DTU Library

Uncertainty in engineering, research, negotiation and adaptive management for water sensitive cities

Mikkelsen, Peter Steen; Geldof, Govert

Published in:
WSUD 2012 - 7th International Conference on Water Sensitive Urban Design: Building the Water Sensitive Community, Final Program and Abstract Book

Publication date:
2012

Document Version
Peer reviewed version

Uncertainty in engineering, research, negotiation and adaptive management for water sensitive cities

P. S. Mikkelsen* and G. D. Geldof*,**

** Department of Environmental Engineering (DTU Environment), Technical University of Denmark, Miljoevej, Building 113, DK-2800 Kgs. Lyngby (E-mail: psmi@env.dtu.dk)*
*** Geldof c.s., Holprijp 2,8804 RZ, Tzum, the Netherlands (E-mail: govert@geldofcs.nl)*

Extended Abstract

A reflexive framework for comprehending, discussing and coping with uncertainty in urban water management is presented, which explains why there are good reasons to perceive and manage uncertainty differently across e.g. the natural, technical, economic, planning and social sciences.

A 2x2 "matrix of decision making" that clearly distinguishes uncertainty/certainty about the problem to be solved (i.e. agreement/disagreement about goals) and about the means to solve the problem (i.e. the knowledge required to achieve the goals) is introduced (Figure 1, upper left, Christensen, 1985) and combined with a concept for characterizing uncertainty using three dimensions (location, level and nature of uncertainty, Figure 1 upper right, Walker et al., 2003). This is then combined with reflections on the appropriate action considering the level and nature of uncertainty characterizing the situation (Figure 1, lower left) and how this connects with the introduced matrix (Figure 1, lower right) and with positivistic as well as constructivist planning approaches.

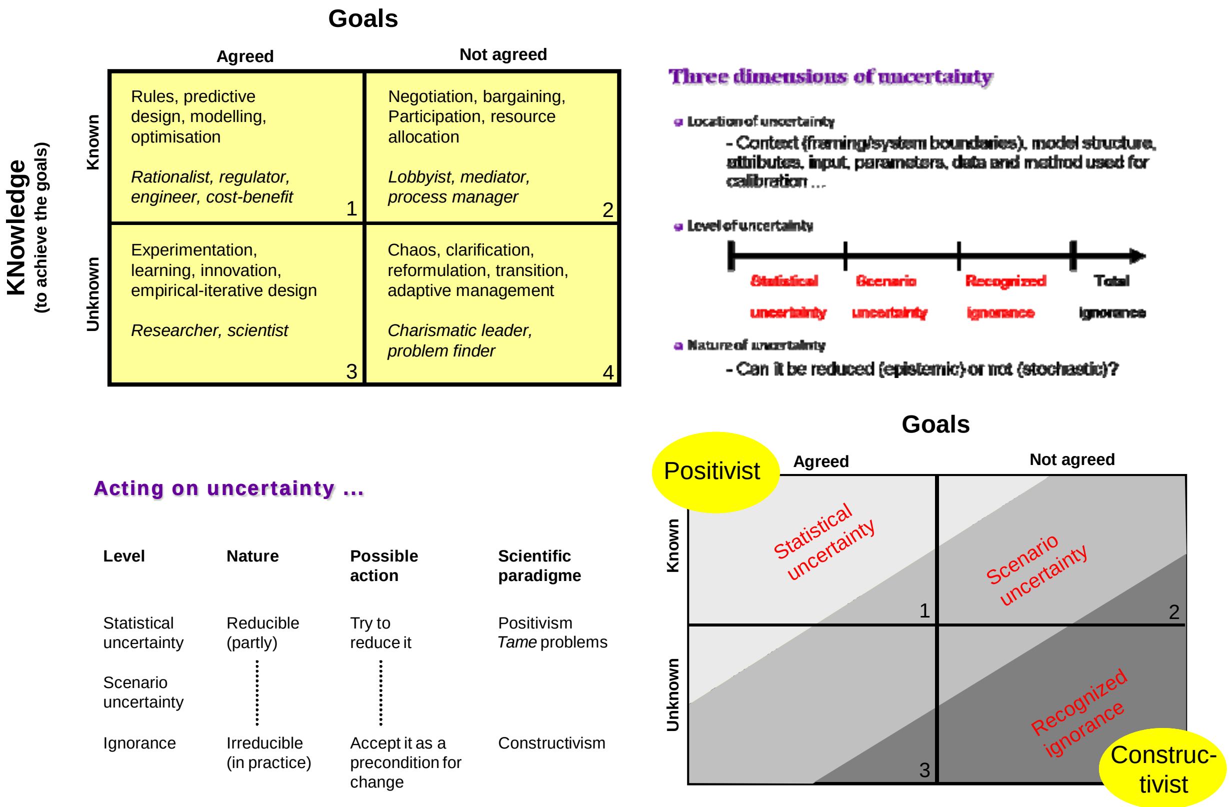


Figure 1. Overall concepts that will be explained, connected and exemplified in the conference presentation.

