

Simple Models, Smarter Decisions: Understanding Prediction Reliability for Better Mine Dewatering Outcomes

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Based on: Benson et al. (2026), Journal of Hydrology

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All models are wrong but some are useful

All models are uncertain but some are more reliable

All models cost money but some enable smarter decisions

Question 1: What are your annual dewatering volumes and cost?

Question 2: Can you reliably meet those volumes and cost?

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Conventional Pump Test Analysis

Aquifer properties

Characterise aquifer properties & hydrogeologic conditions

- Estimate transmissivity (T), storativity (S), boundaries & hydraulic connectivity
- Provide inputs for numerical and analytical models

Well performance

Assess well performance

- Evaluate well efficiency
- Sustainable pumping rates

- Relatively inexpensive
- Stress larger area relative to other field tests

How are pump test estimates applied for Mining

Used for many stages of mining, from pre-feasibility to closure

Pre-feasibility & feasibility

Characterise aquifers to support resource evaluation and mine planning

Pit dewatering & water management

Predict groundwater **inflows** and **discharges**, estimate **dewatering capacity**

Tailings storage facilities

Inform **seepage**, **TSF water** management

Water supply for processing

Locate and **size** production wells

Environmental impact assessment

Predict drawdown and assess impacts on surrounding receptors

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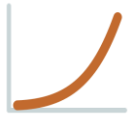
Conventional Pump Test Analysis

Water is pumped from a well at controlled rates, and drawdown is measured over time to infer aquifer and well properties.



Linear response – Aquifer properties

Transmissivity (T) & Storativity (S)



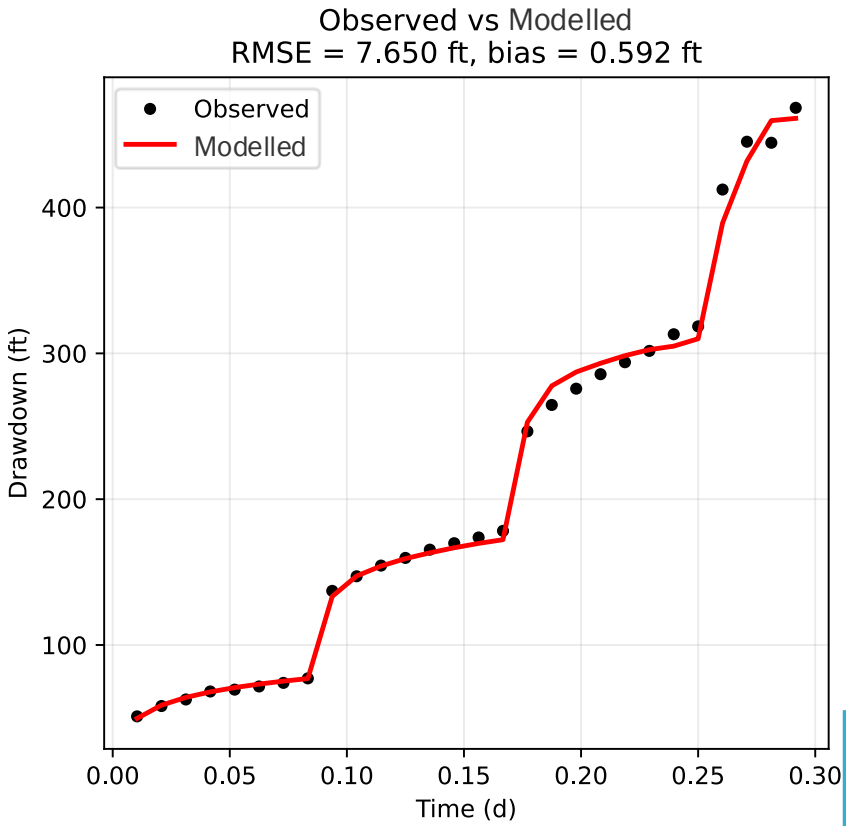
Non-linear response – Well performance

Well-loss terms (C, p), with p typically > 2

$$Drawdown, s(t) = B(t) \star Q(t) + C Q^{p}(t)$$

$$B(t) = \frac{1}{4\pi T}\frac{d}{dt}W(u) \quad | \quad u = r^2 S/(4Tt)$$

Theis (1935), Rorabaugh (1953)



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Conventional Pump-Test Interpretation

- Providing single best-fit value for each key parameter.

