**Answer to the review by Stuart Lane, University Lausanne**

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| 1 | My apologies that this review is a little late. This paper needed quite some thought. I find its goals useful and there is some very useful material therein that the hydrological modelling community should be aware of. I should be honest about a few of my own positions with respect to this work. I don't particularly like this kind of methodology – finding literature this way often means that very interesting papers that perhaps frame themselves differently get lost – and because they are not found other kinds of framing that exist are left hidden. Second, I apologise that there is quite some reference to my own work in my report but I have been working on this topic for almost 20 years. Some of the ideas the authors have could and have been developed a lot more (and the work I refer to, notably Lane 2012, might help them access the work of others besides me). In especially the Discussion, I felt that the authors did not really show as much awareness as might be ideal of some of the dimensions that they address (mental images, framing) and which have already been discussed in relation to hydrology. There could be a lot more useful Discussion and crucially, perhaps my key recommendation, some much deeper thinking regarding what a power-sensitive modelling approach might look like and how it might come about (which itself would have to be a political act).<br><br>The detailed comments identify some of these issues that could be developed. As major comments though, and in addition, I think the following need some treatment in the paper. |
| Answer | Thank you for your supportive comments in relation to the aims of the review.<br><br>Regarding the methodology, we are aware we can never present a complete overview of all papers that engage with the influence of modelling in water, and reflect on this in the methodology as well. It is also challenging that different disciplines write about the topic with different jargons, and also that reflections on the influence of models and modelling are sometimes hidden in papers. We have therefore decided to make a start with collecting papers, combining two methods; a narrative review in which we identified papers that we were already aware of, and in addition did a systematic review to identify others. Also, we specifically have opted for HESS that has an open review process to invite people to share more papers.<br><br>We will enrich the discussion with references to papers that have addressed the question of what power-sensitive modelling might look like. |
| 2 | 1. Models are themselves political objects – they contain intellectual property that can come to have commercial value – the history of how flood inundation modelling went from 1D to 2D in the UK was about primarily the protection of vested interests in intellectual property (for example, see one of the sections in Lane, S.N., November, V., Landström, C. and Whatmore, S.J., 2013. Explaining rapid transitions in the practice of flood risk management. Annals of the Association of American Geographers, 103, 330-42) – this is similarly reflected in James Porter's fascinating work about how flood maps get made (which is essentially based upon flood inundation modelling) and the negotiation between modellers/mappers and regulatory agencies (Porter, J. and Demeritt, D., 2012. Flood Risk Management, Mapping and Planning: The Institutional Politics of Decision-Support in England. Environment and Planning |
| Answer | Indeed, the economic dynamic of modelling has not been explicitly touched upon in the articles reviewed, and we acknowledge it is an important dynamic/driver in relation to the influence of models. We will update the review based on additional articles we have received and that will include a mention of this either as a separate section or in the comments, based on the outcomes of the review. |

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| 2A | A). There is a tendency to reduce politically sensitive modelling to the interface between models, modellers and society – and to overlook the politics of modelling itself and how this also needs to become more politics sensitive. In turn this would sit this paper also in wider Science-Technology-Studies perspectives on power within scientific practice. Politics exists within modelling communities and this can have a profound impact on how modelling is done. Politics can constrain what is modelled and how. This needs more consideration and discussion. |
| Answer | Thank you for bringing this up. The politics of science in relation to models has been included in the review, especially in sections 4.1 and 4.2 on 'Mental models and policy projects', and 'The influence of modellers' choices'. Where possible, we will elaborate based on the additional papers we will add in the review. Also, we agree it can be more specific in the discussion, as well as in the call for power-sensitive modelling and will update the article accordingly. |
| 3 | 2. If we accept the hypothesis that power is imbricated with and within models of the water environment (which I do), the question becomes what to do. The paper has very little on what this means for practice. A starting point may be the obvious point that we should not make recourse to some kind of naïve goal that we should exclude power and politics from modelling such that models give us access to some kind of higher, truer knowledge and models can then reign supreme ; that would simply be an internal contradiction in that it would imply the transfer of power to models and modellers (that is itself be a political statement). So, if power and politics cannot be excluded what would a more democratic form of modelling mean in practice. What do we mean by "democratic"? How might different kinds of politics (e.g. majoritarian versus minoritarian) lead to models being used, power-sensitively, in different ways? What are the ways of using models that allow those excluded from decision making to become included in decision-making through the use of models. When I got to the end of the discussion I felt short-changed that after all the examples this hadn't been thought through. |
| Answer | Thank you for bringing up the question: what now? This paper is part of ongoing efforts to understand the power related to modelling, and other articles are planned that engage with the question: how do we practically engage with the power of models? We base this work on an understanding that each model and modelling process is different and that this requires a flexible approach.<br>What we will do in the current article is to provide a further explanation in relation to the four elements (the mental models and policy projects, the influence of modellers choices, the impacts models have, and engaging with non-modellers) more explicitly, as well as reflect more on practical examples from the reviewed papers on how to engage in a power-sensitive way. |
| 4 | 3. When I wrote the 2014 paper published in HESS I should confess that this was motivated by an extreme skepticism (that I still hold strongly) of socio-hydrology and the focus of the Panta Rhea decade; this included the appearance of diagrams coupling models of people to models of the hydrological cycle that reminded me of those the Dick Chorley and others were advocating in the 1960s and 1970s. Yet again, we as hydrologists seemed to be bolting people onto the natural environment with very little clue as to actually what the "socio-" really means. This was ironic because at the same time there was much interest from social scientists, notably Linton, Budd etc., in the Hydrosocial cycle which had, in my view, a much deeper understanding of how people and water are truly coupled. Now, I regret leaving in Lane (2014) this argument a little too subtle. But, I think the distinction between socio-hydrology and the Hydrosocial cycle does actually matter to this article because the need for political sensitivity reflects (for ethical reasons, at the very least) the need for a much more nuanced understanding of how hydrological models fit into the world. This is lost at the moment in this article. It probably does not need much discussion added but the notion of a hydrosocial cycle and the mutual influences between people and water strengthen the argument that we should also take a political perspective for how hydrological modelling is done. |