Each quadrant in the matrix is an arena for different types of professionals involved in decision making, and is furthermore characterized by one or a few distinct levels of uncertainty: we here distinguish the levels statistical uncertainty, scenario uncertainty, qualitative uncertainty, recognized ignorance and total ignorance, based on Refsgaard et al. (2007). Because the location and nature of uncertainty differs between the quadrants the appropriate management strategy and the role of the water manager as an actor in decision making also differs. The typical arena for an engineer concerned with design, simulation and optimisation is quadrant 1, where uncertainty is statistical and the problems faced can be tamed (to some extent) by reducing uncertainty. Quadrant 2 is the arena for negotiation and resource allocation, which bring the human interaction processes into focus, and Quadrant 3 is the arena for experimentation and learning, where research and science is at focus. These two quadrants are both characterised by scenario uncertainty and qualitative uncertainty, i.e. assumptions can be made about a process or about the future and patterns describing reality can be conceptualised, but there is no basis for assigning probabilities. Completely different skills are needed when uncertainty is large and approaches recognized and even total ignorance (quadrant 4); this is where adaptive management plays an important role and engineering standards and design are less important in the big picture. Quadrant 4 can be characterized as chaotic; projects often alternate between formulating the problem and finding the solution, but it is also where the inherent problem wickedness (Conklin, 2006) can be seen as an opportunity for those who are interested in trying out new ideas.

The framework illustrates how positivistic and constructivist planning approaches are complementary dependant on the location in the 2x2 matrix. This will be exemplified and discussed in the conference presentation using contemporary examples from the field of urban stormwater management, i.e. real time control of urban drainage systems, control of chemical constituents in wet-weather discharges, urban flood risk management and water sensitive urban design. The framework is proposed as a reflexive framework for analysis of decision making processes that make complex situations tangible to practical urban water management.

References

Christensen, K.S. (1985): Coping with uncertainty in planning. Journal of the American Planning Association, Vol. 51, ls 1, pp. 63-73.

Conklin, J. (2006): Wicked problems and social complexity. Chapter 1 of Dialogue Mapping: Building Shared Understanding of Wicked Problems. John Wiley & Sons, Ltd., England. Available at: http://cognexus.org/wpf/wickedproblems.pdf (visited 11 November).

Hauger, M.B. (2005): Uncertainty, risk and modelling in urban drainage. PhD thesis. Institute of Environment & Resources, Technical University of Denmark, 53 pp. + appendix.

Holling, C.S. (ed) (1978): Adaptive environmental management and assessment. Wiley, Chichester.

Refsgaard JC, van der Sluijs JP, Højberg AL, Vanrolleghem PA (2007) Uncertainty in the environmental modelling process – A framework and guidance. Environmental Modelling & Software, 22, 1543-1556.

Walker, W.E., Harremoës, P., Rotmans, J., vand der Sluijs, J.P., van Asselt, M.B.A., P. Janssen and Krayer von Kraus, M. (2003): Integrated Assessment, Vol. 4, No. 1, pp. 5-17.

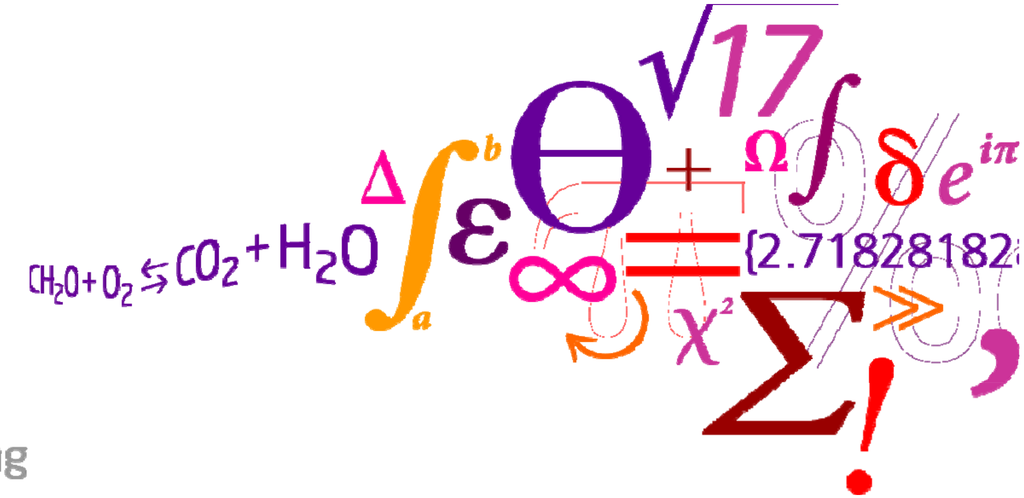
7th International Conference on Water Sensitive Urban Design.
WSUD Conference 2012: Bullding the Water Sensitive Community
Melbourne/Australia, 22-24 February 2012

Technical University of Denmark

Uncertainty in engineering, research, negotiation and adaptive management for water sensitive cities (tentative slides)

