**The Craft of Modeling, the Modeling of Craft**

Matthijs Kouw (Maastricht University, Virtual Knowledge Studio)

*Introduction*

In this paper, I discuss the history of models and simulations in hydrological research on flooding in the Netherlands since the 1930s. First, I will focus on historical developments in hydrological research that have caused engineering practice to shift more and more towards standardized and codified knowledge, mainly in the form of computational models. Current trends in hydrological modeling are characterized by a move from proprietary software to more 'open' software platforms. Second, I argue that the craft typically involved with hydrological research is subjected to technological rationalities, which have repercussions for engineering practice: straddling discovery and manipulation, engineers are immersed in simulation practices that are becoming more and more opaque. Third, I will address some of the ways in which risks associated with the use of simulations are identified within the field of hydrological practice. This will involve a discussion on how virtues like reflexivity and transparency are celebrated within the field, and whether these virtues have traction on risks associated with simulation practice.

By means of this discussion, I intend to reveal how simulations and models are becoming more and more intertwined with the design of technological systems, and how they fulfill a key role in terms of understanding, monitoring, predicting, countering, and communicating risks. In addition, I hope to extend the meaning of the term 'vulnerability', which is commonly understood as a degree of susceptibility to risks. However, another dimension of vulnerability relates more to an ambiguity related to the instrumental use of simulations and models to produce knowledge about risks: on the one hand, simulations and models are expected to facilitate knowledge about risks, but on the other their use itself may imply risks in the form of blind spots, inscription, and uncertainties. In order to assess the interplay of both forms of vulnerability, an inquiry into epistemological, technological, political, economic, and cultural dimensions related to the social reliance on simulations and models is needed.

*Risk and Control: Hydrological Research in the Netherlands since the 1930s*

The initial approach to floods in the Netherlands was largely defensive and focused on the construction of waterworks sufficiently resilient to the relentless attacks of floods, waves, and ice. Designs for such means of protection were largely based on practical experiences and much less on theoretically erudite explanations of the phenomena in question. In that sense, the early science of water flow consisted of observations and practical experience rather than fundamental and law-like explanations. From the early 20$^{th}$ century, the development of flood science can be characterized by an increasing influence of physics and mathematics, which were expected to yield more tangible and law-like theories pertaining to hydrological phenomena. Still, these more quantitative methods coexisted with the by comparison more qualitative practice of measurements by hand and visual observations (figure 1). Gradually, computational models became more dominant in hydrological research, though the combination of physical modeling and computational modeling was still valued highly. As J.P. Mazure, one of the very first engineers in the Netherlands to study tides and storm surges computationally, said: "The result of a computation is never the solution to a problem. At most it is information that may lead to the solution. The value of this information must be evaluated in relation to validity and the reliability of the computational method." (Mazure 1937)

Figure 1 Study of flood countering measures using a model of the Trent river, 1947

The advent of information and communication technologies (ICTs) is often celebrated as the main factor in creating a paradigmatic change by enabling the codification of risks in the form of software. However, this leaves a number of issues unresolved. A first reason to question the key role of ICTs as the cause of paradigmatic change is that there appears to be a desire for codified knowledge of risks prior to the advent and widespread implementation of ICTs. The latter have indeed played a key role in facilitating the move towards codified knowledge, but only because other values were exerting their influence at the same time as well. By tracing the values accompanying the codification of knowledge, it is possible to adopt a more archaeological stance towards the introduction of ICTs: rather than accepting the commonsensical notion that knowledge about hydrological phenomena advances in a linear manner ("progressive understanding") that allows codification in the form of code and software, the introduction of ICTs in hydrological research can be seen as emblematic of a desire to manage, control, and manipulate hydrological knowledge. The introduction of ICTs in hydrological practice can be revealed to be not merely a matter of progress or epistemic certainties (as some engineers tend to do), but rather can be read as desire to manage and control uncertainties.

A second reason to doubt the paradigmatic change toward computational models is that the move to software has not been accepted or celebrated unanimously within the field of hydrology. A number of engineers still point to the need for physical models due to scaling effects that cannot be resolved unambiguously. Such experiments are often considered to be too costly, not to mention the role of demands of time and money allocated to physical modeling by non-engineers or actors with less expertise regarding modeling issues. Others are more suspicious of computational models and argue such models should be continuously validated and verified by making use of physical models.

These developments point to values underlying a changing approach to risks within technological cultures. Rather than keeping the water out at all costs, approaches to risks have been pushed more and more towards distributing responsibilities for risks by means of mechanisms operating on 'the market'. (Beck 1986, van Loon 2002, van den Brink 2009, Metze 2010) The governmental apparatus appears to have retreated for reasons that intertwine with some of the perceived advantages of computational models. Such models are often expected to reproduce knowledge and facilitate robust explanations. As a result, codified knowledge provides an impartial authority that is said to enable a degree of control over risks, while the contemporary engineer increasingly has to adopt more entrepreneurial methods.