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| Answer | Thank you for bringing this up, and we fully agree with the importance of socio-political variables in understanding water systems. However, we did not explicitly focus on comparing socio-hydrology and hydrosocial studies because that could (and perhaps should) very well be a new paper. Nevertheless, we acknowledge that these different ontologies are important to mention, not in the least as the hydrosocial cycle acknowledges the political as a transformational force capable of changing landscapes. We will dedicate time to engage with these different ontologies in the introduction and discussion. |
| | ***Minor comments*** |
| 5 | L36 – but also by the situated nature of the modeller themselves – and the work they do to come to trust their own models – see Lane, S.N., 2012. Making mathematical models perform in geographical space(s). Chapter 17 in Agnew, J. and Livingstone, D. Handbook of Geographical Knowledge. Sage, London |
| | This is a very good point; we will integrate this in the article. |
| 6 | L36-7 – your references here, unless I am mistaken, largely support the counter-factual – do you have any better references of modellers themselves presenting their models as neutral tools? Without this there is a risk that you are setting up a "straw doll". |
| Answer | Indeed, often these positions are not made explicit, which is also shown through the literature review we did. Neutrality is often assumed and non-neutrality needs to be actively proven to challenge the dominant paradigm. Hence the chosen references. |
| 7 | L37-8 – I don't agree with this as it is written – we may think models can travel easily between places but much modelling in practice is about making them work in particular settings. There are studies of hydrological modelling in practice – see for instance Landstrom, C., Whatmore, S.J. and Lane, S.N., 2011. Virtual Engineering: computer simulation modelling for UK flood risk management. Science Studies, 24, 3-22 |
| Answer | A challenge in our article is that we cover many different models, at different moments of their development. Some require a lot of work to make them fit, and others travel more easily based on how they are designed and what they do. We will tweak the sentence: "An additional challenge is that models become increasingly complex and some travel easily between places of application." |
| 8 | L63 – the notion of power sensitive modelling is interesting – but I think the paper is missing a wider link here into science technology studies that argues that power is an inevitable (and sometimes malign) component of any piece of scientific investigation. Isabelle Stengers has treated this generally (her book "Une autre science est possible" is probably the simplest entry point); there is then work around any one of a number of disciplines exploring this as well as some very specific to modelling of the environment (Demeritt, 2001 is a classic in this sense). I appreciate that the paper is about water but it is not well situated with respect to the wider STS work on the demonstrated influence of power upon scientific practice (and the very obvious point that the moment you advocate a model as neutral and therefore *the* valid basis for decision-making, you immediately transfer power to the model and the modeler, that is you make a political decision). Some of these examples also clould be used to develop the argument around L90 a bit more – where it is under-developed in terms of what we already know about the relationship between power and modelling. |
| Answer | This comment strongly relates to the second point you make (or 1A), and we agree that, through the review, we have focused mostly on the influence of models in practice, and less on power in scientific practice. We will bring this out more explicit in section 2, defining models, as well in the discussion, and also bringing out these points through the STS work we have included, such as Knorr-Cetina, 1999, Bijker, 2017; Bijker et al., 1987; Latour, 2000; Latour and Woolgar, 1986; MacKenzie and Wajcman, 1999. |

