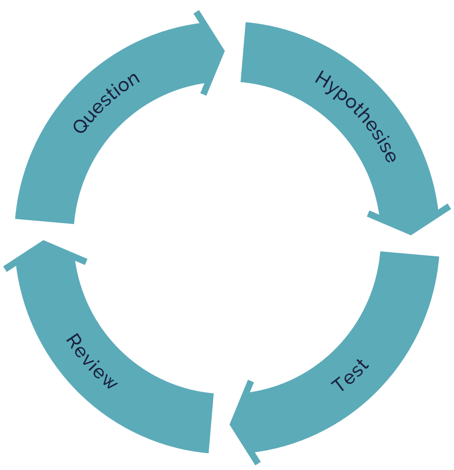
The Seven Wastes in Reservoir Modelling Projects
(and how to overcome them)

Hans Christen Rønnevik – retired chief exploration geologist of Lundin Norway and "GeoLegend"[1] - was recently named Knight of the First Order of Saint Olav by the King of Norway for his contributions within petroleum geology[2]. When asked to explain the background for his success, which includes some of the largest discoveries on the Norwegian Continental Shelf, Rønnevik points to the concept of *continuous discovery.*

Rønnevik recommends a mindset of questioning established truths by using what he refers to as a *quantum physics paradigm*. He advocates not seeing any given theory or established model as the ultimate reality, but something subject to change. This paradigm requires proposing and testing new hypotheses, collecting additional data to review our current understanding of reality and, finally, learning. According to Rønnevik, the latter part is especially important: "*the learning process is never over, you should always hunger for more knowledge*".[3]

Realizing what we *don't know* about the subsurface makes us open to the fact that our current perception is subject to change at any given time. Working under the framework of this continuous discovery process, the likelihood of adding additional reserves to your portfolio will increase, Rønnevik argues.



The key to the success of Lundin Norway's Chief exploration geologist, Hans Christen Rønnevik: a continuous discovery process where we use the available data and our current knowledge as a whole to question established truths, evaluate new hypotheses and put these to the test by exploring previously uncharted territory. Thereafter, when we get new data, we review our current understanding of reality and learn.

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1 https://100years.aapg.org/geolegends/person/articleid/42596/hans-ronnevik-ronnevik?utm_medium=website&utm_source=1

2 https://lundin-norway.no/2019/08/14/order-of-saint-olav-to-lundins-exploration-legend/?lang=en

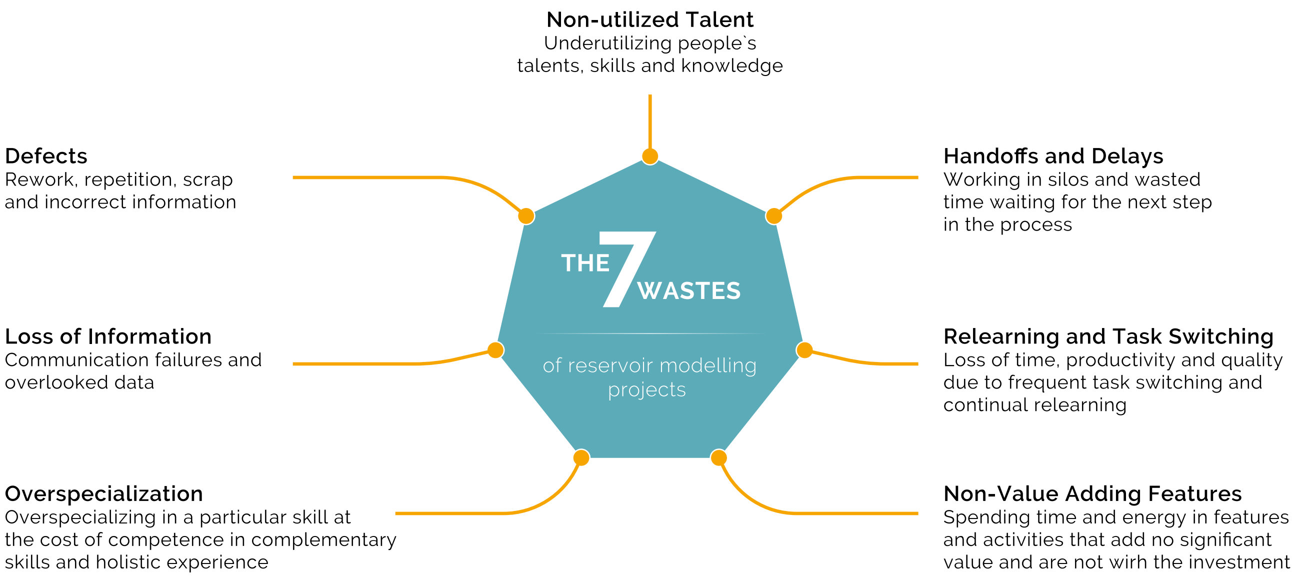
3 https://e24.no/podcast/e24-podden/oljen-ringenstrollmannfarst.olavsorden/