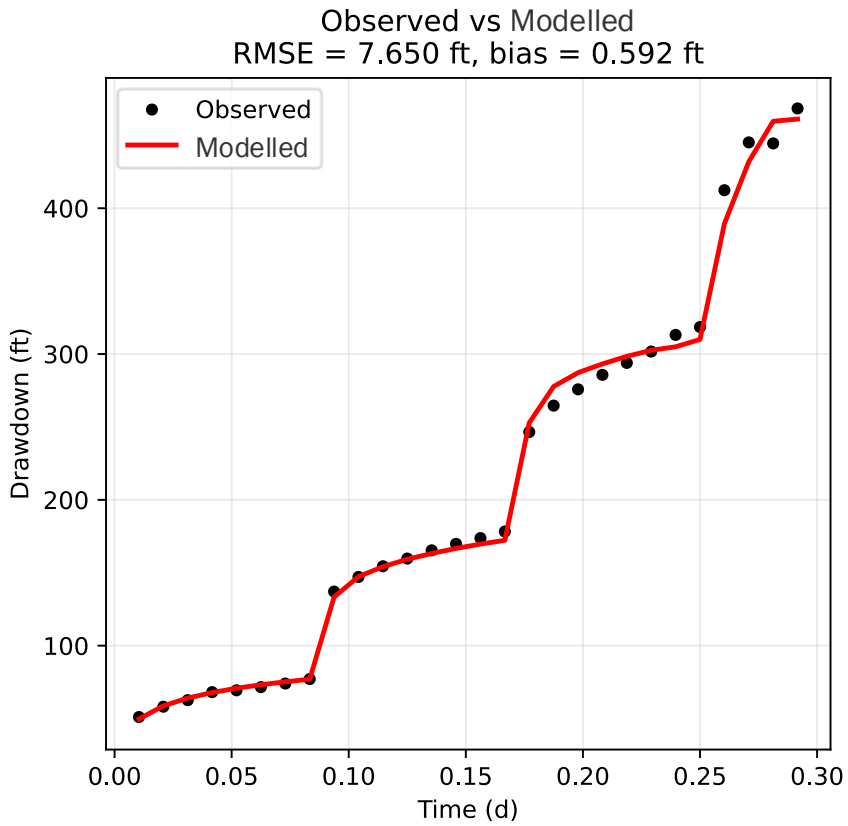
One “best-fit” value per parameter

T — **Transmissivity**
how readily the aquifer transmits water

S — **Storativity**
water released per unit drop in head

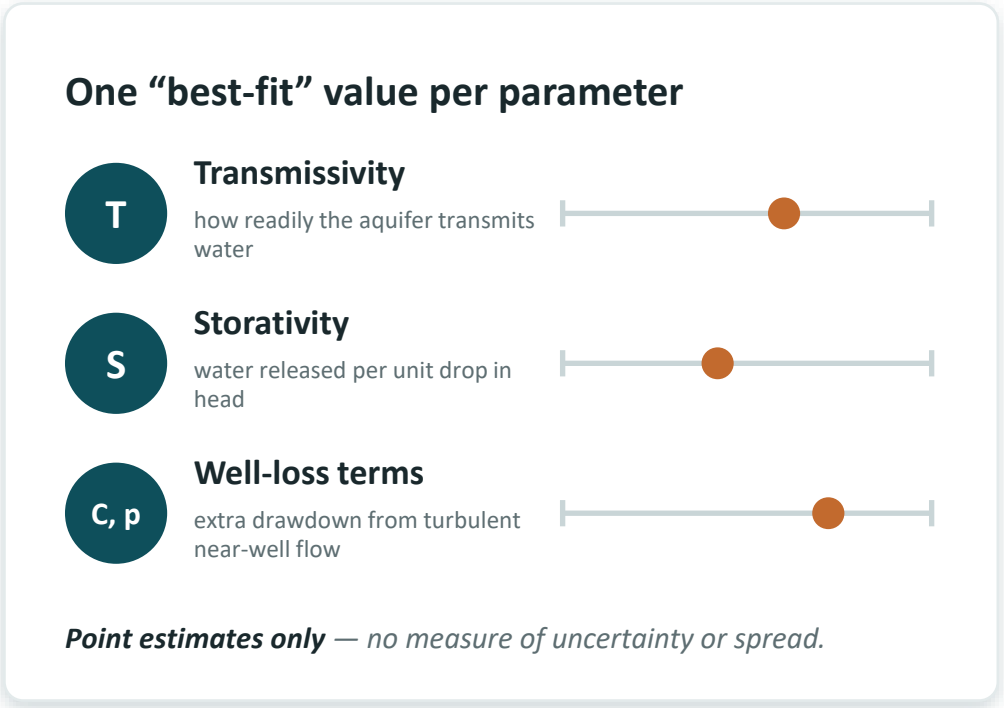
C, p — **Well-loss terms**
extra drawdown from turbulent near-well flow

Point estimates only *— no measure of uncertainty or correlation.*



Sources of Uncertainty in Pump Test Analysis

- Observation uncertainty, signal to noise ratio at late times
- Structural uncertainty, i.e., analytical model assumptions, including homogeneity, infinite domain, well fully-penetrating aquifer
- Parameter uncertainty – the main source of uncertainty addressed in this approach.

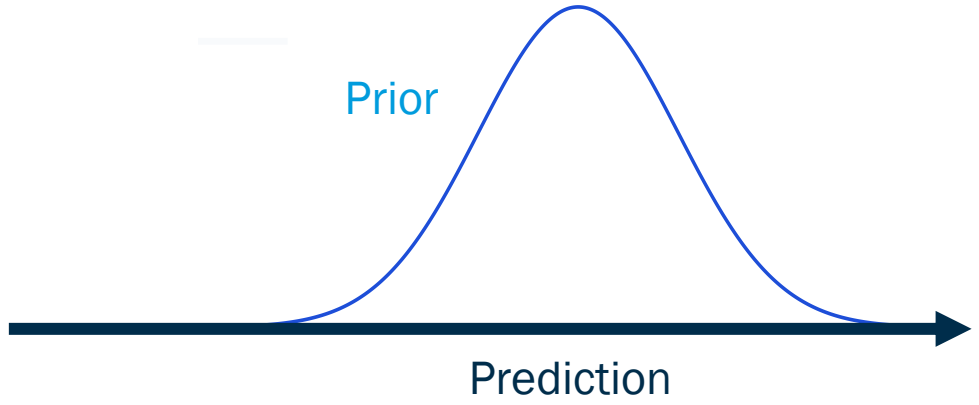


No uncertainty = no understanding of reliability

Uncertainty Analysis - Bayesian Framework

$$\underbrace{P(\theta)}_{\text{what we knew}} \quad \underbrace{\mathcal{L}(\theta|\mathbf{d})}_{\text{what we learned}} \propto \underbrace{P(\theta|\mathbf{d})}_{\text{what we know now}}$$

Mathematical formula that combines prior parameter knowledge with observed data to produce an updated probability distribution of parameter values.