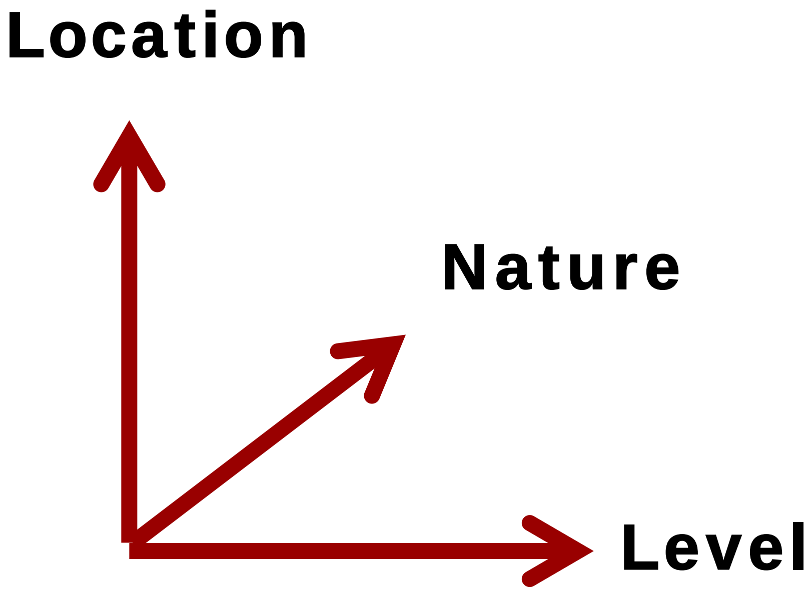
Peter Steen Mikkelsen[1] and Govert Geldof[1,2]

[1] *DTU Environment, Technical University of Denmark*
[2] *Geldof c.s., Holprijp 2,8804 RZ, Tzum, the Netherlands*



DTU Environment
Department of Environmental Engineering

A draft framework for communicating about uncertainty



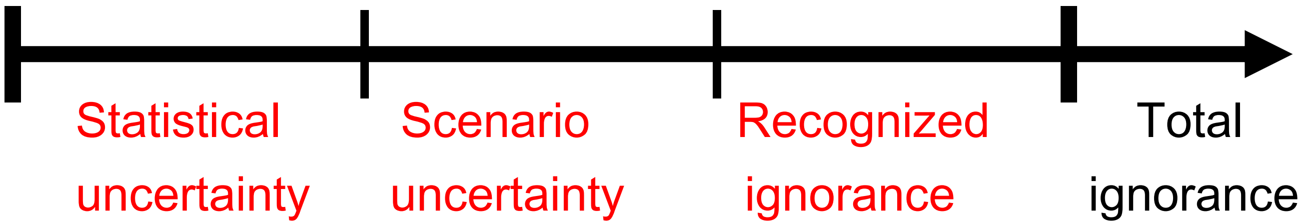
- What is often referred to as "uncertainty" actually hides important technical distinctions (EEA, 2001);
- *“Any departure from the unachievable ideal of complete determinism”*
- A three dimensional concept
- Inspired by
  - Walker et al. (2003): Defining uncertainty. A conceptual basis for uncertainly management in model based decision support. *Integrated Assessment,* ***4***(1), 5-17.
  - Christensen (1985): Coping with uncertainty in planning. *J. Am. Planning Assoc*., ***51***(1), 66-73.
- Supplemented with thoughts developed to a large extent in collaboration with Govert Geldof, NL, around teaching in *Environmental Management & Ethics* course at DTU.

Three dimensions of uncertainty (Walker et al., 2003)

- Location of uncertainty

  - Context (framing/system boundaries), model structure, attributes, input, parameters, data and method used for calibration ...

- Level of uncertainty



- Nature of uncertainty

  - Can it be reduced (epistemic) or not (stochastic)?