Throughout my 15-odd years in the oil and gas industry, working alongside excellent people in academia, subsurface teams and software vendors, I have often been asking myself the following two questions:

1. Why do we spend years of effort on building reservoir models?
2. What hinders us from fully utilizing our reservoir models as part of a continuous discovery process?

Theoretically, the answer to the first question is straightforward: if we can establish models of the unknown reservoir that honor all data, from all subsurface disciplines, reservoir physics and current knowledge, then we should be able to predict the future behavior of the reservoir and increase our understanding. Questions regarding business decisions ("*where should we drill?*"; "*how many wells?*"; "*in which order should we drill?*"; or "*how should we potentially operate our fields?*") can be tested in the "lab" before committing to field decisions.

In practice, however, cost overruns, schedule delays, limited predictability and frequent surprises have put the value of reservoir models under scrutiny[4]. To understand these symptoms as well as what may be preventing us from employing models as the foundation for continuous discovery, let us look at what I came to see as "**the Seven Wastes in Reservoir Modelling Projects**" and understand how we can overcome these challenges:



4 https://uis.brage.unit.no/uis-xmlui/handle/11250/2566243

1: Non-Utilized Talent

Fresh out of university, I joined a subsurface team working alongside highly skilled and experienced people from all disciplines. What struck me as odd about this first experience was that the official (base case) reservoir model, which was used for decision support, had been outdated for many years. We had available data from numerous new wells that had been drilled since the model was created and we had access to new dynamic data collected from the past years of production. None of these data were incorporated into the model.

At first this puzzled me. The asset had spent millions of dollars on drilling new wells and installing sophisticated tools to measure well pressures and rates. Why would you make this investment and then leave the data untouched in the subsurface modelling? I was particularly surprised because I had read papers (then written 10-20 years earlier[5],[6]) talking about integrated modelling and rapid model updates.

One day, a clue presented itself through a statement by the lead reservoir engineer: "*If I have to do another round of history matching on this model, I'd rather quit my job!*". It was, to be fair, a strong statement uttered in frustration during a heated discussion. In hindsight, however, I came to see it as a symptom of how we fail to adequately utilize human talent in reservoir modelling processes.

Repeatedly expecting skilled professionals to manually manipulate an outdated model to fit new data is not putting their skills to the best use. When you work hard, only to see your deliverables perceived as "flawed" by the receiving party, it is human nature to lose motivation about current tasks and start looking for alternatives[7]. To further understand why reservoir modelling projects often end up in this situation, with members of the subsurface team feeling underappreciated and not given the chance to fully utilize their talent, let us look at items number two and three of the **Seven Wastes in Reservoir Modelling Projects.**

#2 Handoffs and Delays & #3 Relearning and Task Switching

As we naturally perceive a reservoir model as a collection of building blocks, we have historically established a *linear* working process with handoffs between different subsurface disciplines. Geophysicists interpret the seismic data, providing input to the geo-modelers in charge of building a 3D grid of the reservoir. The grid is thereafter handed over to a new team of geologists, which will transfer their knowledge regarding potential geological concepts in combination with well log data inter-

5 https://www.onepetro.org/conference-paper/SPE-20750-MS

6 https://www.onepetro.org/conference-paper/SPE-35533-MS

7 https://hbr.org/2018/01/why-people-really-quit-their-jobs

preted by a petrophysicist to populate the 3D grid with geological properties. This “relay race”, with handoffs from discipline to discipline, continues until we encounter a reservoir engineer delivering a history matched model.

