Hydrodynamic and Virtual Tracer Analysis of Richland-Chambers Reservoir

Using 2D CE-QUAL-W2 and 3D AEM3D Models for Water Supply Management

PLUMMER

Nabin Basnet, P.E.

water Quality Solutions

Kareem Hannoun, Ph.D.

trwd Tarrant Regional Water District

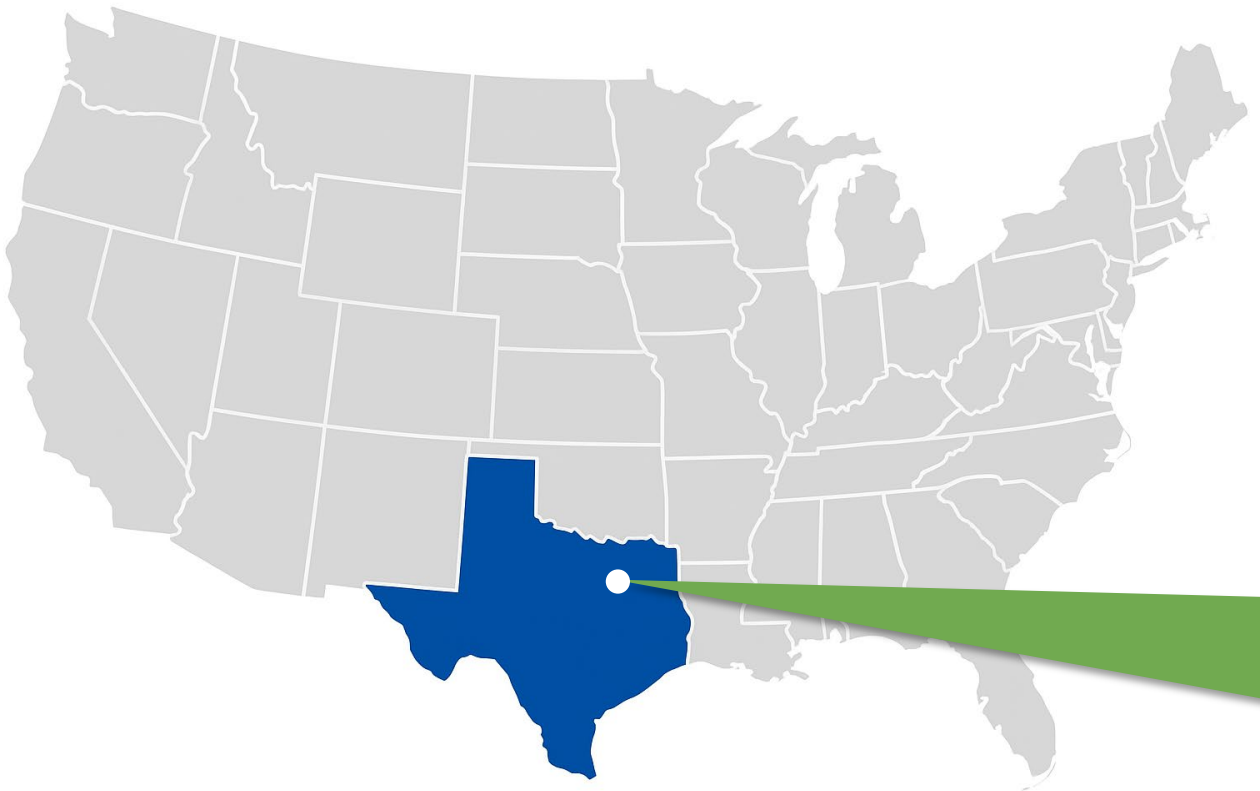
Mark Ernst

NALMS 2025 Myrtle Beach

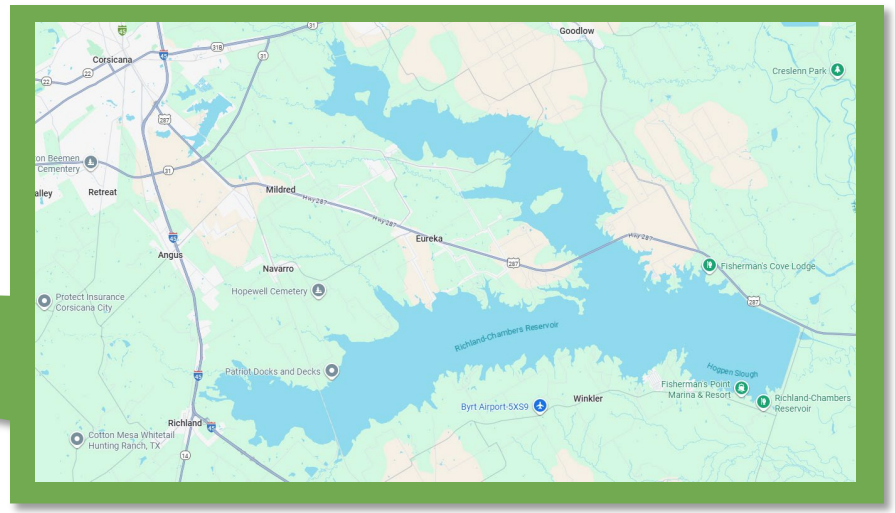
November 4-7, 2025

Richland-Chambers (RC) Reservoir Overview

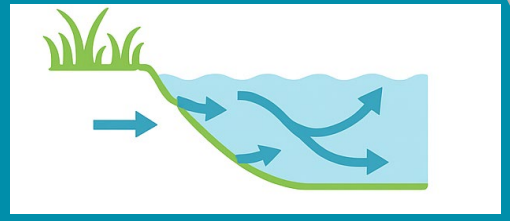
70 Miles South of Dallas, Texas



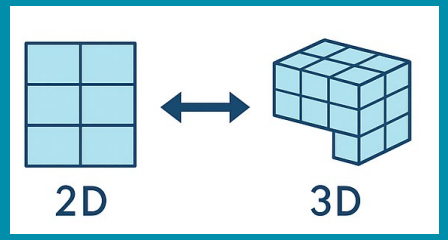
- Third-largest inland reservoir in Texas: 45,000 acres, serving over 2.3 million people.