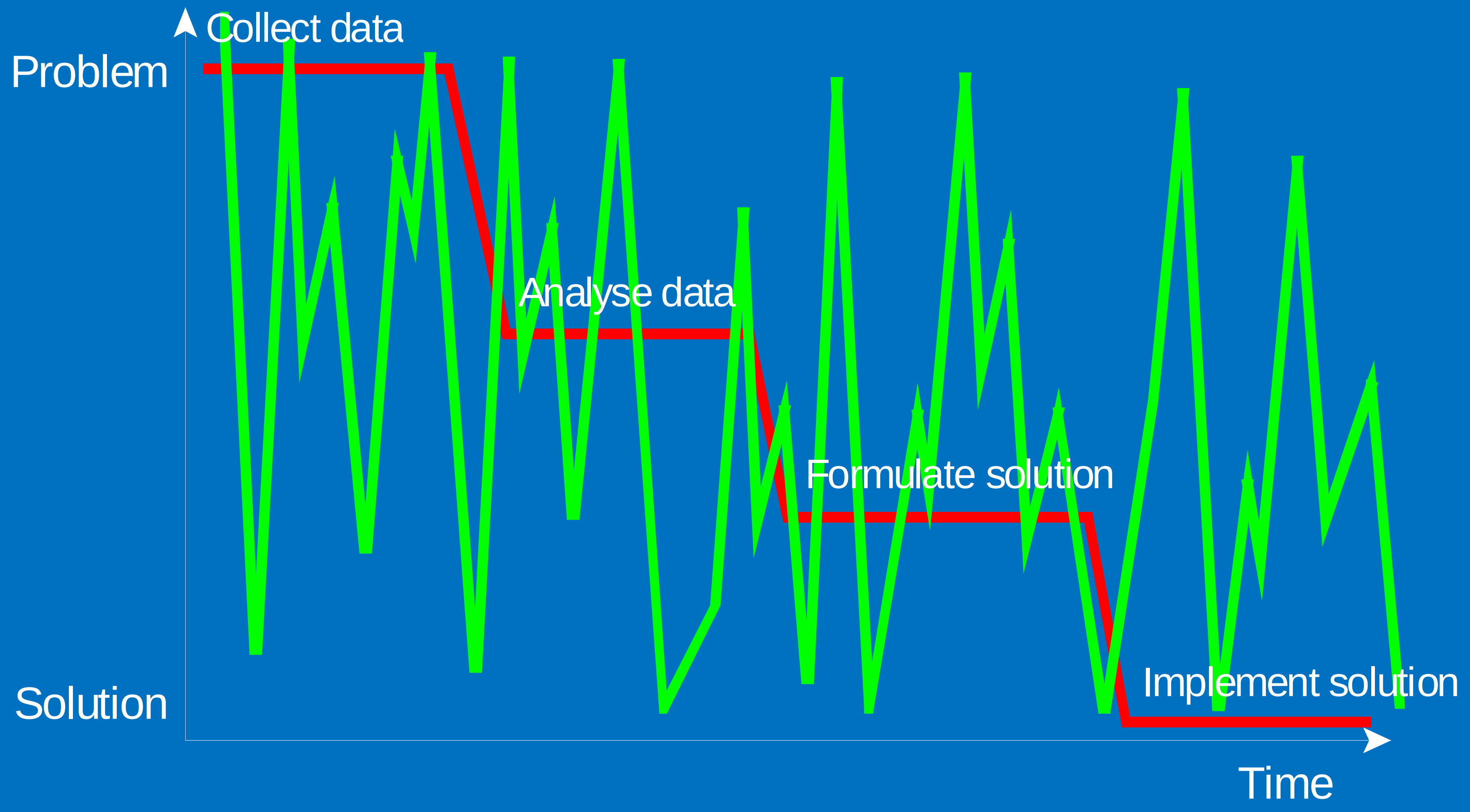
Uncertainty and decision making (Kristensen, 1985)

Goals

KNowledge (to achieve the goals)	**Agreed**	**Not agreed**
Known	Rules, predictive design, modelling, optimisation *Rationalist, regulator, engineer, cost-benefit* 1	Negotiation, bargaining, Participation, resource allocation *Lobbyist, mediator, process manager* 2
Unknown	Experimentation, learning, innovation, empirical-iterative design *Researcher, scientist* 3	Chaos, clarification, reformulation, transition, adaptive management *Charismatic leader, problem finder* 4

Hard system projects (tame problems)

Soft system projects (wicked problems)