Historical analysis can show that the introduction of computational models was not just a matter of advancing scientific knowledge, but co-produced in accord with institutional and political motives underlying simulation practice. There is a danger in explaining the introduction of computational models as a shift informed by an increasingly sophisticated understanding of natural phenomena, since such an explanation downplays the disruptive effects accompanying the translation of hydrological knowledge into computational environments, where the computability of knowledge is achieved.

*The Instrumentality of Simulations and Models*

Critiques of simulations and models often emphasize the dangers their use may render in terms of issues related to representation: simulations are inscriptive, inscribe values into the phenomena or systems they are expected to make more tractable, and are thus far from innocent. However, it is questionable whether this form of critique suffices in studying vulnerabilities relate to hydrological modeling. First, it cannot be assumed that critique of simulations and models in terms of representation has traction on the full scope of engineering practice. Second, critiques in terms of representation may not be able to focus on the ways in which simulation practice yields vulnerability. I will deal with these points in turn.

Engineers appear not to be committed exclusively to representing reality accurately, but often quite explicitly distort reality in order to acquire the ability to intervene effectively. This is illustrated by well-known expressions of the engineering community, such as "all models are wrong, but some are useful" and "garbage in, garbage out", which illustrate a key function of simulations and models in engineering communities. The goal is not so much to proof anything, but rather to make explicit the consequences of the engineer's own assumptions. The usual lament of the errors involved with simulating and modeling should be augmented by a study of the values attributed to models by those who work with them. One way to do so is by focusing on presentation rather than representation.

Since the world is not predictable but rather has to be made such, what is considered to be at risk or vulnerable depends on processes of knowledge production. It is necessary to move beyond the typical focus of inquiry into risks: the accident. Singular events where something has gone awfully wrong can serve the rhetorical purpose of the 'freak accident', which is a mere glitch in an otherwise robust system. Simulation practice pertaining to risks should be understood as sites of knowledge production, where knowledge is a shared belief, but not necessarily a justified belief, which again does not bode well for an exclusive focus on representation. A simulation or model may be seen as empirically accurate, and may only turn out to be wrong in retrospect. It is important to assess how simulation practice informs the process of producing knowledge about risks, and how that will render susceptibility to risks. In that sense, this paper's focus on immersion is meant as a study of the ability of those working with simulation to engage their practice critically.

*Immersion and Epistemic Opacity*

The increasing social reliance on simulations and models can be discussed by focusing on the problem of immersion, which indicates the state of a subject being entangled in technological practices that shape that subject's experience of the world, varying in degree and persistence (Turkle 2009). Although flood-related risks are not always as predictable as some actors in technological cultures wish, they are made subject to control by incorporating them into software environments devoted to making risks tractable. Control thus implies protection, but also a state in which technological cultures are put at risk due to relationships of dependence or inscription. In that sense, control can involve both lack and excess: vulnerabilities emerge from either a lack of knowledge, or an excessive desire to make risks tractable, which may stifle processes of discovering and reflexively dealing with risks.

Studies of risks will often point to accidents related to 'the unforeseen' as events of slippage where this lack and excess of control can become apparent. However, my aim is not so much a study of such accidents, but rather one of assessing vulnerability that is at work in the practices aimed at making risks known. It may be possible to prevent accidents by articulating the degree to which those trying to understand them are vulnerable. Producers and users of simulations and models may be entangled in rationalities that create commitments to codifying knowledge, and thereby shape the process of acquiring knowledge about risks. Commitments to making risks tractable results in the central problem related to immersion: how do those immersed in technological practices perform a balancing act between discovery and manipulation?

The repercussions of immersion in engineering practice can be studied by looking at the impact of software on the craftsmanship of the modeler: increasingly subjected to technological, institutional, economic, and political rationalities, the engineer's activities are embedded in values that push for a move from idiosyncrasies of the individual modeler towards knowledge that can be shared by other engineers. The craft of modeling is rejected in favor of approaches to modeling where the creativity involved with developing and validating a model are subjected to formalization – a veritable modeling of craft.

An example of a more formal approach to the craft of modeling is a current trend towards open platforms and open source models in hydrological research. Figure 2 shows a screenshot of software used to integrate different model components, which are allowed to interact by means of a modeling protocol named OpenMI. Such modeling infrastructures allow engineers to knit together a functioning model from a variety of model components, which are able to communicate due to the OpenMI protocol. As a result, engineers engage in what they call 'shopping' – the process of using different model components to tease out a model that is most suitable for solving the problem at hand. As a result, engineers display less of a commitment to being able to fathom the entire scope of design processes and decisions that went into a particular model (abilities commonly seen attributed to the craft of the trade), but rather tinker with already existing parts.

