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Performance-Based Management of Pump-and-Treat Remedies

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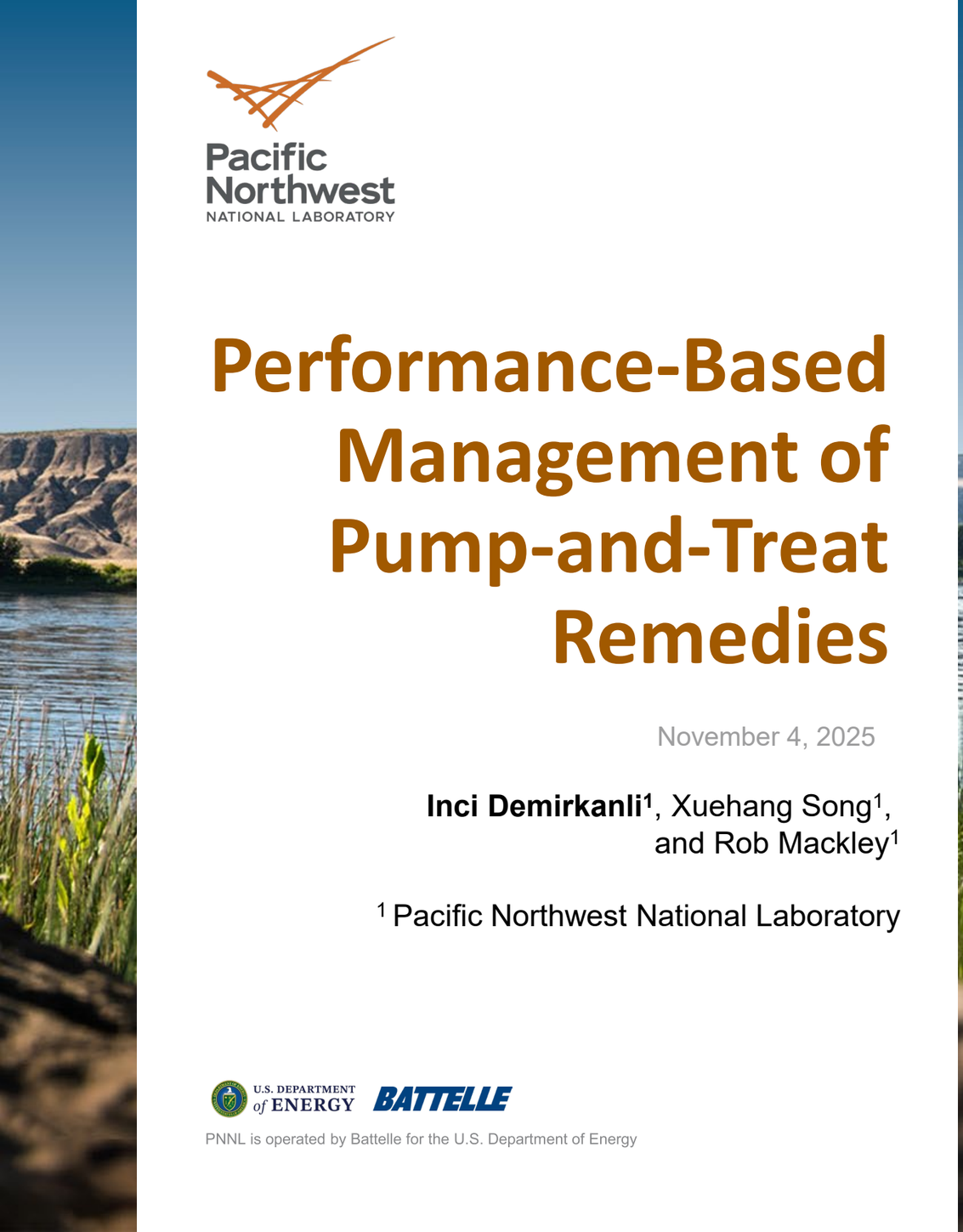
[1] Pacific Northwest National Laboratory



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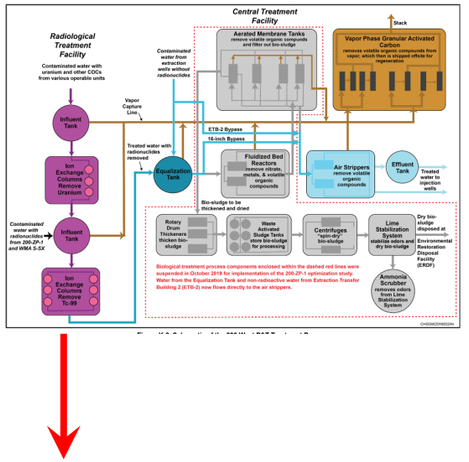
Pump-and-Treat (P&T) Systems