- Managed by Tarrant Regional Water District (TRWD).
- Receives inflows from Chambers Creek, Richland Creek, and Shannon Wetlands.
- Study focuses on hydrodynamic and tracer modeling for pump station planning.



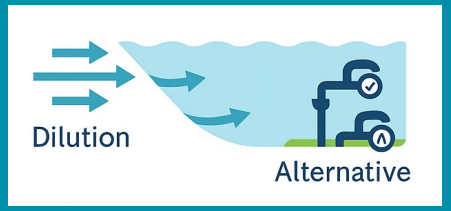
Study Objectives



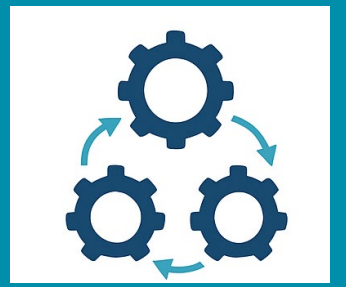
Mixing and transport of wetland inflows within RC Reservoir



Compare CE-QUAL-W2 (2D) and AEM3D (3D) model performance



Dilution and travel time to existing and alternative pump station locations



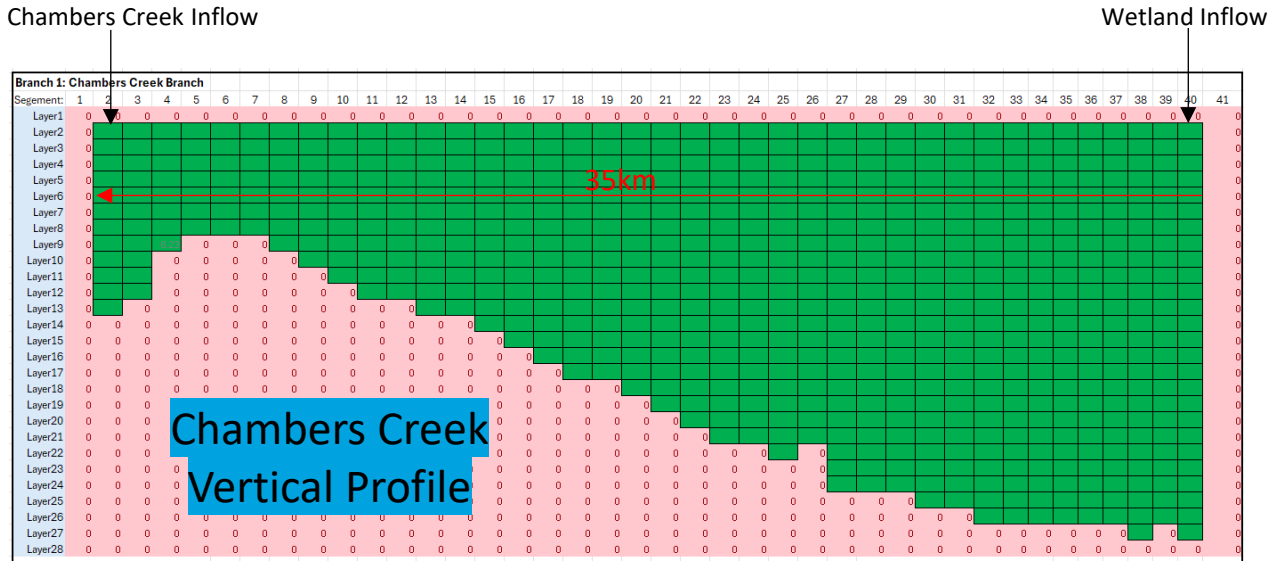
Framework for future reuse and water quality management studies