The apparent advantage of such a process is that it is easy to transfer the specialized skills of employees from project to project. When the grid has been established on field A, you can reallocate the structural geologist to field B and repeat the specialized task. In reality, however, this “waterfall” approach has major drawbacks.

Having team members constantly switching tasks and moving back-and-forth between projects is a major hindrance to a continuous learning process. Since we know that project plans are subject to change, we need an integrated and automated environment that promotes *strong interdisciplinary collaboration* within the subsurface team, so that we can react and adapt to these changes. When the waterfall process breaks down because of time-consuming handoffs or because of resources not being available when needed (as they are often reallocated to other projects), a reservoir modelling project may quickly descend into a never-ending necessary evil. Moreover, this silo-based predicament also tends to foster items 4 and 5 on the list of the Seven Wastes.

#4 Non-Value Adding Features & #5 Overspecialization

In an environment where model components are made by one group of highly skilled specialists and delivered to the next group of highly skilled specialists in organizational silos, the work delivered is (as it needs to be) subject to rigid QA processes, both within and outside each silo. Hence, it is only natural that we want to make sure that our delivered work is 100% correct when handed off. In other words, each discipline is under pressure to do more and more “flawless work” to minimize expensive back-and-forth.

However, when the work you deliver is only a small part of something larger, you often have no certain way of knowing whether or not the additional time you spent making that seemingly perfect relative permeability model will truly make an impact on the business objective of drilling a new infill well. Working in a waterfall setup means working in an assembly line and not necessarily seeing the big picture. But understanding the big picture as a team is precisely what enables continuous discovery and fosters motivation.

As I think back to the many QA sessions and partner meetings I have attended, where 20+ people have gathered in a room for days to discuss (and argue) over the quality of a small part of the modelling work, it is easy to feel disheartened. Even if nobody in the room at the time really knew whether using “modelling approach one” versus “modelling approach two” would influence their business decision, none of the arguing parties was willing to budge. In the heat of the moment, it becomes too easy to focus on the details and defend your views with all necessary means, instead of taking a holistic approach adapting the quantum physics paradigm suggested by Hans Christen Rønnevik – i.e., accepting that both parties are potentially right, but may ultimately be wrong.

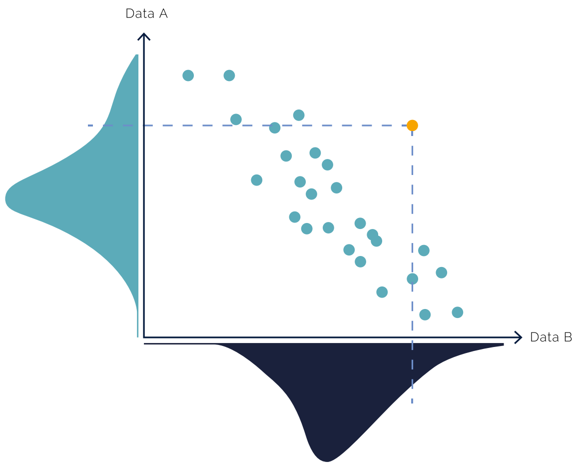
Disciplines may come to resent one another for how they are always ignoring each others' concerns. With decision gates fast approaching and with people eventually agreeing to disagree, the question that remains is: what is the consequence of spending far too much time arguing over details that ultimately may not affect the decisions, and which only a fraction of the people in the room can follow? The answer to that question may be found by looking at the last two wastes.

#6 Loss of Information & #7 Defects

Reservoir modelling implies solving an *inverse problem* with a non-unique solution in high dimensions by using sparse and often indirect measurements that are collected over time. For this reason, it is not surprising that modelling truly is a never-ending task. Hence, the assumption that reservoir modelling is a one-off process (where you start a project, deliver models, and move on) goes against the very nature of the problem.

When communication between the different disciplines breaks down, key messages are lost in translation, or alternative plausible modelling options are forgotten or overlooked, the resulting models will fail to incorporate the available data and knowledge from the entire team.

More problematic, however, are the potential defects that occur in the resulting models due to inconsistencies between different data sources that are input to the modelling process. These defects are often not discovered until business decisions have been made. Defects may eventually break down trust within the subsurface team, break down trust among partnering oil and gas companies, and ultimately lead to a process that fails to utilize human talent.