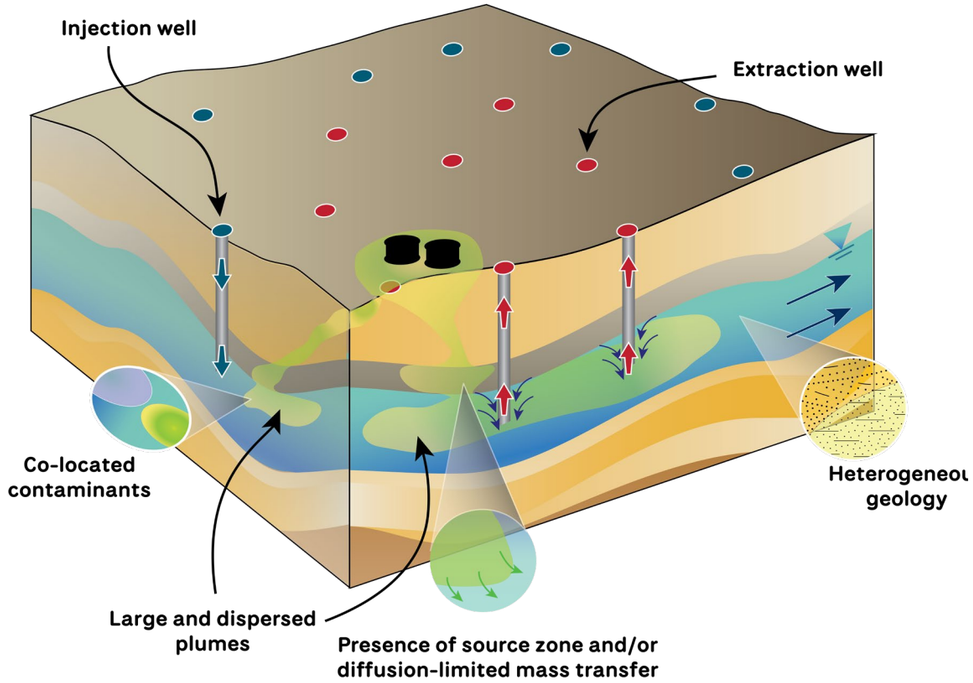


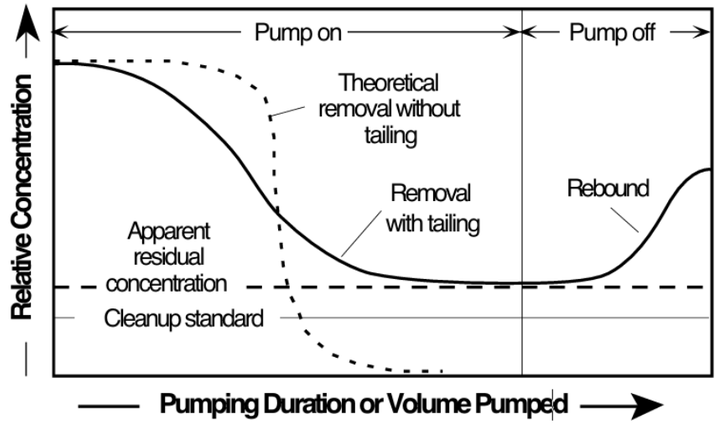
- Pump-and-treat (P&T) systems have been used for
  - Hydraulic containment;
  - Source control; and/or
  - Removal and treatment of contaminated groundwater
- The system includes:
  - A well network for groundwater extraction
  - Above-ground ex-situ treatment unit
  - Disposal system for the treated water

Pump-and-treat extraction well (adapted from PNNL-24741)

P&T Performance & Lifecycle

- Initial designs typically address large-scale containment and bulk treatment, and may not be an optimal design for mass removal and long-term effectiveness
  - Early goals focus on volumetric pumping
- Performance diminishes due to factors such as:
  - Heterogeneity
  - Large and dispersed plumes requiring multiple pore volume flushes
  - Presence of source zone and/or diffusion-limited mass transfer
  - Recalcitrant/competing contaminants





USEPA. 1994. "Methods for Monitoring Pump-and-Treat Performance."

