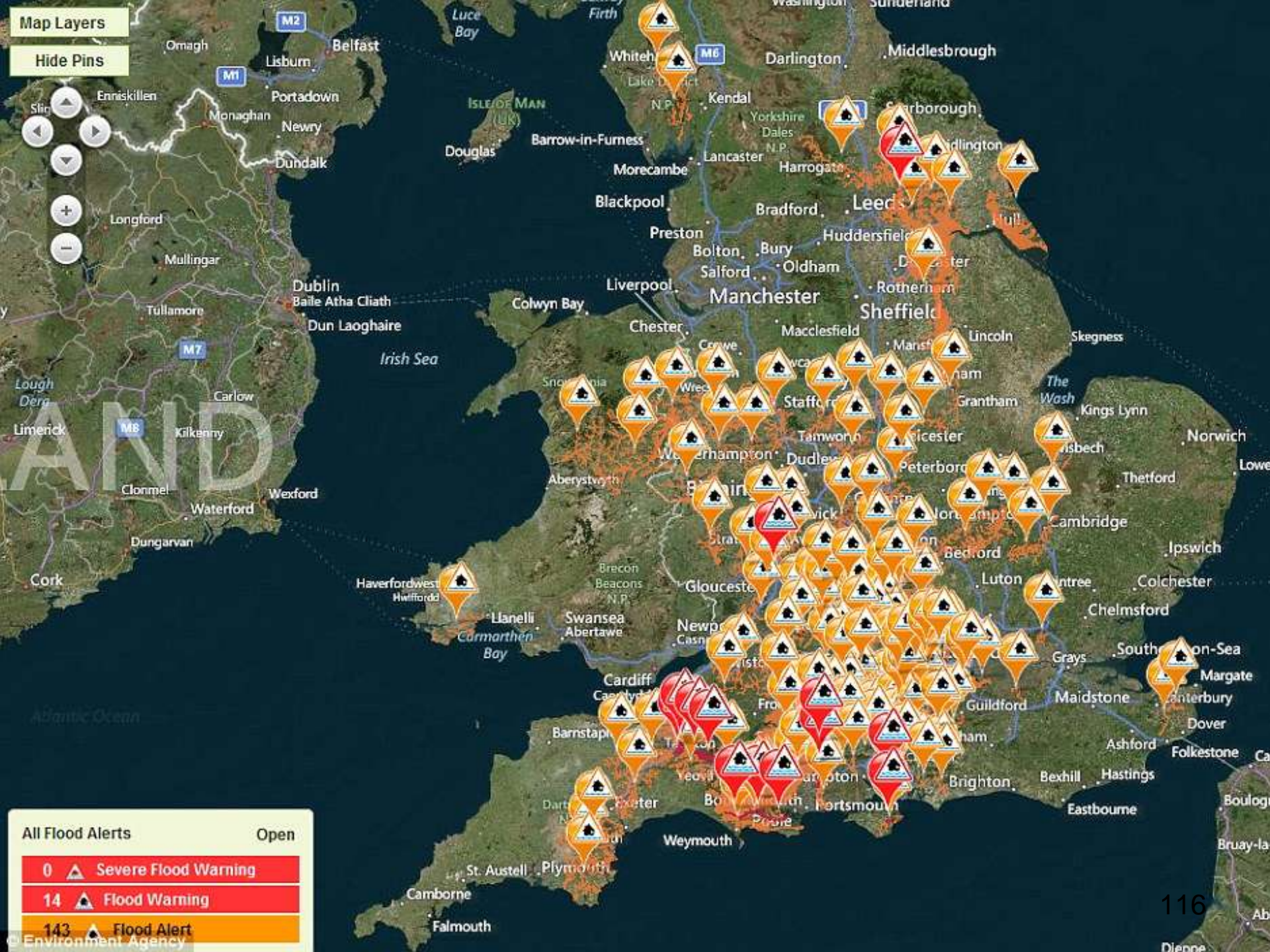
Large-scale solar PV deployment in the UK - 2011 to Feb 2014*		
	No.	Capacity MWp
Operational	184	850
Under construction	48	538
Awaiting construction	194	1,656
TOTAL	425	3,037
In planning	98	1,149
GRAND TOTAL	523	4,168

