Optimal risk management support in actively managed well catchments by means of probabilistic vulnerability criteria

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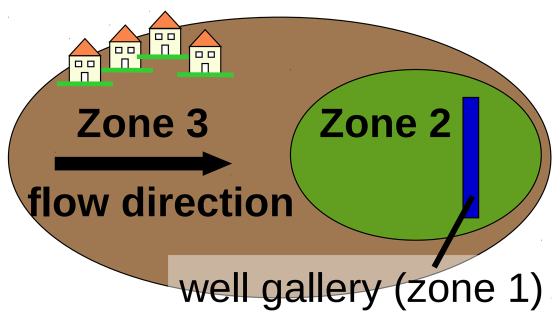
Motivation

Complete risk management schemes need to know: *(1) What kind of hazards exist within a water catchment, (2) how these hazards can be controlled and (3) knowing that they are controlled.*



Optimal allocation of financial resources between risk mitigation and improved monitoring is indispensable for efficient and rational risk management. This requires to assess the utility of planned data acquisition.

Approach

We provide a probabilistic risk management approach for actively managed well catchment that quantifies uncertainty and allows to assess the utility of planned data. It is based on probabilistic intrinsic transport-based well vulnerability criteria:

(a) The probability distribution of peak arrival time from source to well;
(b) Possible levels of peak concentration arriving at the well;
(c) Probability distribution of reaction time until a threshold level is exceeded (e.g., drinking water standard); and
(d) The probability distribution of well down time (exposure time).

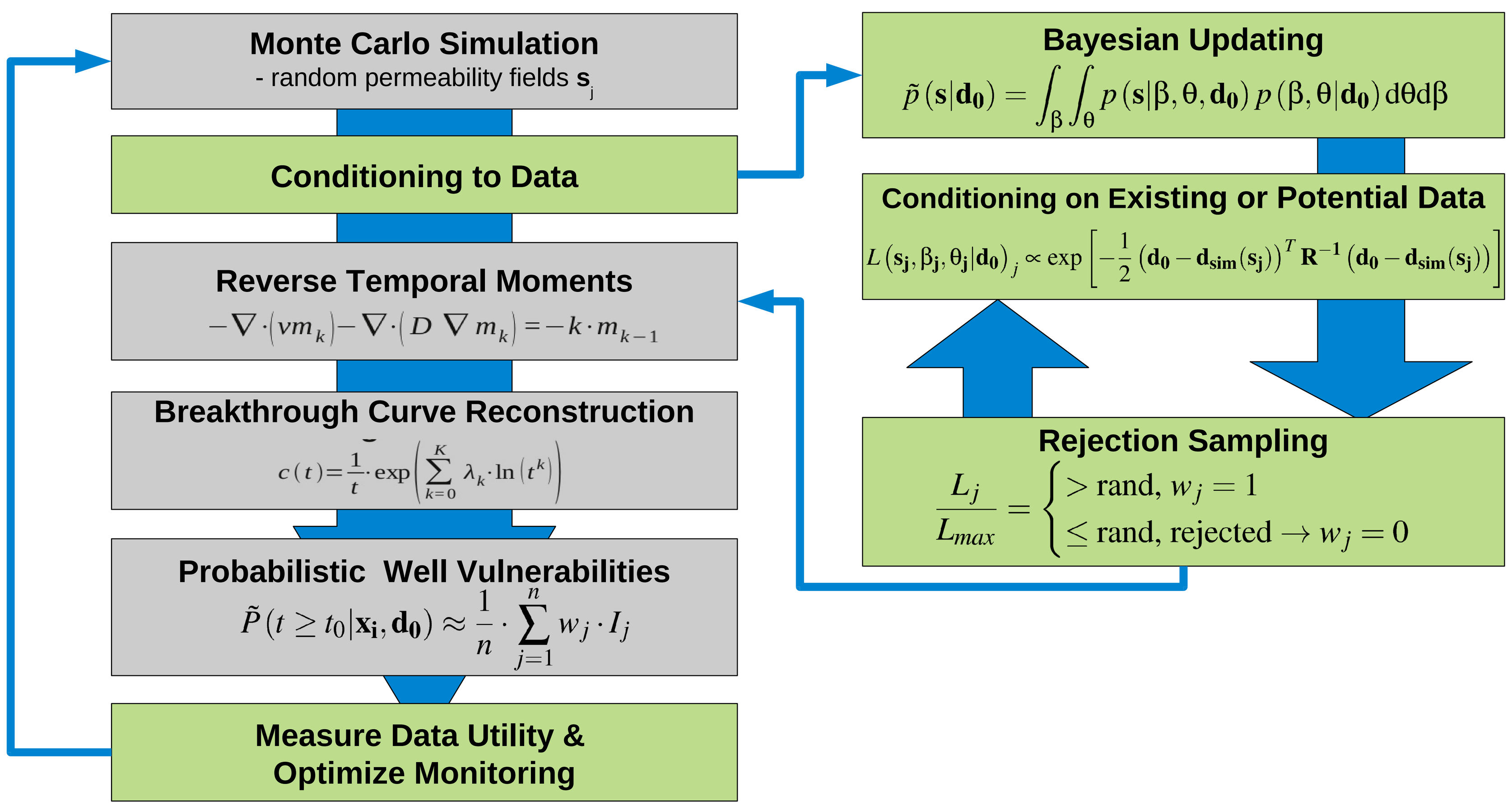
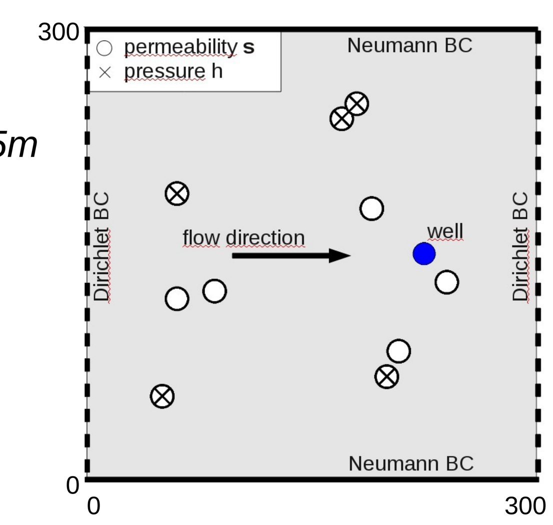