Potential effects occurring when ignoring dependencies among different modelling components. A model can be plausible if we look at data independently but can easily be identified as not plausible if we look at all data simultaneously.

Overcoming the Seven Wastes

An industry outsider looking at the Seven Wastes might be excused for finding it surprising that oil and gas projects have been profitable at all. While, in some projects, serendipity may have played an important role, in most cases the many heroes working in the oil and gas business have contributed to a large degree to compensate for the Seven Wastes. But there should be no doubt: unless we are able to step away from the Seven Wastes, it will be hard to trust the value of reservoir models to a much greater extent than that they are "*good at accurately predicting the past*", as Hans Christen Rønnevik states it.

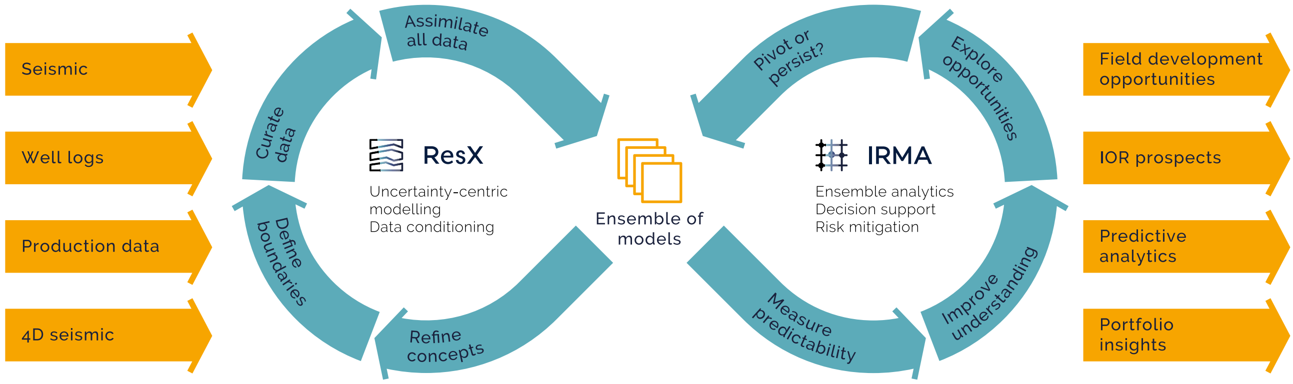
Fortunately, addressing the Seven Wastes in reservoir modelling projects is not as difficult as one might think. It requires, however, that we abandon the notion that we can ever create the "perfect" digital twin of the reservoir – the so-called "case centric" approach – which is really the root cause of the Seven Wastes.

Instead, we need to establish a framework and use tools that enable us to embrace the fact that, at any given time, our current perception about the reservoir is uncertain and will change as we gather new data and continuously learn – the so-called "uncertainty-centric" approach.

The key to accomplishing this transition from a case-centric to an uncertainty-centric modelling approach is to establish an end-to-end workflow that enables us to automatically connect the different modelling components while capturing and propagating uncertainty throughout. The ability to automatically close this loop between input data and output simulation model has been present in modern reservoir modelling software tools for many years now. Despite this, however, the majority of reservoir modelling projects still fail to fully utilize this functionality and close the loop. In my experience, this is often a result of a misperception regarding what tools can and cannot do, combined with a thirst for features that allow us to implement more details into the models than we can really justify given our current data.

Einstein's advice to make everything as simple as possible, but not simpler, should be the mantra in any reservoir modelling project, as it will enable us to quickly adapt or pivot when new data from the reservoir shows that our current understanding should be questioned. The more detail we introduce in our modelling workflows, the harder it will be to implement and maintain them, and the harder it will be and the longer it will take to adjust when new data calls for it. Any additional time we have to spend building and maintaining models or modelling workflows means less time we will have for actually *using* these models to explore the subsurface and having interesting conversations that ultimately increase our understanding of the reservoir.

This is why my first advice when Resoptima deploys our integrated reservoir modelling software in a new asset team is always to establish a **Minimum Viable Workflow** as quickly as possible. Establishing such a workflow can happen surprisingly fast if we employ a stochastic, ensemble-based modelling approach, allowing input parameters to vary within defined boundaries instead of requiring a "best guess" or expected values. When the entire asset team is in a position to look at all available data as a whole and immediately see how our modelling choices and data interpretation affect the resulting ensemble of models, we can start to iterate quickly, revising our workflow and modelling inputs to continuously learn and improve.