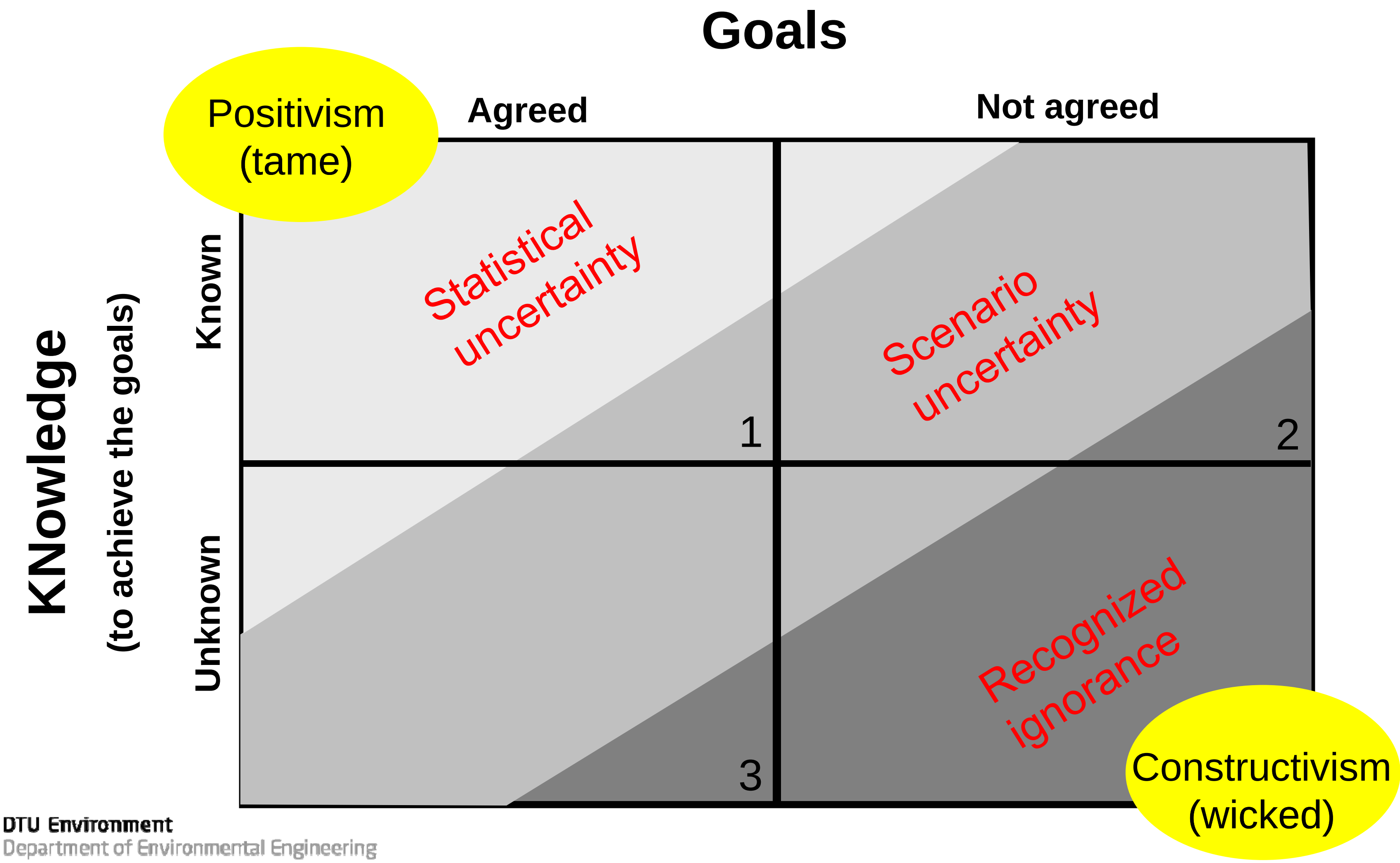


(Conklin, 2006)

Acting on uncertainty ...

Level	Nature	Possible action	Scientific paradigme
Statistical uncertainty	Reducible (partly)	Try to reduce it	Positivism *Tame* problems
Scenario uncertainty	⋮	⋮	
Ignorance	Irreducible (in practice)	Accept it as a precondition for change	Constructivism *Wicked* problems