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| 9 | Shackley, S., Risbey, J., Stone, P., and Wynne, B.: Adjusting to policy expectations in climate change modeling – An interdisciplinary study of flux adjustments in coupled atmosphere-ocean general circulation models. Climatic Change, 43, 413–454, 1999<br>Demeritt, D.: The Construction of Global Warming and the Politics of Science, Annals of the Association of American Geographer, 91, 307–337, 2001<br>Lahsen, M.: Seductive simulations? Uncertainty distribution around climate models, Social Studies of Science, 35, 895–922, 200B.<br>Sundberg, M.: The Everyday World of Simulation Modeling: The Development of Parameterizations in Meteorology, Science Technology and Human Values, 34, 162–181, 2009<br>Brysse, K., Oreskes, N., O'Reilly, J., and Oppenheimer, M.: Climate change prediction: Erring on the side of least drama?, Global Environmental Change, 23, 327–337, 2013. |
| Answer | Thank you for these references. We had initially chosen to keep the introduction and definition of models short, and focus on showcasing and learning from the "water"-articles to acknowledge the specific approaches and culture that define how models are used and discussed in the water sector. We also see the importance of bringing in lessons from other fields, and will dedicate space for this in the discussion. |
| 10 | L84-88 See Lane (2012) op cit. |
| Answer | Thank you for the reference. |
| 11 | L108 – water is not just about hydrology but also hydraulics – is there a reason you did not also look at hydraulics. Note also that this way of searching likely misses more specific model applications or where models are not really referred to as "models" even if modelling is an integral part of what is being done. |
| Answer | This is true, and we will redo the query to include hydraulic models and other types (hydro-dynamic for instance) by adapting the query to:<br>TITLE-ABS-KEY ( "water model*" OR "hydr* model*" ) AND TITLE-ABS-KEY ( justice OR equit* OR politic* OR ethic* ).<br>(including 307 articles instead of 293, part of which can be explained by including now the 2nd half of 2022. We will also include the articles published in 2023, resulting in 323 articles included in the systematic review) |
| 12 | L115 – but isn't this also an important result in the context of this paper? |
| Answer | Yes, it is indeed an extremely important outcome! There is very little written, unfortunately. We will highlight this more explicitly in the article as outcome. |
| 13 | L124 – clarify what you mean by "narrative style" |
| Answer | We have changed this to 'narrative review' to clarify |

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| 14 | L145-150 – see in particular Beck (1999) who talks about "mental images" - Beck, M.B., 1999. Coping with ever larger problems, models, and data bases. Water Science and Technology, 39, 1-11 – but there is also a wider literature on framing in hydrological modelling and its critical role in shaping what is modelled – see Odoni, N. and Lane, S.N., 2010. Knowledge-theoretic models in hydrology. Progress in Physical Geography, 34, 151-71 – this applies also from L160 onwards |
| Answer | Thank you for sharing these resources. We are looking into it to see how it can enrich our article. |
| 15 | L172-4 see for this argument made for the case of flood risk modelling in relation to Slow Science and the need for scientists to put themselves where, in the spirit of Isabelle Stengers, you escape the constraints that allow you to develop a different understanding of the world - Lane, S.N., 2017. Slow science, the geographical expedition and critical physical geography. The Canadian Geographer, 61, 84-101 |
| Answer | Thank you for the reflection. We will elaborate on this further in the discussion. |
| 16 | L185 – in this section you have also missed communities of practice within modelling communities – see Lane 2012 op cit |
| Answer | We have included the reference to communities of practice, in addition to epistemic communities. |
| 17 | L268 – this is in my view a bit narrow and through the examples used misses some wider thinking about what makes a modeler choose a model – and how this is a very political process – see for example Lane et al., 2013 op cit. ; but also the role of power within the academic system in constraining what is deemed acceptable modelling – see for example Lane 2012, op cit. – and this prompts me to note that the notion of power is largely explored in terms of examples at the modeler-society interface and that the article does not really consider enough power within the academy and how this influences modelling as a practice |
| Answer | Indeed, this comment relates to comment number 2 and 8, and is indeed a gap in the review, which is based on the content of the papers we have. With the inclusion of additional papers in the review, this topic will come out more explicitly. |
| 18 | L284 – see also Lane 2012 for a discussion of this around how modellers come to trust their models and how this rarely conforms with how we present the modelling process; this includes notions of performativity in modelling, the role of academic norms in controlling trust, the difference between trust in the model and trust in the modeler, the importance of communities of practice for trust in the modeler, and other kinds of trustess (e.g. those forced to live with model prediction) |
| Answer | Thank you for pointing this out. We will include the article in the review. |