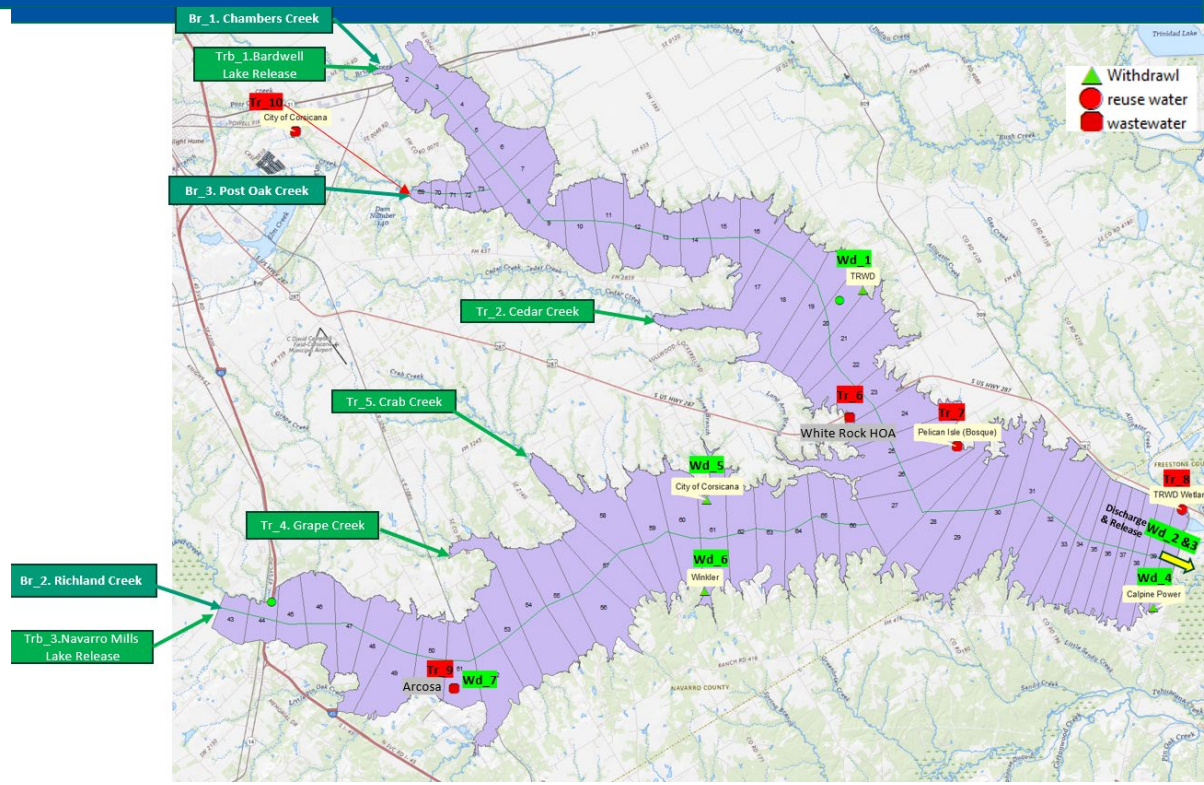
Modeling Approach

- Two complementary models developed:
  - CE-QUAL-W2 (Version 4.5):
    - 2D (Longitudinal-vertical) hydrodynamics
    - 1D laterally averaged
  - AEM3D (Version 535):
    - 3D hydrodynamics
- Both used same bathymetry, hydrologic, meteorological, and water quality datasets.