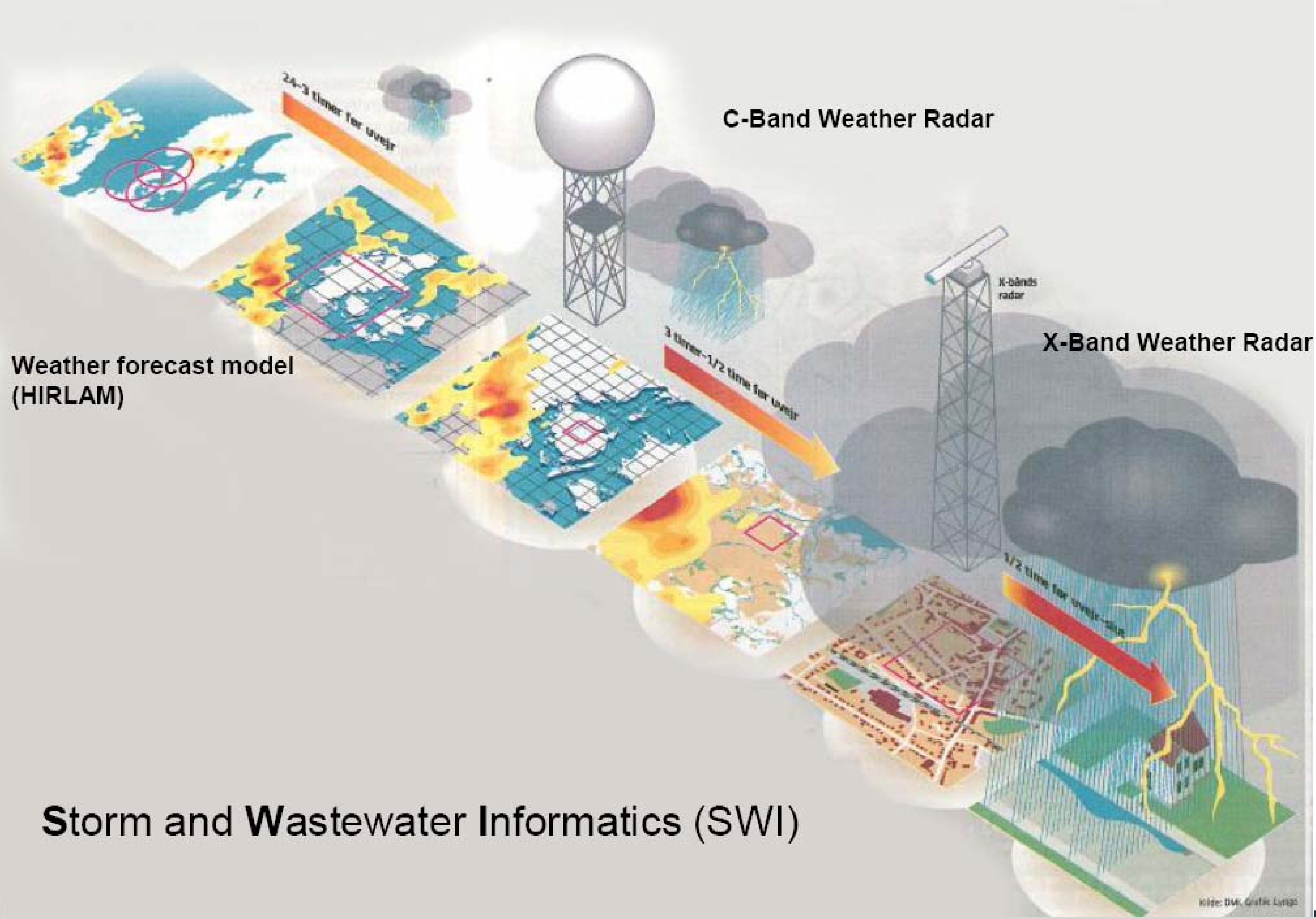
Uncertainty and decision making



Examples of tools for dealing with uncertainty

- Stochastic state-space modelling for probabilistic forecasting in real time control of urban drainage systems (statistical uncertainty)
- Safety margin in design of urban drainage systems (statistical uncertainty, scenario uncertainty)
- 3PA for communication in Urban flood risk management (qualitative uncertainty, ignorance)