Land use assuming 2ha/MWp
Land ha
425
269
828
1,518.5
574.5
2,084 ha

*Source: Dept of Energy & Climate Change - UK Solar PV Strategy Part 2 - April 2014

Map Layers

Hide Pins



All Flood Alerts		Open
0	▲ Severe Flood Warning	
14	▲ Flood Warning	
143	▲ Flood Alert	

© Environment Agency

The 2014 floods

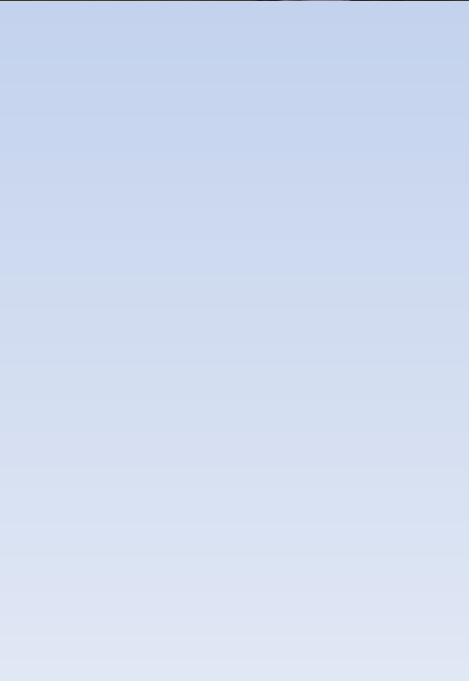
The Somerset Moors

(a reminder)



GETTY IMAGES









The aftermath



What the 'experts' say about all that flooding in 2014

- “**Water management techniques** could have helped prevent the effect of flooding on villages, towns and over surrounding land seen recently.”
- “We need to look at how forestry, **land management** and soft-engineered flood alleviation schemes can hold back water in the upper reaches of rivers.....”

YES - quite right But it's all been said before.....

...But its all been said before.....

DEFRA/EA R&D project FD2114
Review of impact of rural land use &
management on flood generation
(E. O'Connell et al)

- *“There is substantial evidence that local flooding can be affected by changes in (rural) land management and management practices.”*

...But its all been said before.....

Making Space for Water

- The Government will promote changes in rural land management to ameliorate runoff and reducing the incidence of flooding on a local scale

...But its all been said before.....

Catchment Flood Management Plans

- CFMPs apply the recommendations of FD2114
- They promote the use of rural land use and soil management to reduce rural runoff to reduce flooding at settlements in accordance with MSfW policy.
- They identify where it can be effective

...But its all been said before.....

Best Farming Practice & Environmental Stewardship

- *Encourage farmers to reduce runoff, soil erosion and pollution through good land and soil management*

...But its all been said before....

National Planning Policy Framework

- *“When determining planning applications LPA’s should ensure flood risk is not increased elsewhere & is **reduced** wherever possible.”*

What's been said before

- FD 2114 - rural land use & soil management affects local flooding
- M S for W - managing rural land & soil is part of government **policy** to manage flood risk
- CFMPs – **implement the policy** and say where it's **effective**.
- Best Farming Practice & Environmental stewardship **contribute to it's delivery**
- NPPF - provide an **opportunity to deliver the policy ...** when considering applications for Solar Parks in rural areas

So what do FRAs for solar parks say ?