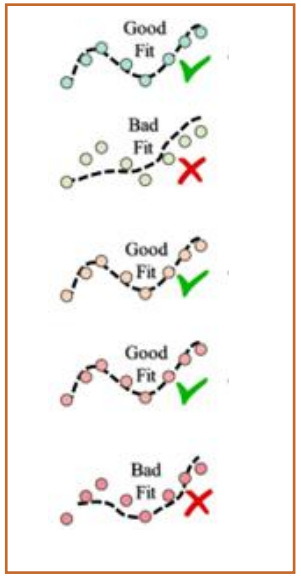


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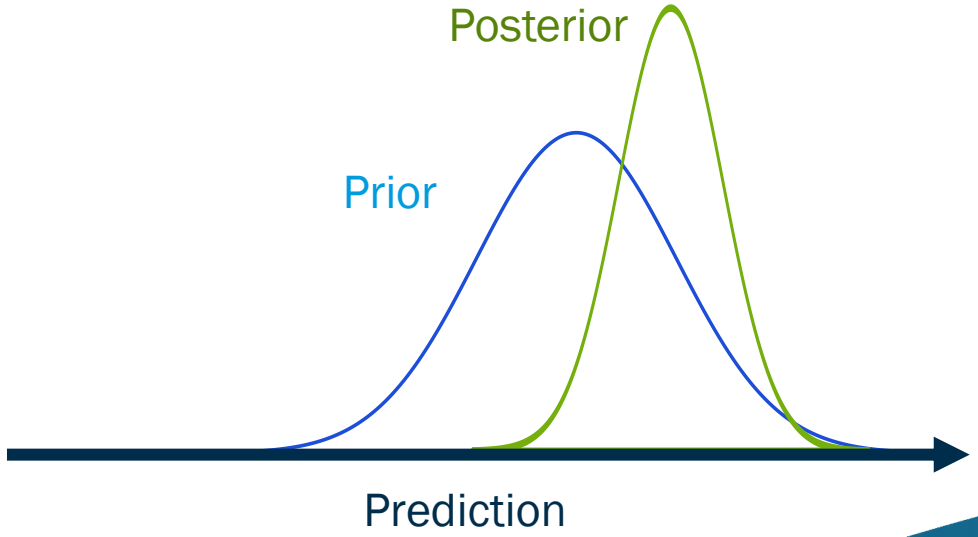
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Observed Data



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Uncertainty Analysis - Bayesian Framework

Updating prior knowledge with pumping test observations

Prior

p(M)
Expert knowledge
or broad ranges
of T, S, C, p

Pumping Test Data

Observed drawdown
from pump test

Posterior

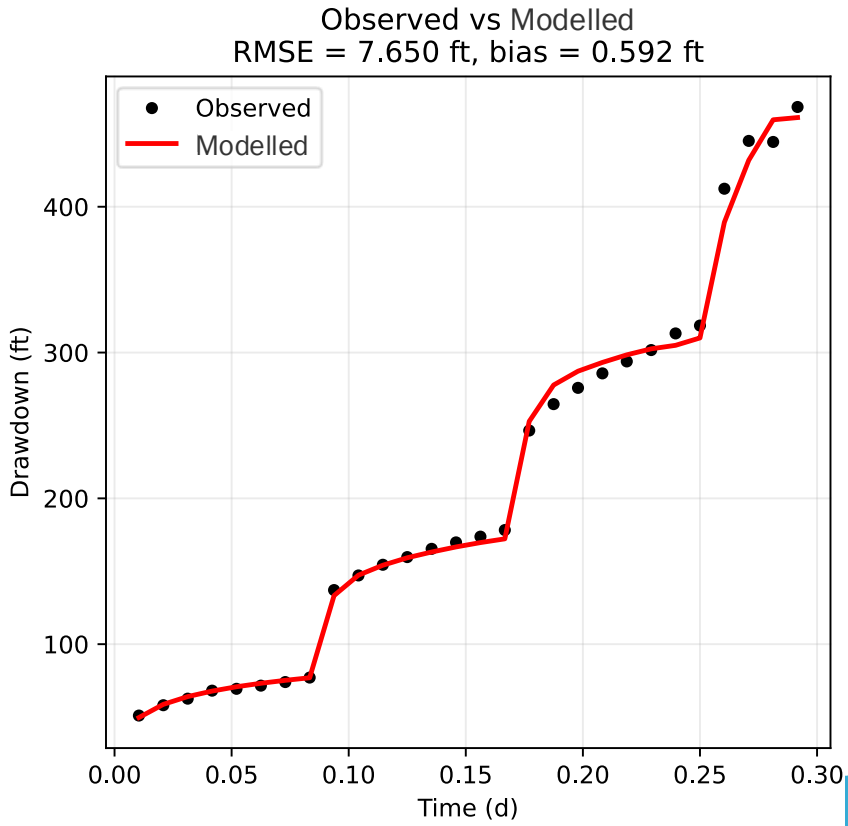
p(M|D)
Full probability
distribution of
all parameters

$$\underbrace{P(\theta)}_{\text{what we knew}} \qquad \underbrace{\mathcal{L}(\theta|\mathbf{d})}_{\text{what we learned}} \qquad \underbrace{P(\theta|\mathbf{d})}_{\text{what we know now}}$$