Performance-Based P&T Optimization

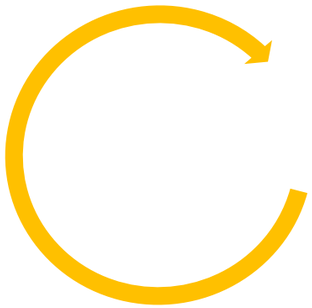
Performance-based management of P&T systems applies adaptive, data-driven optimization to improve long-term remedy effectiveness and cost-efficiency.

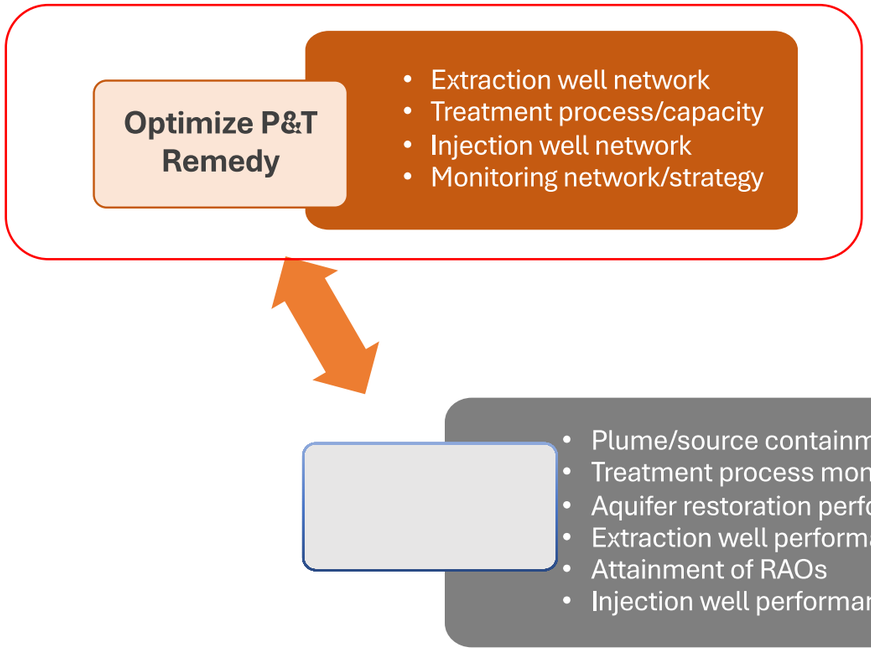
Initial Remedy Objectives:

- Address immediate risks
- Achieve hydraulic containment and volumetric extraction goals

Later Remedy Objectives:

- Iteratively optimize the remedy to improve or maintain effective contaminant mass removal and/or containment
- Continuously evaluate the lifetime of the remedy





CSM = Conceptual Site Model
RAO = Remedial Action Objective
MNA = Monitored Natural Attenuation

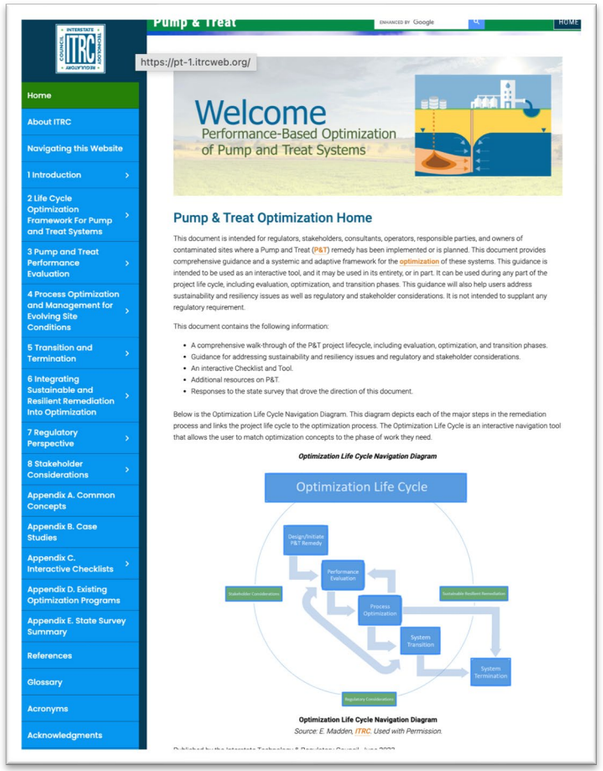
Performance-Based Remedy Optimization Actions