Figure 1: Methodology to determine conditioned probabilistic intrinsic well vulnerability criteria

Example & Results

h_{in} = 1.5m



h_{out} = 0.0m
$Q_p = 1 * 10^{-4}$ m³/s
α_L = 2.5m
α_T = 0.25m
$\lambda_x = \lambda_y$ = Matérn-model
$\Delta x = \Delta y$ = 1m

Figure 2: Illustrative Example, showing location of measurements (Design 0)

	value	unit
μ	[-7.5 -5.5]	[-]
σ²	[1 3]	[-]
κ	[0.5 5]	[-]
λ_x	[10 25]	[m]
λ_y	[5 15]	[m]
q_{rg}	120	mm a^{-1}
σ_{rg}	10	mm a^{-1}

Table 1: Uncertain model parameters

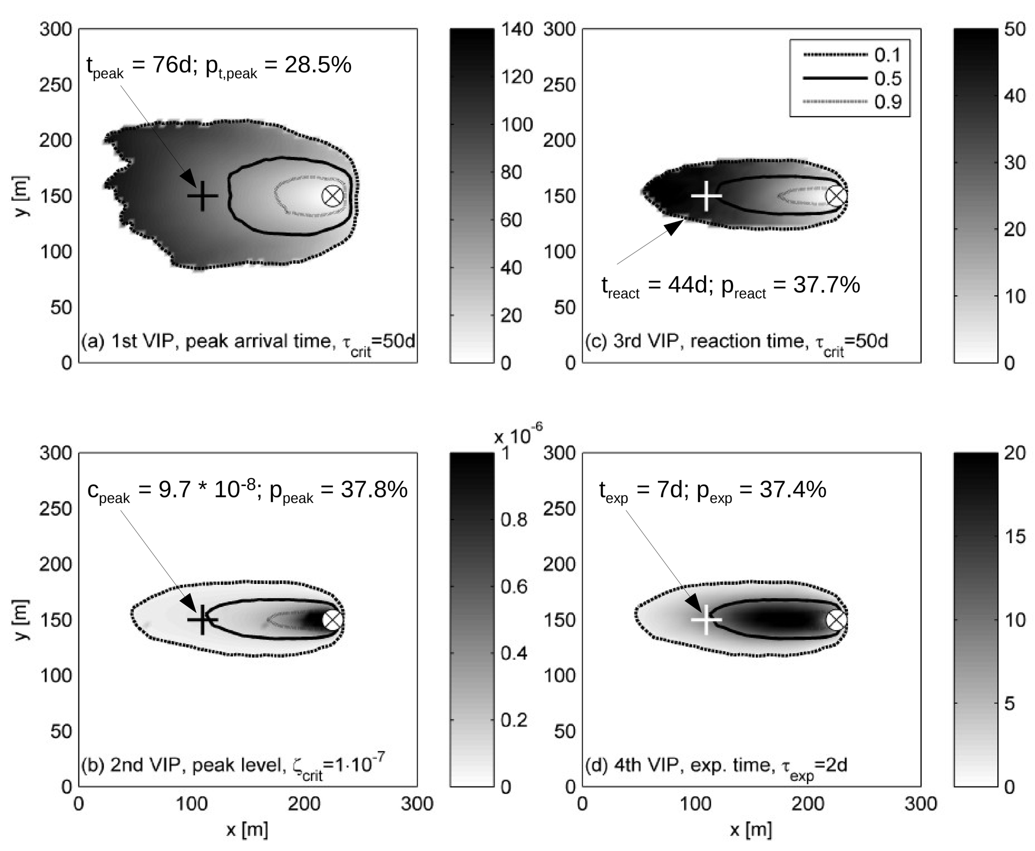


Figure 3: Probabilistic isopercentiles [0.1, 0.5, 0.9] for the four intrinsic well vulnerability criteria (a)-(d) from n=500 simulations. Grey-scale maps show the ensemble mean of the respective well vulnerability criteria.

Risk Evaluation

Risk Acceptance – Areal & Reliability Costs:

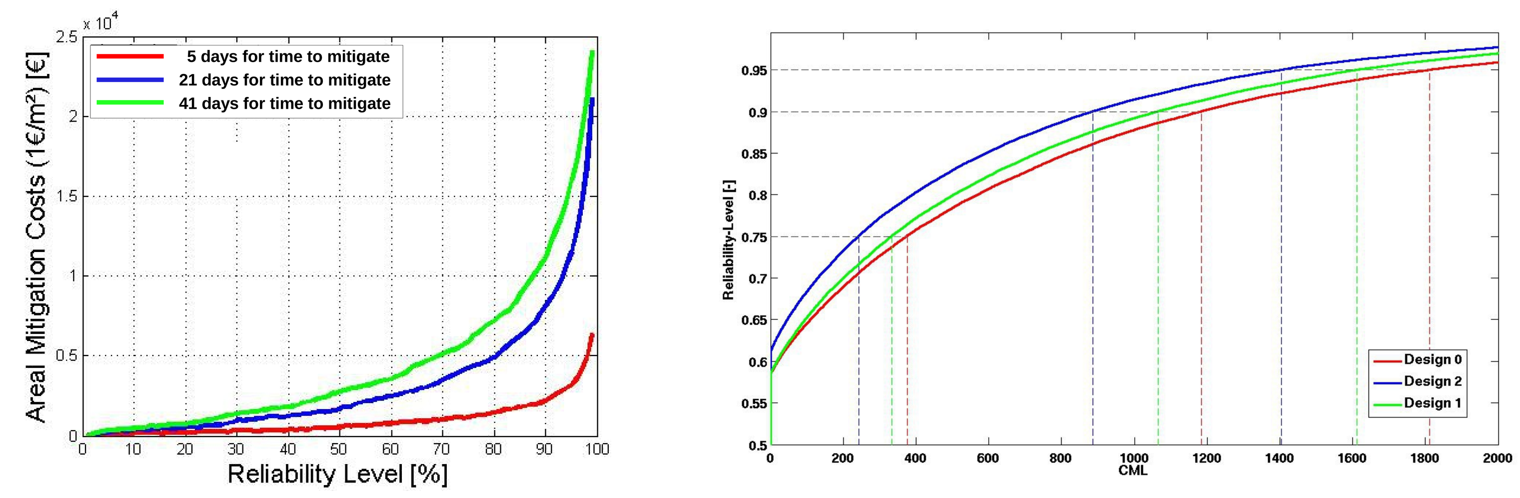


Figure 4: Costs for size of protection area at desired reliability, depending on speed of early-alert systems (left). Additionally the cumulative probability distribution of customer minute loss (CML) at loc. A (n=100) is shown (right).

Risk Reduction – Utility of Monitoring: *($U=(A_{R90}-A_{R10})/A_{R50}$)*

VIP	„critical value“	Unconditional Uncertainty U_{uc}	Design 0 U_{D0}	Design 1 U_{D1}	Design 2 U_{D2}
t_{peak}	τ_{crit} = 50d	43.1%	25.2%	12.45%	10.12%
c_{peak}	$c_{crit} = 1 \times 10^{-7}$ [-]	14.6%	10.4%	12.83%	10.60%
t_{crit}	τ_{crit} = 50d	14.6%	10.4%	11.18%	9.03%
t_{exp}	τ_{exp} = 2d	14.5%	10.3%	12.45%	10.12%

Table 2: Showing the fractional area [%] of delineated catchment area according to the four VIP maps that is sacrificed to uncertainty for the unconditioned and the conditioned (Design 0-2) case.