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Uncertainty Analysis

- Built prior distribution from expert knowledge

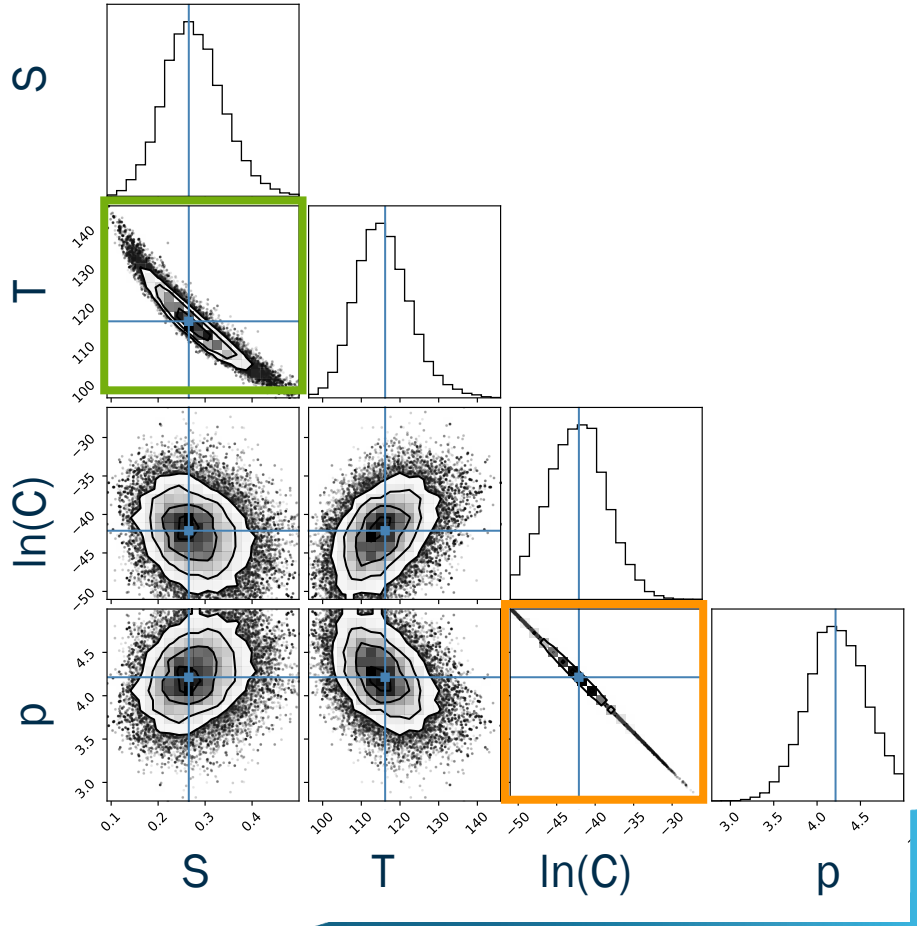


Uncertainty Analysis Results – Non-Uniqueness Problem

Pump test posterior parameter distribution

- S and T
  - negatively correlated, non-Gaussian
- Non-linear well loss parameters
  - negatively correlated

- Many parameter combinations fit the data equally well.