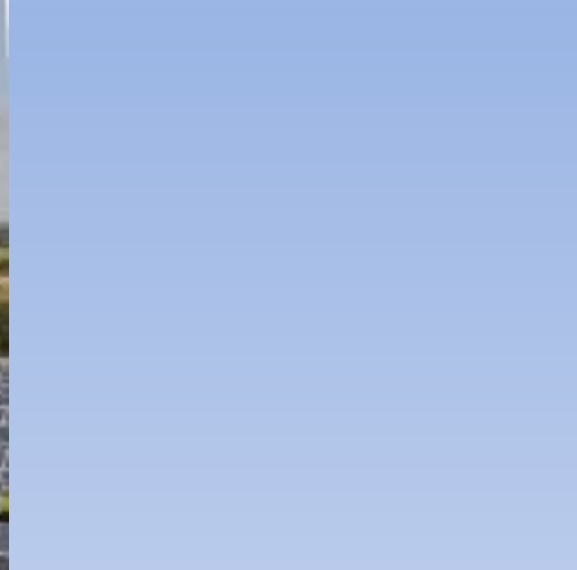
Flood Risk Assessments for Solar Parks

some uncertainties for discussion

- 1. Soil compaction or soil degradation due to construction and during operational lifetime**
- 2. Assumption - Solar panels don't increase runoff significantly**
- 3. Standard of mitigation - 100 year or what?**

The first uncertainty Soil degradation









An example Before

(Grade 2 agricultural Land! Carbon footprint? EIA?)