- ... and more



Storm and **W**astewater **I**nformatics (SWI)

See more on http://www.swi.env.dtu.dk

Stochastic state-space modelling

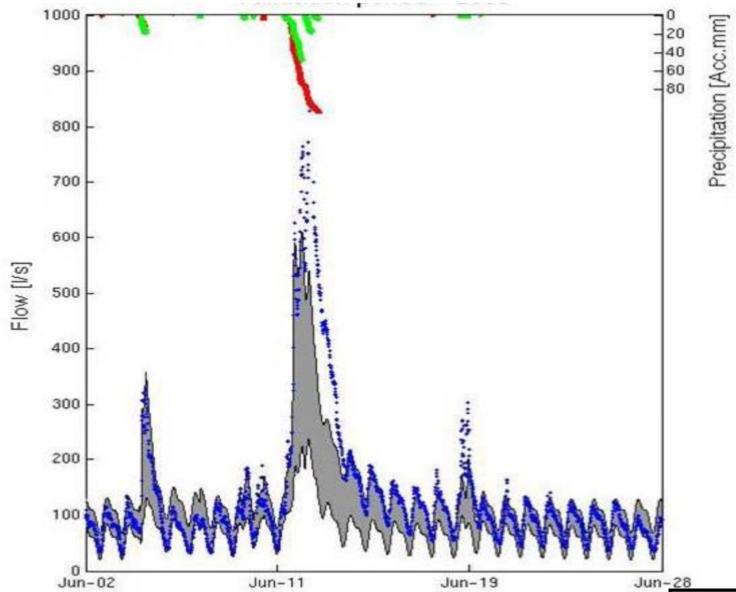
Drift term (deterministic)

Observation noise

Diffusion term (stochastic)

$$dX_t = f(X_t, u_t, t, \theta)dt + \sigma(X_t, u_t, t, \theta)d\omega_t$$ System equation

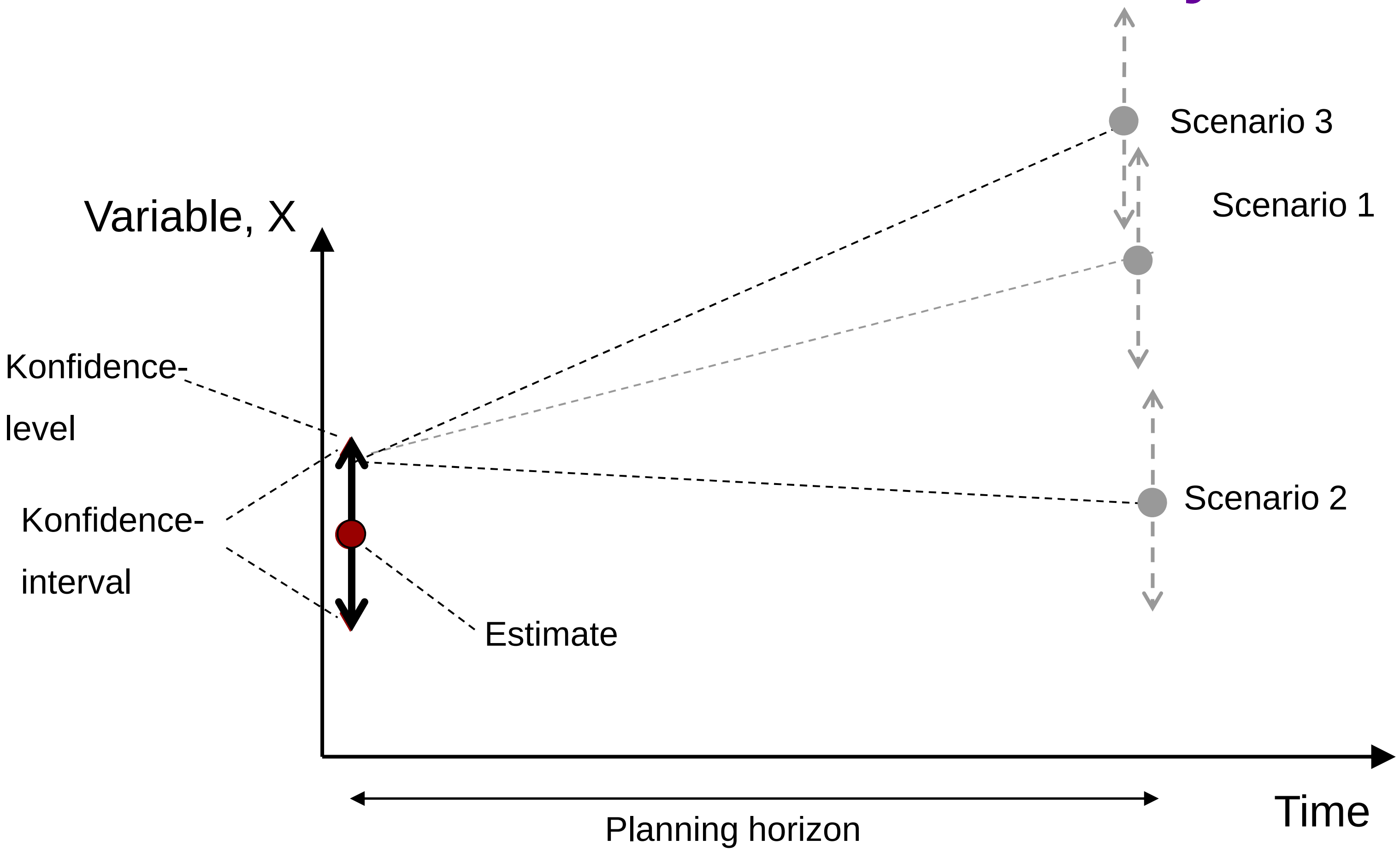
$$Y_k = h(X_k, u_k, t_k, \theta) + e_k,$$ Observation equation