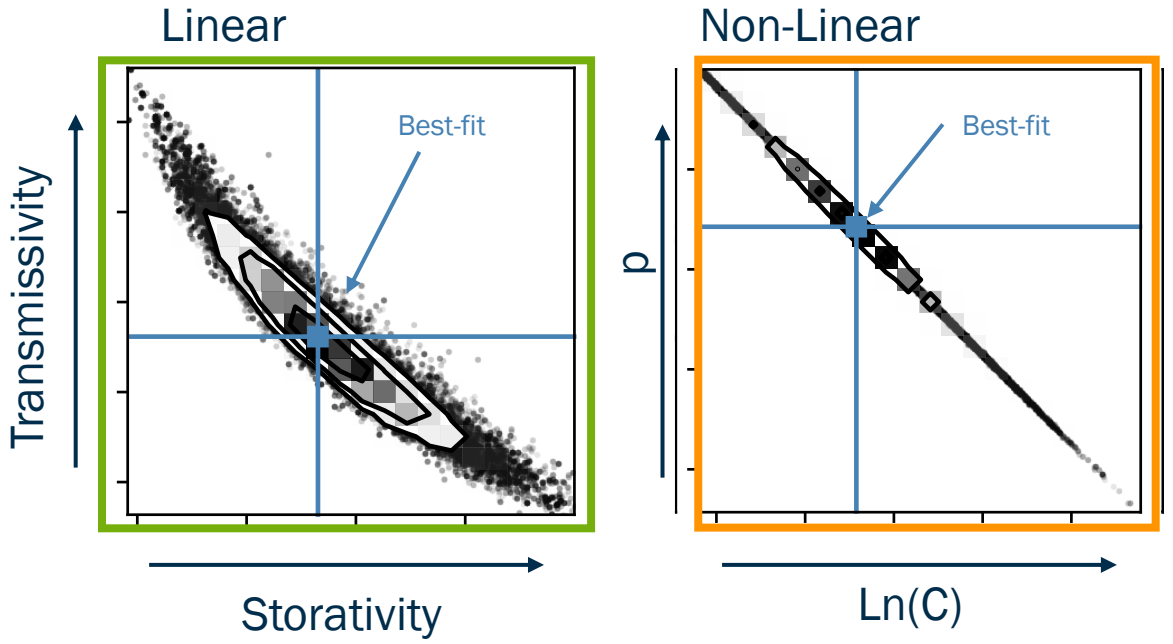


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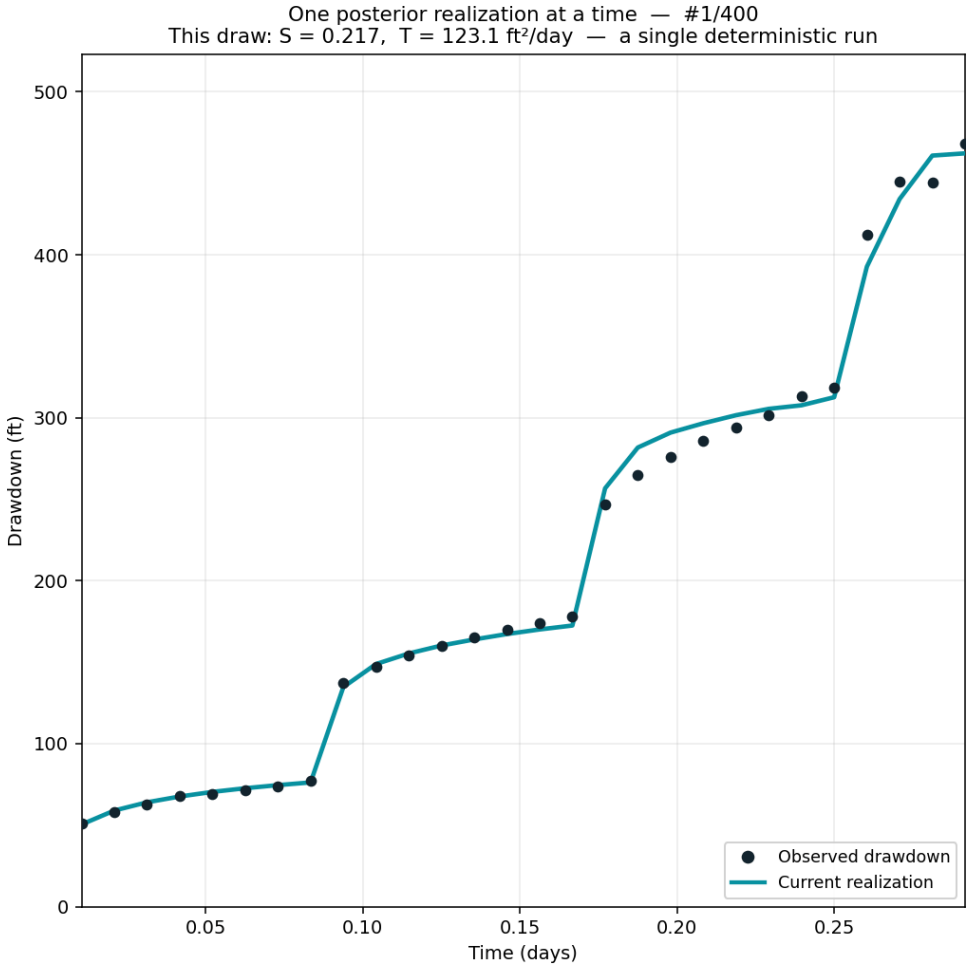


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Now we have uncertainty, we can estimate how reliable our predictions are



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Dewatering/Cost Tool

Example to demonstrate the potential usefulness of this approach

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Dewatering/Cost Tool

Example to demonstrate the potential usefulness of this approach

Question 1: What are the projected costs associated with annual dewatering?

Question 2: What is the probability of meeting dewatering demands at a certain price threshold?

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Dewatering/Cost Tool

Method:

1. Single well step drawdown test performed

2. Determine “best-fit” parameters, T, S, and non-linear well loss

3. UA performed to estimate posterior distributions of T, S, and non-linear well loss parameters

4. For 400 parameter realisations, a forward run was performed to estimate annual operating costs across a range of pumping rates
   a. Links drawdown to operating costs:
   Drawdown → total dynamic head → power → operating costs

Parameter Uncertainty to Financial Uncertainty

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Dewatering/Cost Tool

Total dynamic head

$TDH = d^W + s(t) + h^i$

h^i = pipe friction (Hazen-Williams, $\propto Q^{1.85}$)

Power (kW)