after





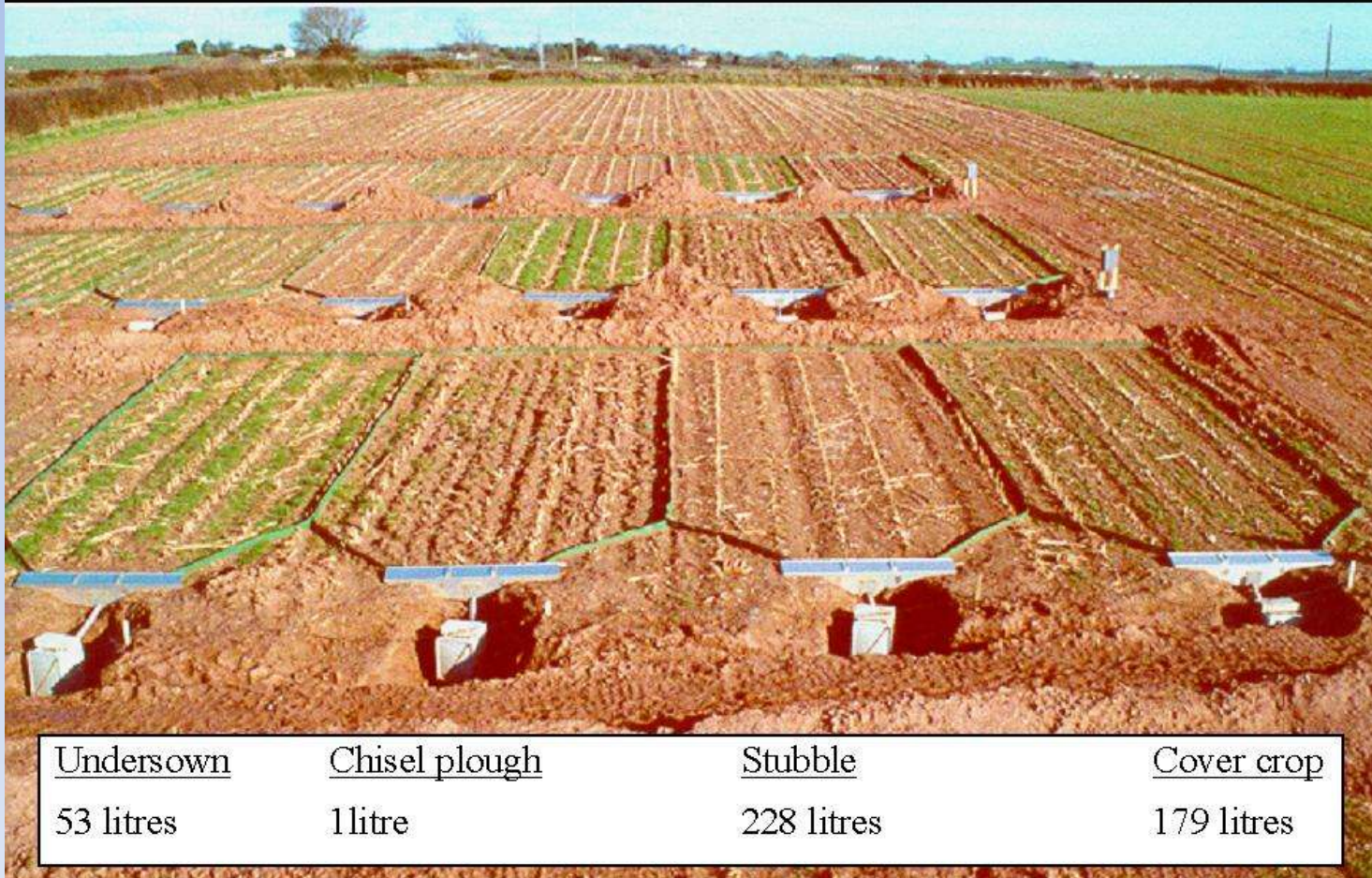








Soil condition – some numbers



Source: Richard Smith EA Runoff volumes generated by 25mm of rain in 24 hours – plot size 10m x 4.5m

Runoff & soil condition

Runoff from maize stubble (IGER 2000)

Winter - Feb / April 2000, North Wyke Devon

Compacted stubble		Chisel ploughed stubble	
Runoff		Runoff	
m3/ha	% of rainfall	M3/ha	% of rainfall
433.5 m3/ha	20%	5.8 m3/ha	0.5%

Runoff from grassland (NSRI Cranfield 2007)

Grass – poor soil structure		Grass – good soil structure	
Runoff		Runoff	
m3/ha	% of rainfall	m3/ha	% of rainfall
	~60%		~2%

The
problem
soil
condition



The solution - Deliver MSfW, Planning & CFMP policies and Best Farming Practice

1. **FRA's** need to take into account **soil condition**
2. **Pre-development runoff** calcs. should assume **soil is in good condition** in accordance with Best Farming Practice. (NPPF Reducing flood risk)
3. After construction the soil should be **chisel ploughed** to mitigate soil compaction during construction
4. **Planning applications** should include an enforceable **soil management plan** to keep soil in good condition & for **decommissioning**.

The second uncertainty

Do solar panels increase runoff?

- **Assumption - Solar panels don't increase runoff significantly** because.... rain falls off them and, regardless of ground slope, it flows evenly across the rain-shadow of the down slope row of panels... so most, if not all of the ground is mobilised for infiltration.

The assumption explained



In practice





Kinetic compaction & rivulets forming





Example to illustrate scale of issue

Area of rain-shadow not mobilised for infiltration				
8.25MW				
16ha site				
35,000 panels				
Solar panel footprint	5% not mobilised	10% not mobilised	20% not mobilised	30% not mobilised
50,000m ²	2,500m ²	5,000m ²	10,000m ²	15,000m ²
%age of site area	1.6%	3.2%	6.2%	9.6%

- Area of rain-shadow not mobilised for infiltration is a function of **ground slope**
- **Research** is needed to guide practitioners
- Until then apply the **precautionary principle**