This type of modeling creates increasingly modular and complex models, which creates a degree of epistemic opacity (Humphreys 2009), which points to the inability of those working with simulations to fathom the design principles and assumptions of the simulations and models that are so dominant in engineering practice. As a result, pinning down the source of modeling errors becomes more difficult, while the model's functioning is effectively black-boxed. The intimacy of modeling hydrological phenomena has been replaced with a different type of craft: the ability to tease out the model from already existing computational fragments and applications, which is expected to fit with the problem in question. Virtues related to craft do not appear to become superfluous in digital environments. Craft appears in a different form due to its encounter with investments in the codification of knowledge from which it cannot emerge unscathed.

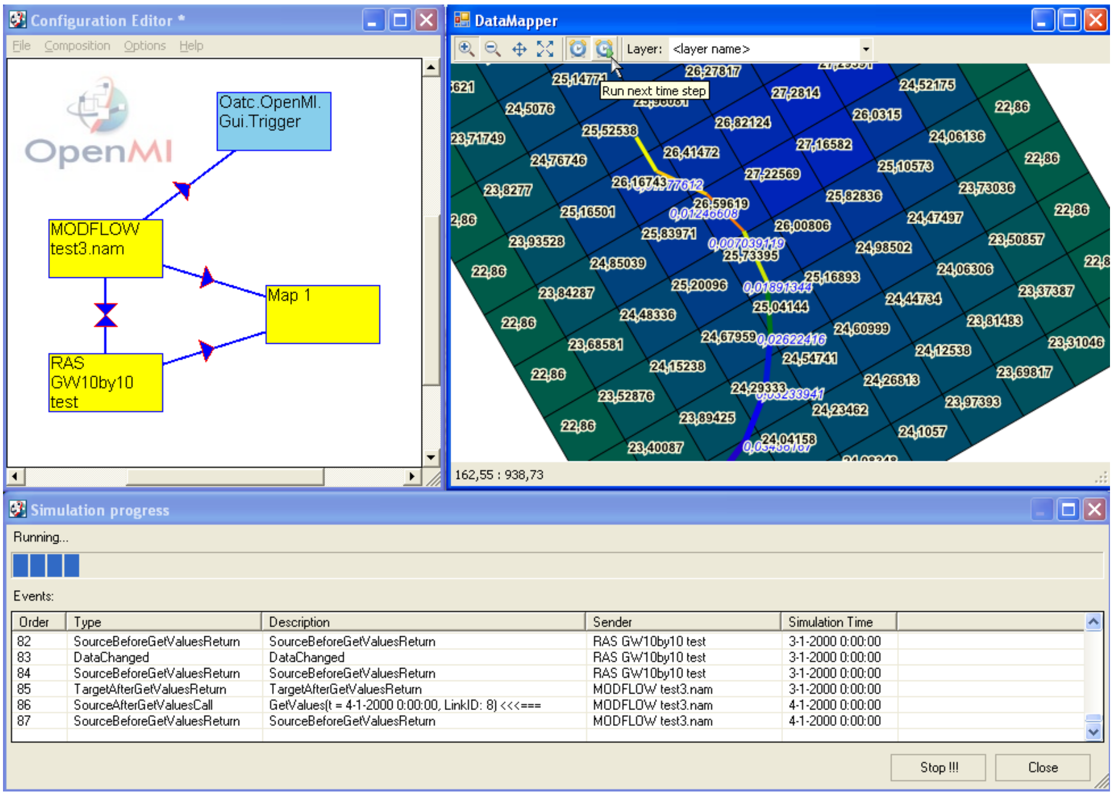


Figure 2 Integration of the HEC-RAS and MODFLOW models using the OpenMI protocol

Simulations can thus be empowering, but might also involve uncertainties and risks difficult to assess. What balance is struck here between the promise of simulation-enabled discovery and the inscriptive effects of simulations as prostheses of human perception? How does engineering practice straddle standardization and customization? Does the encoding of risks culminate in a homogenization of solutions for risks, or is it still possible for the engineer to escape the increasing momentum of the epistemic currency of software?

*The Politics of Reflexivity and Transparency*

The aforementioned issue of epistemic opacity makes clear that it needs to be asked to what extent and how the structures in which the knowing subject is immersed can be analyzed. Open platforms and open source are commonly celebrated as recipes for reflexivity and transparency within hydrological research. Recent work in the field of software studies (Wardrip-Fruin 2009) also pushes for legibility of technologies, in this case by making the processes of software more legible.

However, it is not self-explanatory that reflexivity and transparency indeed provide the solution to vulnerabilities related to immersion and epistemic opacity. Codification also appears to extend to the supposedly empowering and 'creative' processes that are expected to enable transparency and reflexivity. In addition, transparency may also serve a rhetorical purpose in creating 'innovative solutions' by means of providing 'tools' for knowledge production in communities of experts. Also, such processes can be aligned with the context of hydrological research in the Netherlands, which can be characterized by a move to more independent institutions that deliver practical solutions within the context of problems deemed socially relevant. Commitments to participation, reflexivity, and transparency are fueled by a combination of technological prowess and new institutional configurations, and deserve further scrutiny.

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