CE-QUAL-W2 Model Configuration

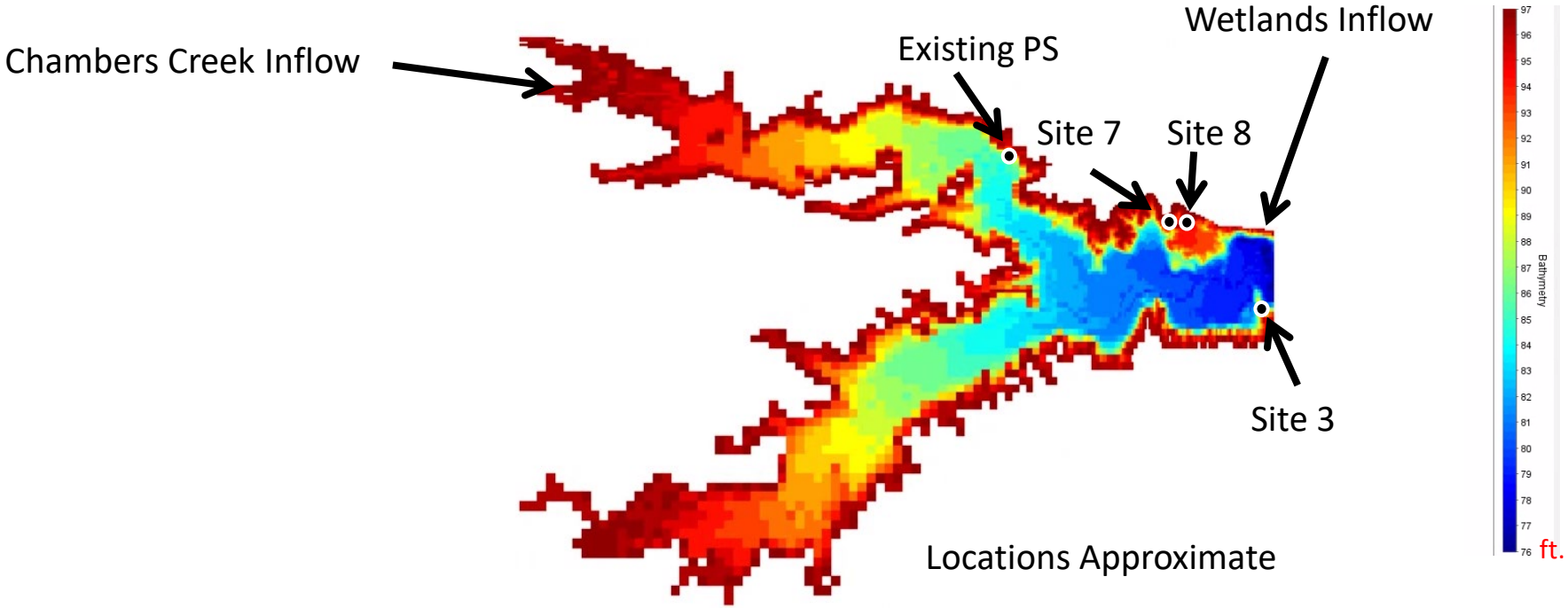
- Longitudinal Resolution: 500–1,000 m
- Vertical resolution: 1 m.
- Simulation period: 2011–2022
- Number of Branches: 3
- Number of Tributaries: 10
- Number of Withdrawals: 7