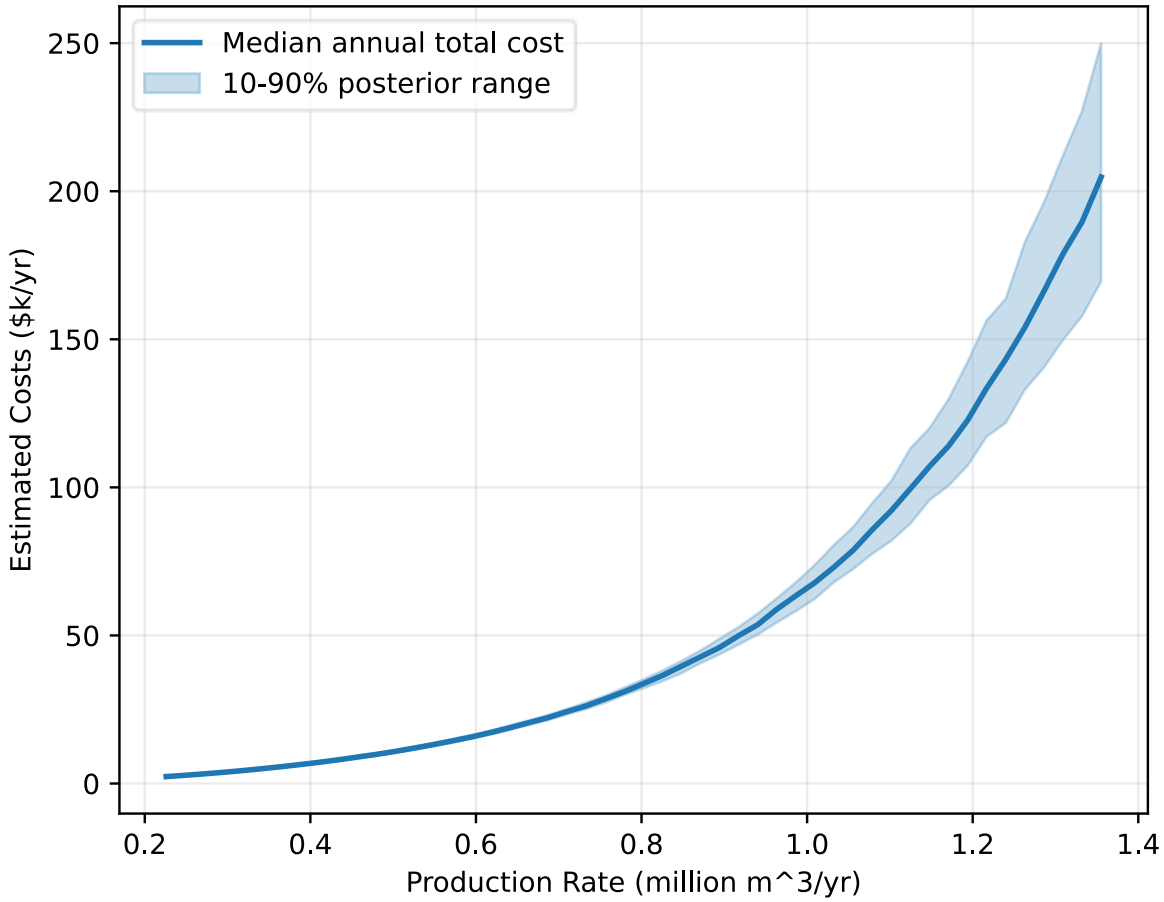
$kW = Q \cdot TDH / E_p \cdot (units)$

Pump efficiency E_p = 0.75 assumed

Annual cost

$Cost = kW \times hrs \times 0.10\$/kWh$

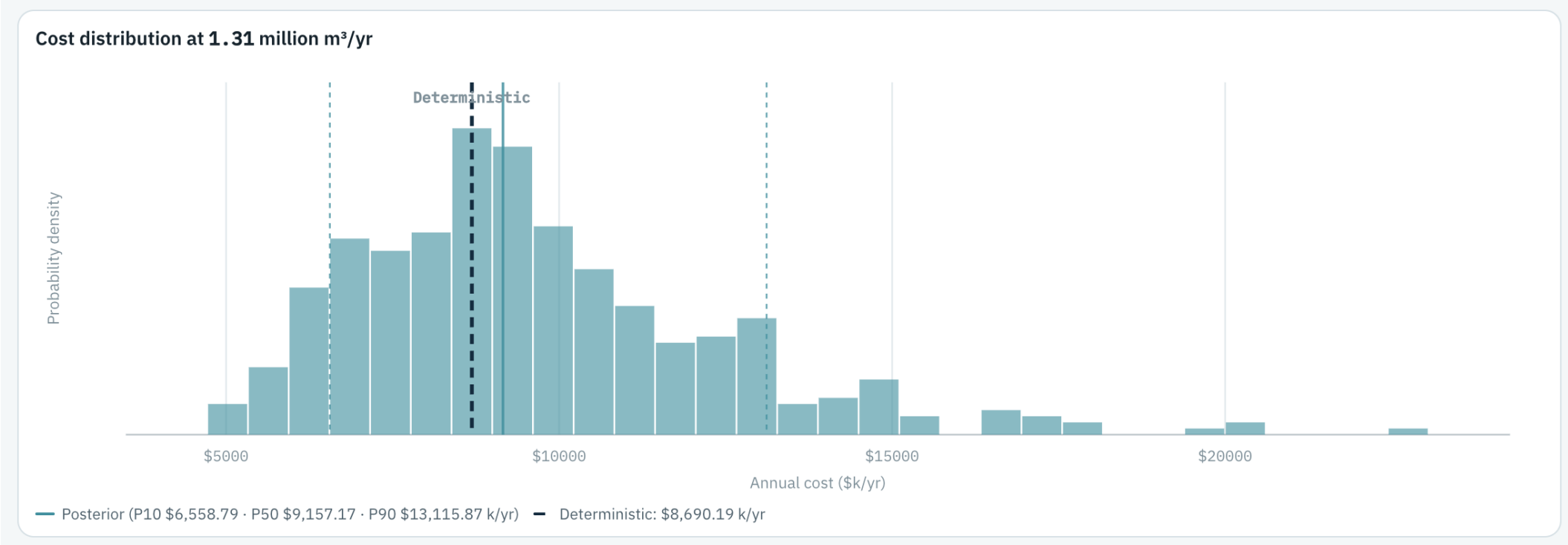
Operating cost only; no capital costs



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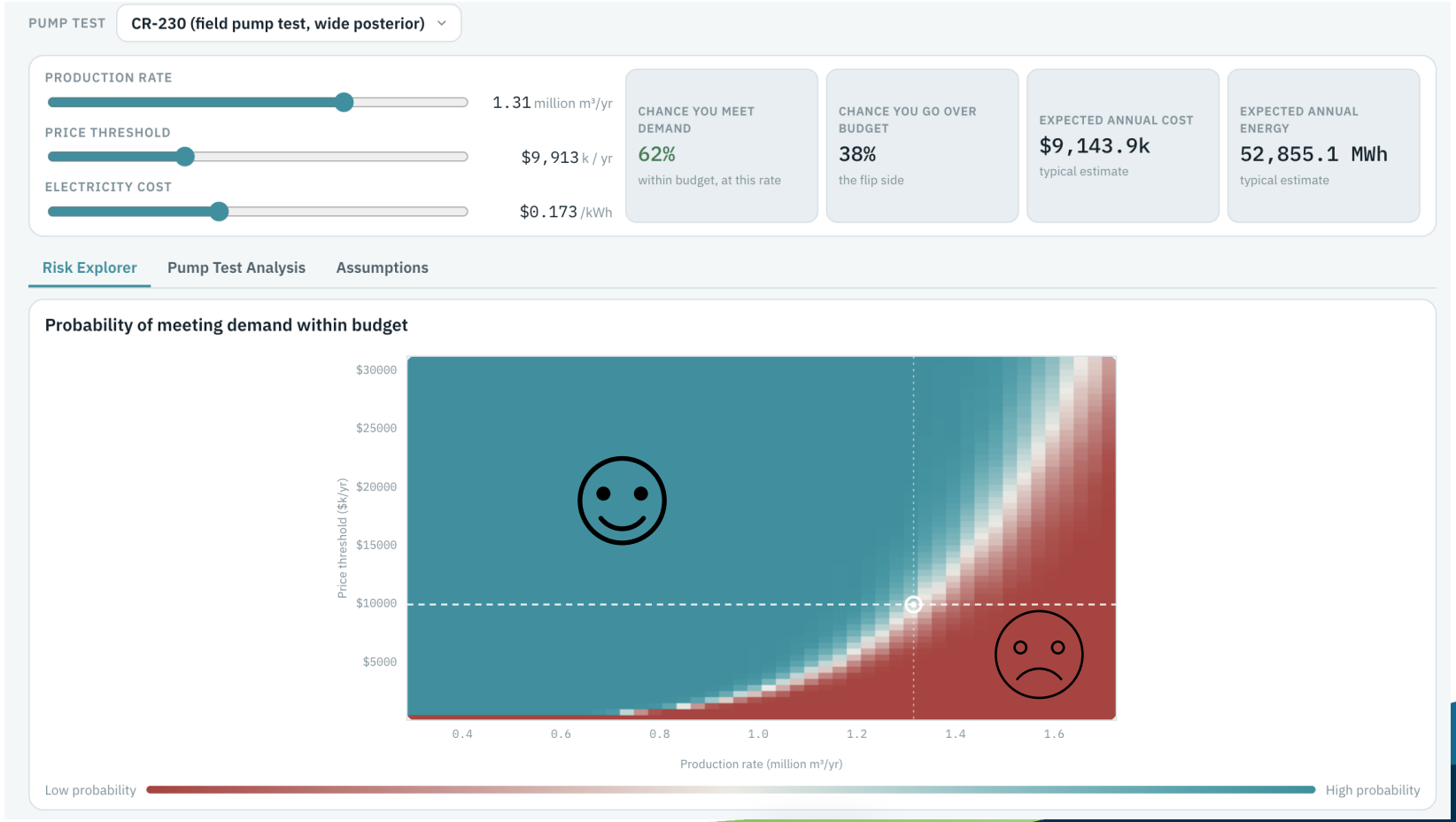
Mine Dewatering Example

Question 1: What are the projected costs associated with annual dewatering?



Mine Dewatering Example

Question 2: What is the probability of meeting dewatering demands at a certain price threshold?



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Dewatering Risk Console

Dewatering Risk Console

One pump test, honestly costed: the probability you meet demand within budget — not just a single best guess.