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| 19 | L375 – I would largely agree that models can be highly exclusionary – but it is also important to think about their role as a means of supporting political interventions – you do not pick here with reference to Landstrom et al (2011) that you do cite but also Lane et al (2011 (Transactions of the Institute of British Geographers) where a community made a hydrological model that in turn allowed them to make a political intervention – which then shifted a stalled flood risk management project. They used their model to show that the models used by the UK Environment Agency had not addressed everything it could do. This modelling built a "new public" capable of making an intervention and so unsettling the process. Modelling was used as a means of unsettling the dominance of a particular kind of modelling. The public then got what they wanted – upstream storage – achieved because they pointed out to the EA that this worked if you embarked upon local flood protection measures for houses flooded frequently but designed the storage to stop more extreme and wider impact floods – this then became the Pickering scheme but it did then have to make recourse to an engineered solution and not simply more natural storage. |
| Answer | The review becomes stronger based on recommended papers, as we have received from you, K. Beven and B. Tran. We will include this paper under section 4.3.2 - inclusive and exclusive assessments |
| 20 | L446 – I don't recall this division – we had one model which was part of showing the potential for upstream flood storage and which was written and used with the community through the competency group meetings – and a second which used an off the shelf model, HEC-RAS, to look at how river management influenced flooding of farmland. The latter was fascinating as the competency group ended up concluding that vegetation management (or lack of) did indeed cause flooding – but that was what the local EA wanted (move away from protecting farmland from flooding). However, the EA was mobilizing the argument that vegetation doesn't impact flooding as this was easier to make (a "scientific one") than the political one (allow flooding of farmland). Thus, this model then allowed the local members of the group to make interventions of a political nature. |
| Answer | Thank you for this elaboration. We will update the text to reflect the project better. |
| 21 | L460 – this criticism was also the philosophical basis of the Pickering and Uckfield work – the need to build knowledge controversies and to use them to effect change. That is, progress is made when we find ourselves put in a position where what we hold to in terms of beliefs and knowledge is challenged – what Isabelle Stengers argues in 2005 should be the essence of being scientific (putting yourself in a slightly different position such that you end up coming wp with a different understanding of the world around you) – see Stengers, I., 2005. The cosmopolitical proposal. In Making things public, eds Latour and P. Weibel. Cambridge, MA: MIT Press, 994—1003. |
| Answer | Thank you for this reference and context. We will use this to strengthen the discussion and the call for power-sensitive modelling |
| 22 | L496-7 – no – these papers were part of an inter-University collaboration under a UK government initiative to support interdisciplinarity research for rural environments following the 2001 Foot and Mouth Disease outbreak |
| Answer | We will adjust this, thank you for pointing this out. |

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| 23 | L519 – section ending here – this is quite under-developed and there is a lot more you could say (see comments above) about how modellers are reflexive during the modelling process |
| Answer | Indeed, we have been brief on this and will elaborate. |
| 24 | L561 – I think you should reflect on the scope of your suggestions here – following Nowotny et al.'s ideas – there are models developed for models' sake (to improve the model being used) and there are models developed as part of practical applications (more "Type 2 science") – and ones in between. The modellers and the relationship with the modelled – will change according to where one is on this spectrum – and hence the way politics is mobilized will change. I think there is a risk that the former is not appreciated enough (model development is situated within an academy that is itself highly political) is perhaps overlooked and ultimately a get out clause for a reader of this paper (who might mistakenly think that the political sensitivity of modelling only appears when a model is used to effect something in society). This is a nuance that is a bit lost at the moment. |
| Answer | We engage with this question in section 2, defining models, and follow King and Kraemer who confirm your point that the models developed for models' sake can also be very political (L. 68-73). We will re-emphasise this in L561. |
| 25 | L570 – I have to say I am a bit disappointed here with these four recommendations – with such a rich paper they are very thin indeed and miss a whole set of other possibilities. A good example is what does "democratising modelling processes" mean – democracy can be done in different ways that will cause the modelling processes also to change in different ways. The notion of democracy itself needs thought – we all too often see it as being about some kind of majority representing process – but what about the role of modelling as part of a minoritarian politics – allowing minorities to get the power needed to make a political intervention in a system from which they have been excluded? All of this is left tantalizingly undeveloped. The how under (i) through (iv) is also undeveloped. |
| Answer | We agree that using a word as 'democratising' can be explained in different ways and will further clarify this, as well as the other three recommendations. We will further attempt to better connect this to the insights provided in the literature review, to give examples on how the recommendations can be operationalised. However, we have opted for four broad recommendations that would help to define case-specific actions to engage with the power of models, based on an understanding that each modelling process looks different. We will clarify this too in the call, and foresee an article in the near future that elaborates on different (practical) possibilities on how to engage with the power of models. |