Appeal Decision

Appeal Ref: APP/D3315/A/13/2203242

Land at Glebe Farm, Tolland, Lydeard St

Lawrence, Taunton TA4 3PR

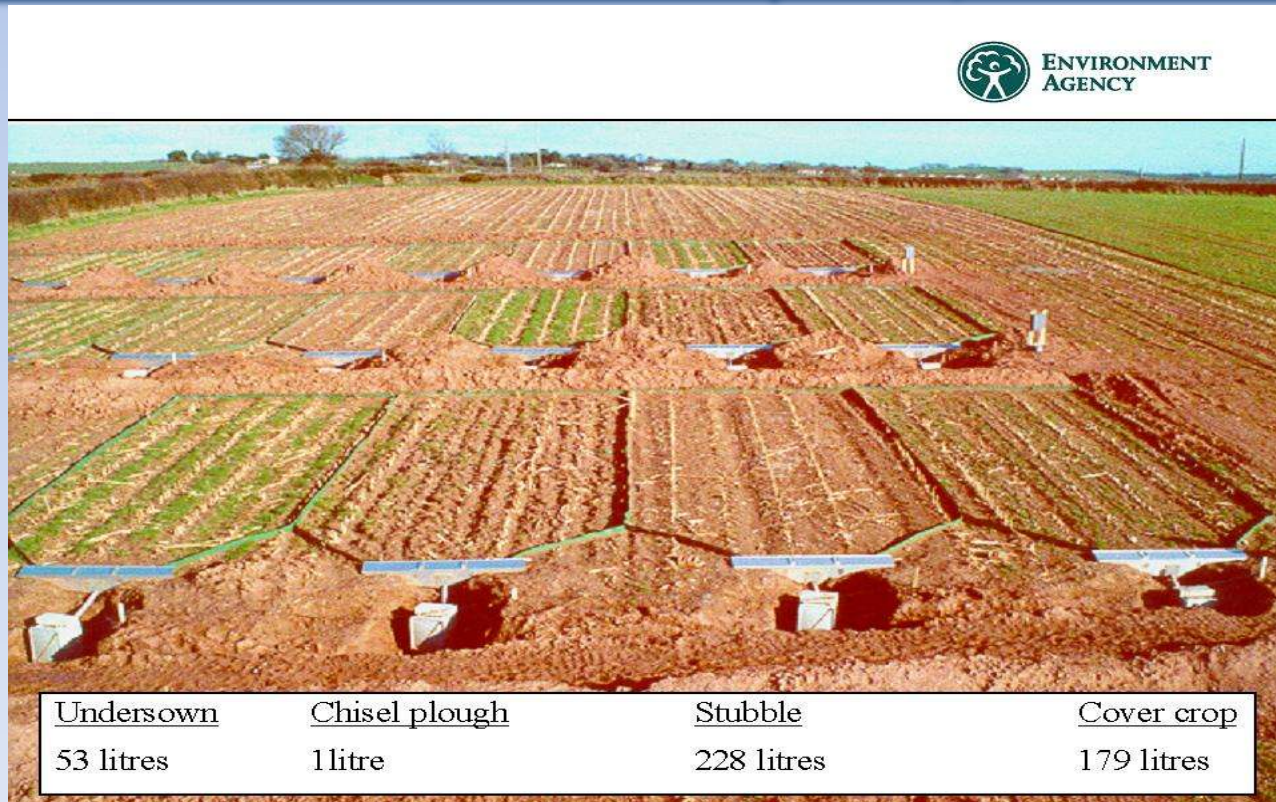
17. The planning application was accompanied by a Flood Risk Assessment (FRA). A carefully considered and professionally well-informed letter of objection to the proposed development makes the important point that **it would be unsound to assume that rain falling on each row of solar panels would flow evenly into the rain-shadow of the row below, so as to mobilise the same percentage of the ground for infiltration as was available before the panels were installed.** Rather, because the panels would be set at a downward slope and aligned to follow the contours of the land, rain-water would be likely to fall in a column from the lowest corner of each panel, and could then form rivulets flowing down through the rain-shadows of the rows below without utilising their whole area for infiltration, thus increasing the amount of water run-off from the site.
18. **I find that argument persuasive.**

The third uncertainty

Standards of mitigation

- Flood risk to settlements - 100 year
- Flood risk to agricultural land - 10 to 20 year?
- Drowning of agricultural land drainage outfalls - 2 to 10 year ?

Thank-you Richard et al for reminding us poorly managed (or regulated) agricultural land and soil is the flood-risk elephant in the room, now and as agriculture responds to climate change and Govt. incentives for solar parks, bio-fuels etc



Source: Richard Smith EA Runoff volumes generated by 25mm of rain in 24 hours – plot size 10m x 4.5m