- Optimization involves identifying and implementing actions at any stage of a removal or remedial response to improve remedy effectiveness and cost-efficiency.[1]
- For P&T remedies, optimization aims to:
  - Reduce overall costs through more efficient treatment and pumping operations
  - Accelerate cleanup progress and shorten the duration of active pumping
- Common optimization actions include:
  - Treatment process optimization: enhancing treatment effectiveness, reliability, or throughput
  - Contaminant mass recovery optimization: improving extraction efficiency and reducing rebound potential:
    - ✓ Dynamic well network management: adjusting well operation schedules or configurations to sustain hydraulic containment and maximize contaminant removal
    - ✓ Total P&T capacity adjustments: aligning with current plume conditions, contaminant loading, and cleanup objectives

[1] USEPA. 2012. "National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion."

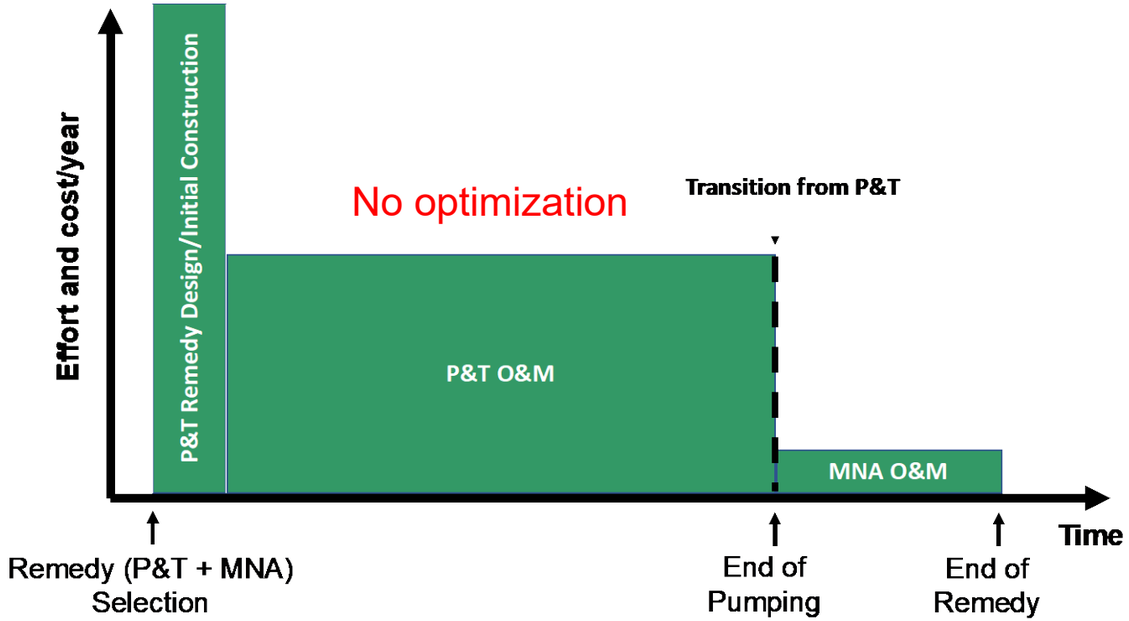
ITRC Guidance

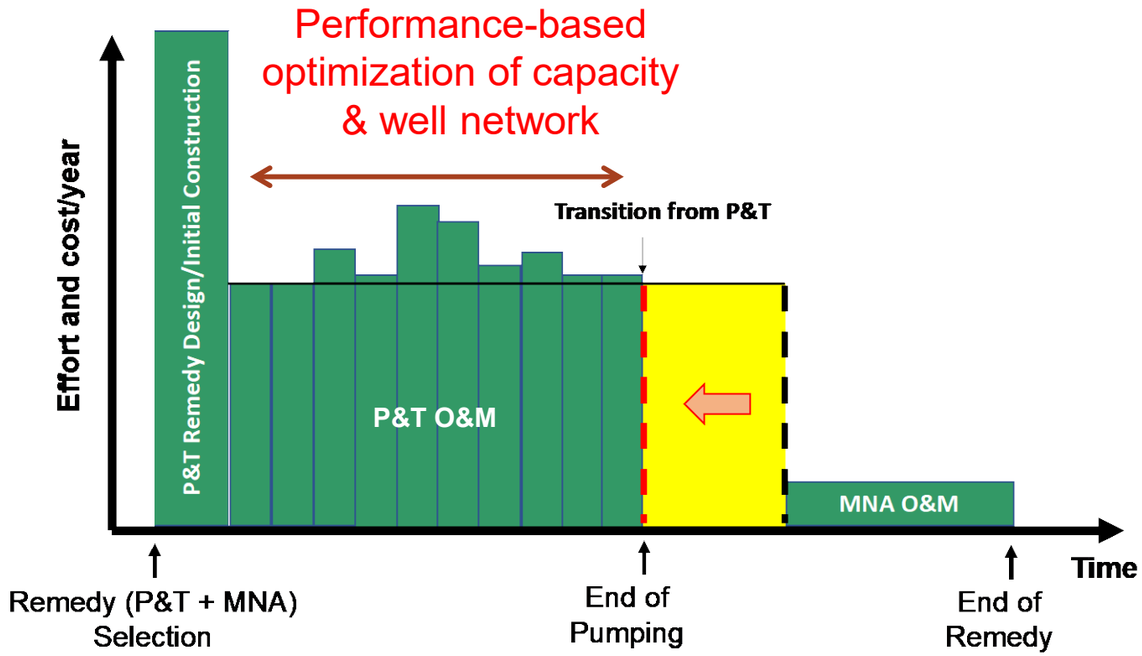
- Interstate Technology Regulatory Council (ITRC)
- New performance-based P&T optimization guidance published in 2023



Adopted from the guidance

https://pt-1.itrcweb.org/





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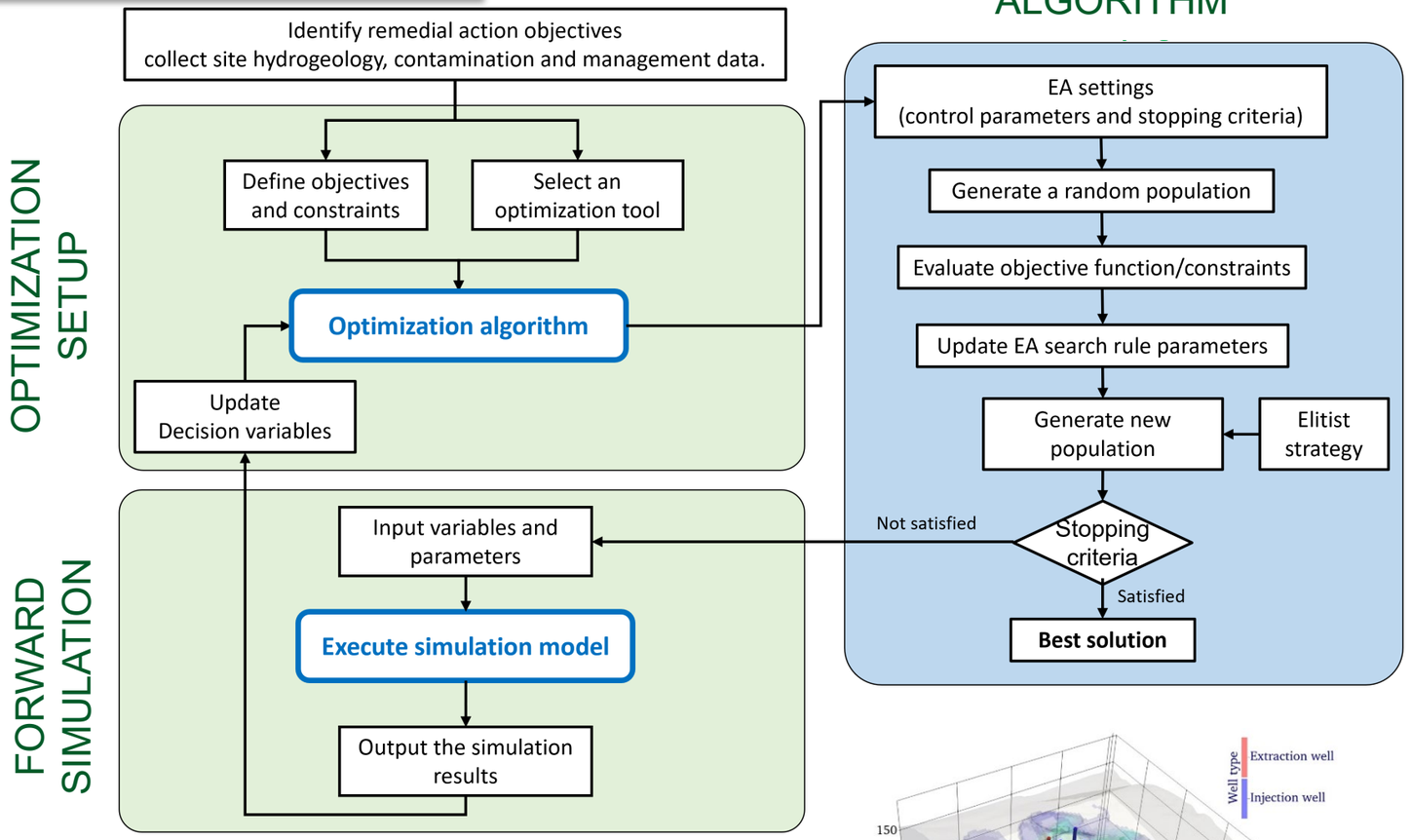
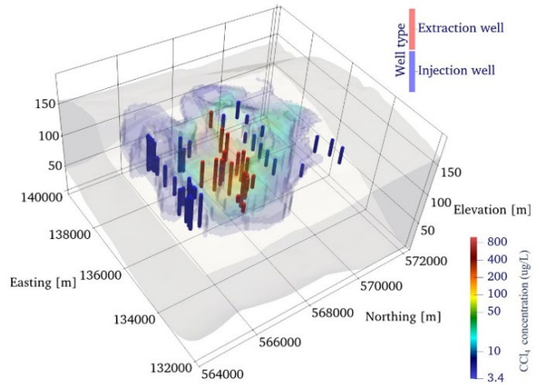
Computational P&T Remedy Optimization