Addressing the Seven Wastes through an uncertainty-centric approach, based on an end-to-end integrated and automated workflow that quickly closes the loop between input data and simulation models and provides analytics for insights and decision support.

By now, some readers may be left with a "so what?" feeling. Integrated, closed-loop, uncertainty-centric reservoir modelling has been discussed in oil and gas literature for decades and numerous papers and case studies have been written. However, as history has proven time and time again, making something run once to establish results for a research paper is one thing, but to consistently repeat the process on any field, of any size, anywhere in the world, is dramatically more difficult. While a change in process and mindset is fundamental for a continuous discovery framework, process alone will only take you so far. This is the reason we in Resoptima have put all our focus into developing technology to overcome the challenges seen in earlier, less successful and less robust approaches.

We had to transfer the tedious task of "making the data fit together" out of the hands of overworked team members and over to computers, in order to decisively compress the time to go from an ensemble of unconditioned models to fully conditioned models – from months or years to hours or days. This time compression is foundational to establishing such an uncertainty-centric and iterative approach to reservoir modelling.

The key elements of our solution are:

- We implemented unique algorithms for data conditioning under uncertainty that make it possible to update all parameters in the model components *where they belong*. Instead of trying to compress the millions of parameters that define a 3D reservoir model into a handful of scalar variables or scenarios, we individually assess and update *all* parameters directly where they are originally defined.
- Our algorithms look at *both* the static and dynamic data *simultaneously*, instead of following the traditional two-step approach of first conditioning models to static data and then subsequently conditioning them to dynamic data through a "history matching" step.
- Our technology breaks down the data conditioning process into millions of individual problems, where changes occur locally and only when strongly supported by data. This ensures that uncertainties are not reduced unless the data calls for it, and are hence propagated forward to where they may impact decisions.

Asset teams can then spend their valuable time and knowledge analyzing the conditioned models, quickly testing out new hypotheses, looking for new value-creating opportunities, using model analytics tools, and – most importantly – quickly adapting when new data are collected that call for a revision of the current modelling concepts.

Changing the way people work – for the better

Addressing the Seven Wastes of reservoir modelling projects fundamentally boils down to two defining factors:

1. Implement a process that allows assets teams to quickly establish a repeatable workflow for uncertainty-centric reservoir modelling, where the inputs are the current data and the enabling constraints that define the boundaries for the unknown parameters.

    - When we are allowed to work and explore within this framework, we foster an environment where we can fully utilize our collective strengths.
    - We avoid loss in time and loss of information due to handoffs and we ensure that all input to the reservoir modelling workflow is put to use.

2. Employ software tools that look at all available data simultaneously in the conditioning phase, enabling the subsurface team to incorporate new data quickly and continuously improve their knowledge about the subsurface.

The key to adding value to both greenfield and brownfield developments lies in the advice of "GeoLegend" Hans Christen Rønnevik: "**establish an environment for a continuous discovery process.**"

- Learn from our data, but look at the data as a whole and be prepared to pivot when new data changes our perception of reality.
- Make our models as simple as possible, but not simpler, and embrace uncertainty in everything we do in an automated framework.
- Most importantly: always thirst for new knowledge and learn.

There is a major opportunity in subsurface optimization and that is why we focus on helping asset teams make this transition every day, in every corner of the world[8,9]. Unlocking the estimated 1 trillion barrels of oil equivalents still remaining in discovered assets[10] requires work processes and software tools that allow this to happen. Overcoming the Seven Wastes is an essential ingredient for a successful transformation in reservoir modelling — one that yields rapid, substantial and sustainable business value.

About the author and Resoptima.

Jon Sætrom is the Chief Science Officer at Resoptima.

If you would like to know more about how Resoptima's software and products address the challenges discussed in this article, please visit our Resources page on **www.resoptima.com**, where you will find an extended version of this article as well as papers and additional information about our products and services.

8 https://www.spe.org/en/jpt/jpt-article-detail/?art=2909

9 https://www.onepetro.org/conference-paper/SPE-188557-MS

10 https://www.mckinsey.com/industries/oil-and-gas/our-insights/an-analytical-approach-to-maximizing-reservoir-production