PROOF OF CONCEPT

PUMP TEST: CR-226 (synthetic teaching example)

PRODUCTION RATE: 1.03 million m³/yr

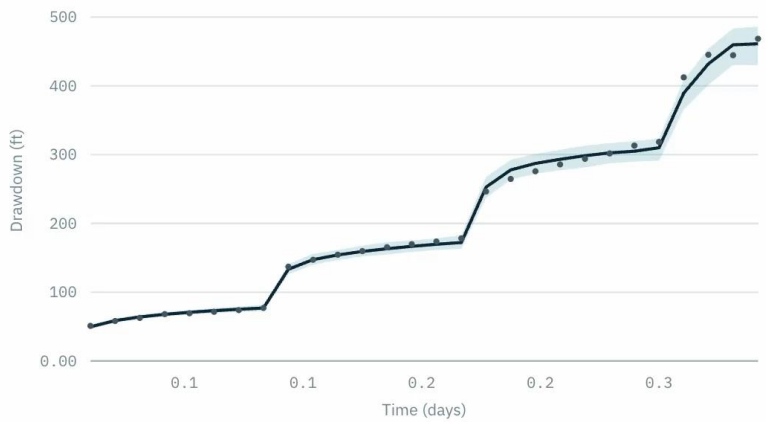
PRICE THRESHOLD: $107 k / yr

ELECTRICITY COST: $0.100 /kWh

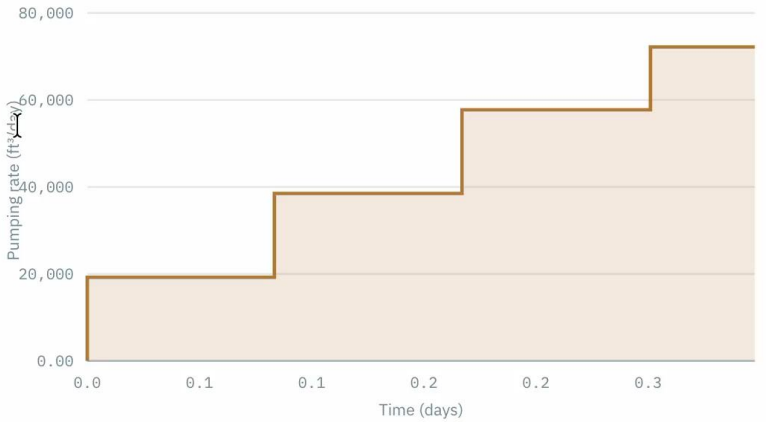
CHANCE YOU MEET DEMAND	CHANCE YOU GO OVER BUDGET	EXPECTED ANNUAL COST	EXPECTED ANNUAL ENERGY
100%	0%	$73.1k	730.9 MWh
within budget, at this rate	the flip side	typical estimate	typical estimate

Risk Explorer | Pump Test Analysis | Assumptions

Observed drawdown vs. time



Pumping rate vs. time



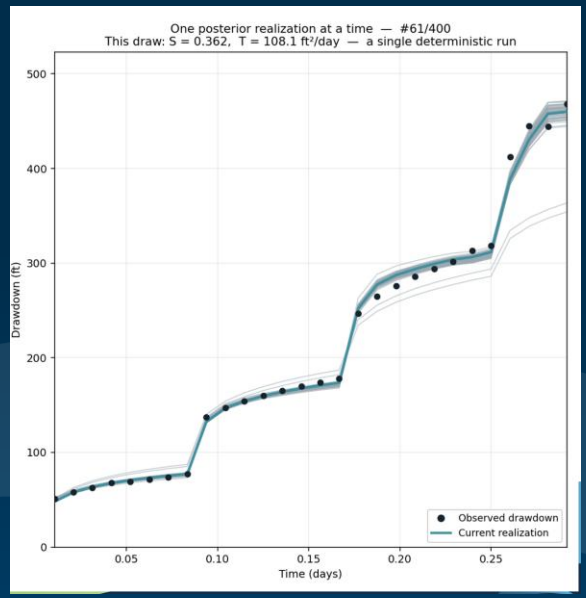
Posterior parameter distributions

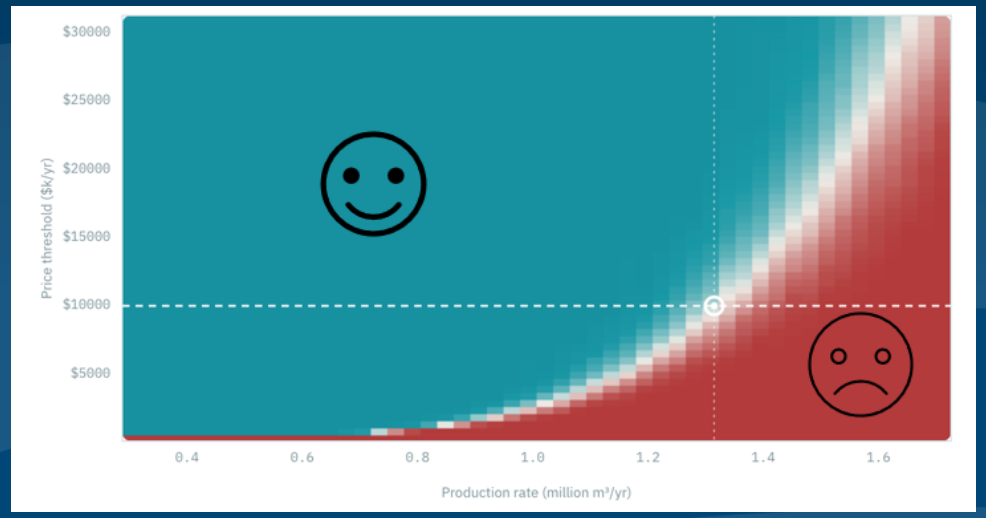
Storativity, S | Transmissivity, T (ft²/day) | Well-loss coefficient, ln(C) | Well-loss exponent, p

Simple models

↳Informed understanding

↳Smarter decisions





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