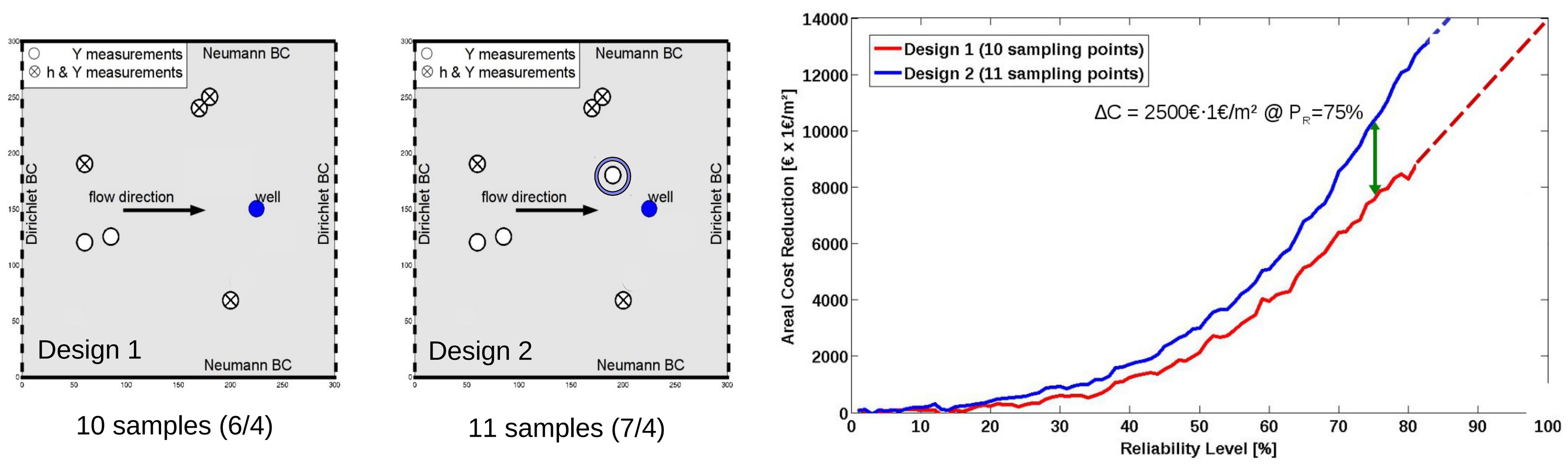


Figure 5: Utility of one additionally planned sampling location to reduce areal costs (Unconditional – Design) through uncertainty reduction ($U=(A_{R90}-A_{R10})/A_{R50}$) in capture zone delineation.

Risk Treatment – Decision Support:

- Damage D_i[€] - Replacement Cost Method: $D_i = t_{exp,i} \cdot Q_p \cdot \gamma_i$

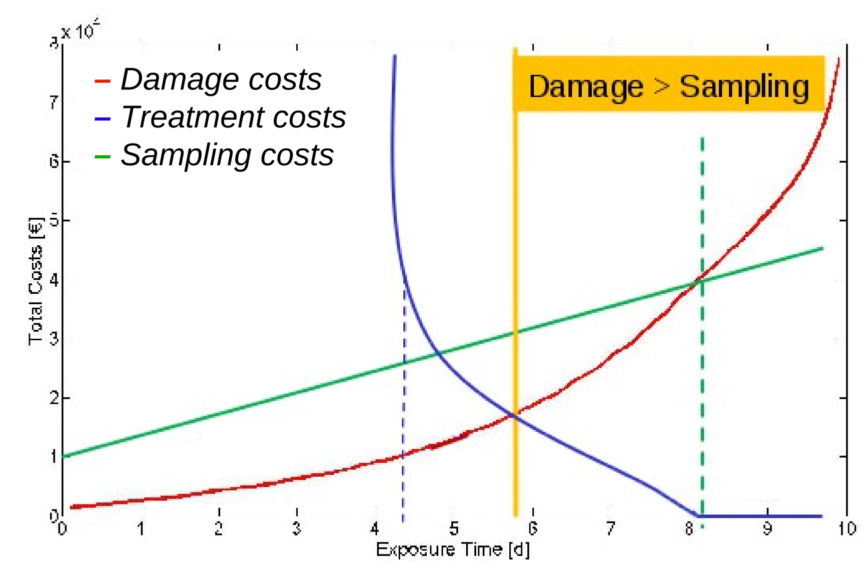


Figure 6: Rational risk-based decision support. Here comparing two alternatives (water treatment, data sampling).

Outlook

- Optimal site exploration for maximum reliability at minimal costs.
- Generalize physical scenario (e.g., varying pumping schedule in cooperation with DTU).

Literature

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[2] *Frind, EO; Molson, JW and Rudolph, DL: Well vulnerability:* A quantitative approach for source water protection. *Ground Water Vol. 44 No. 5 (2006), p. 732–742*

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