Notation:

X_t:	State variables
u_t:	Input variables
θ:	Parameters
Y_k:	Output variables
t:	Time
ω_t:	Standard Wiener process
e_k:	White noise process with $N(0, S)$

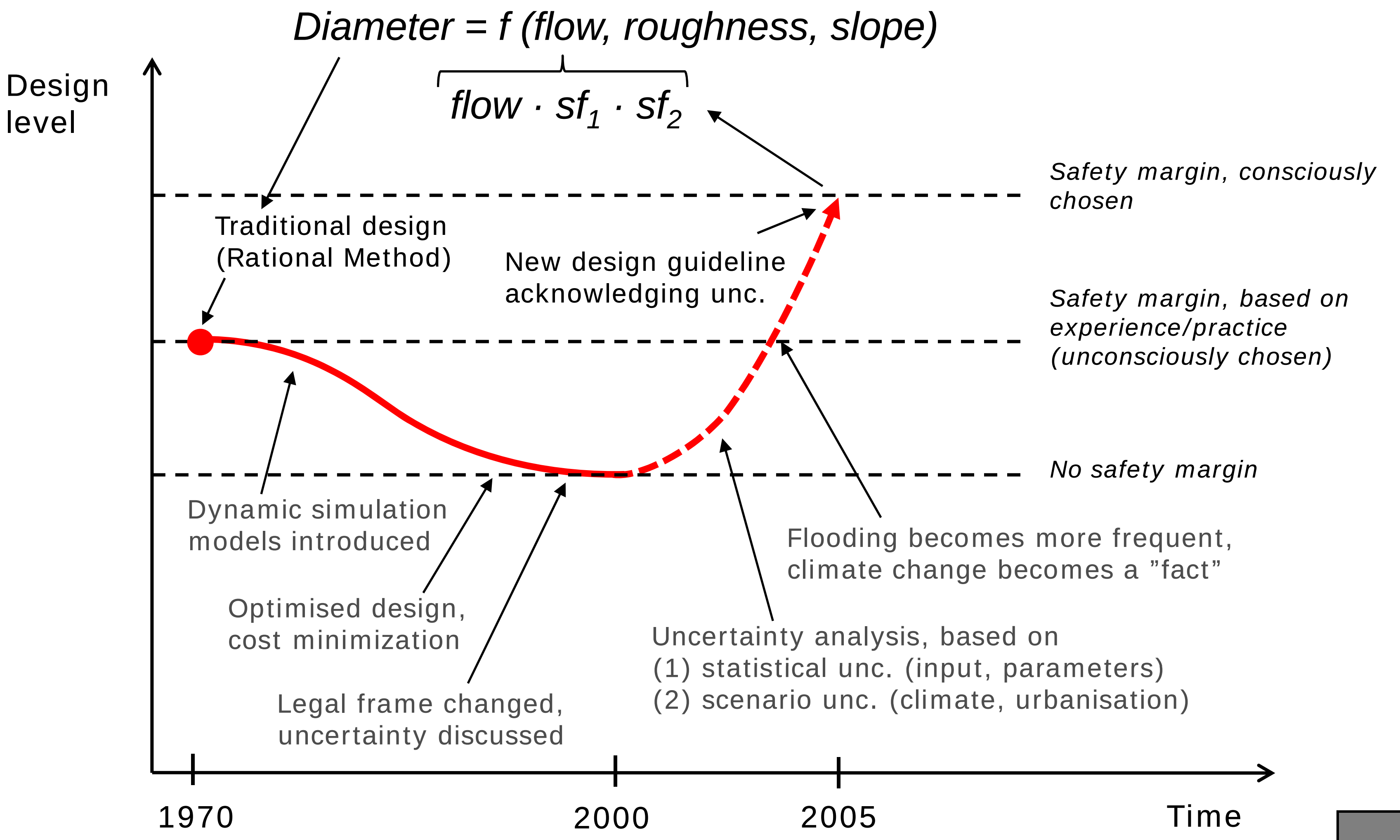
Statistical and scenario uncertainty



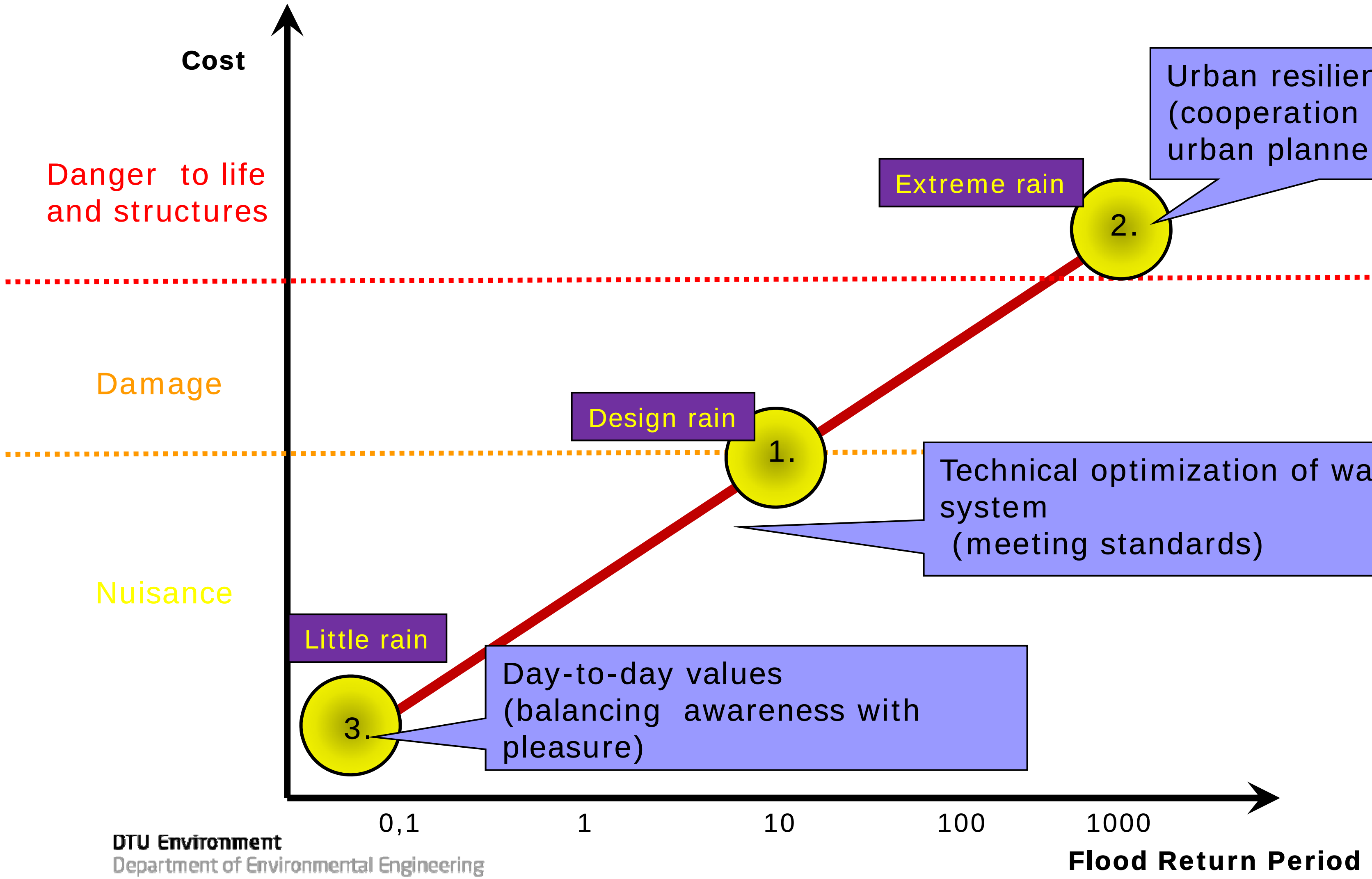
Scenarios don't need to be related to time (different assumptions)

Ignorance is ignored (we lack methods to deal with it)...

Temporal evolution of safety margin in sewer design, Denmark



The Three Points Approach (Fratini et al., 2011)



Conclusions

- Different levels of uncertainty calls for different management approaches
- ”Tame” problems can be managed using statistical methods and positivistic planning approaches. Statistical uncertainty can be quantified using models and sometimes reduced
- ”Wicked” problems are characterised by recognised ignorance that cannot be reduced, but patterns can provide useful insights
- Planning for Water Sensitive Cities has many ”wicked” charateristics, and constructivist planning based on step-wise learning may be the only useful way ahead
- The developed framework for comprehending, discussing and coping with uncertainty can be used for reflection when aiming to make complex decision situations tangible to practical urban water management