- Requires a coupled Simulation-Optimization framework
  - **Forward simulation** – evaluating contaminant fate and transport under varying pumping and capacity regimes
  - **Evolutionary algorithm** – adjusting extraction-injection well locations, pumping rates, until convergence criteria are met
  - **Optimization setup** – selecting optimization goals and scenario inputs

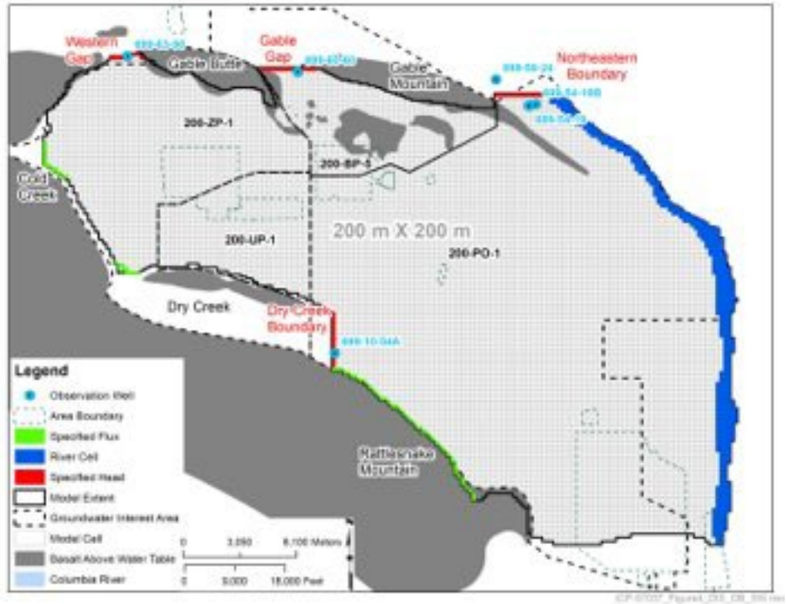
Define:
- Optimization goal (e.g., mass recovery, pumping timeframe minimization, etc.)
- Constraints
  - Treatment capacity
  - Well installation rules

Define:
- Rules for accelerating initial realizations or convergence





Summary/Next Discussions



- P&T optimization evaluations are critical for:
  - Adapting to evolving site conditions
  - Maintaining long-term effectiveness
  - Maximizing cost-efficiency
  - Driving end-state decisions
- Optimization evaluations include:
  - Treatment process assessments and modifications
  - Total capacity impacts
  - Well network adjustment needs
- Forward simulation models (e.g. Plateau-to-River [P2R] and optimization frameworks (e.g., OPTIMA) require an integrated computational ecosystem composed of:
  - Forward simulations
  - Coupled optimization algorithms
  - Computationally intensive and would benefit from surrogate modeling

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