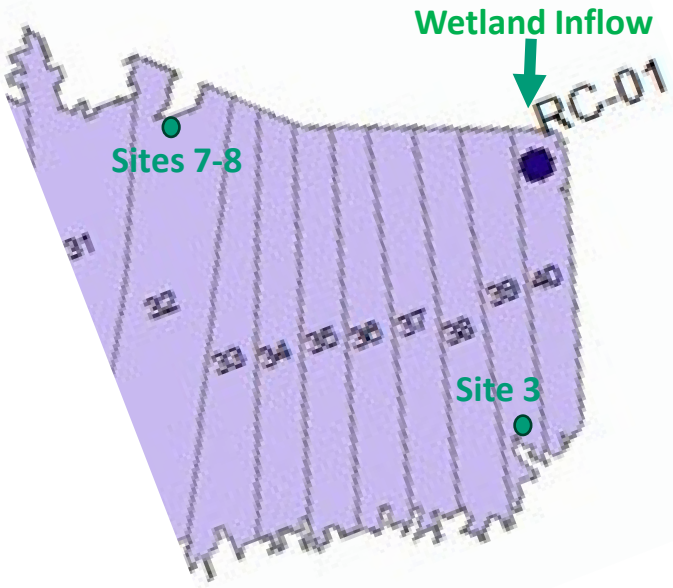
AEM3D Model Configuration

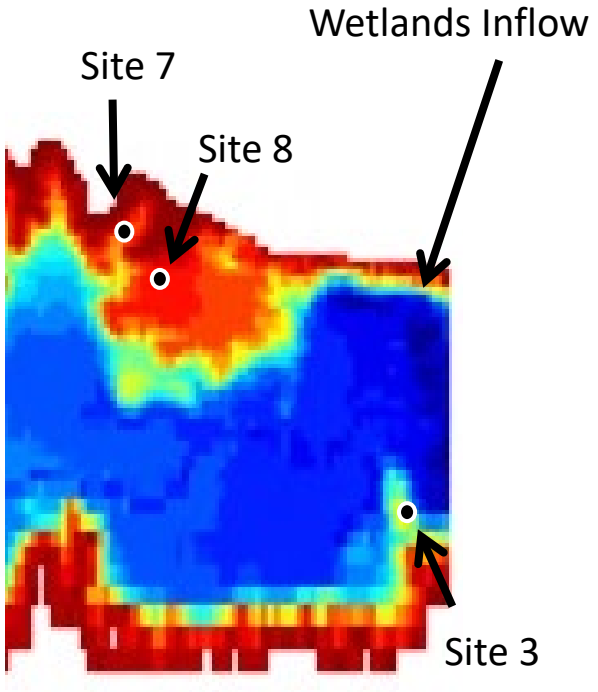
- Grid resolution: 100x100 m to 400x400 m horizontally, 1 m vertically.
- Refined grid near inflows and pump station sites (3, 7, 8).
- Simulation period: 2022-2023
- Boundary conditions and forcings consistent with CE-QUAL-W2.



2D vs 3D Model Grid Comparison

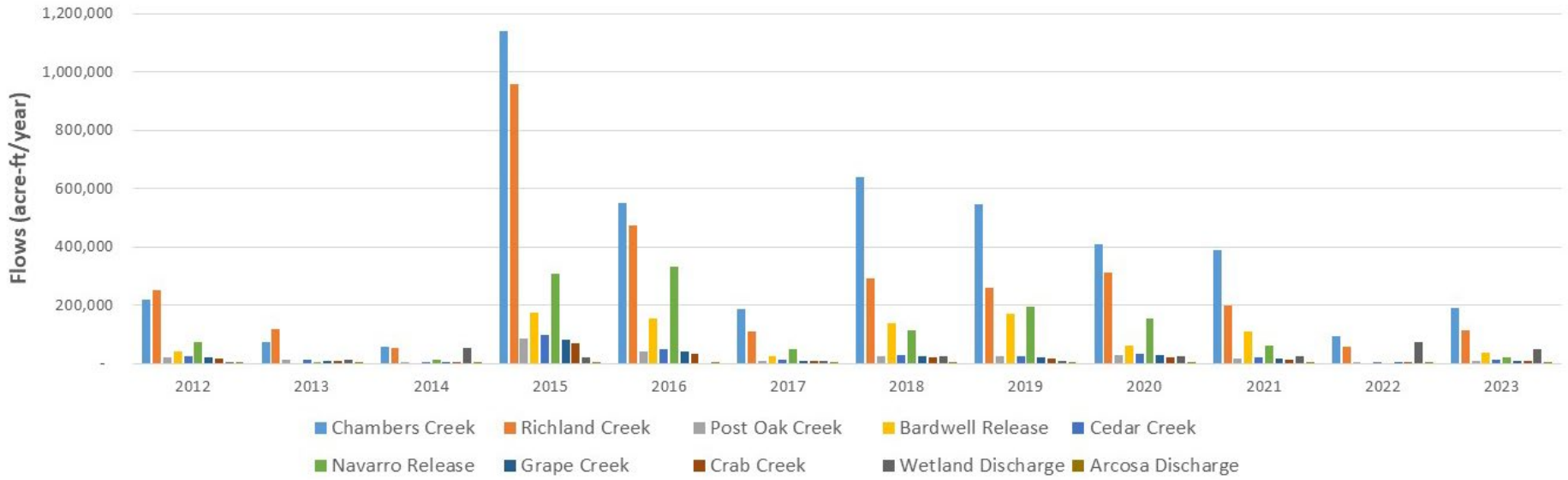
- 2D model contains inflow and Site 3 in adjacent horizontal segments
  - 3D model distance from inflow to Site 3 ~25 horizontal cells
- 3D model separates Sites 7 from 8 due to greater lateral resolution
- Both models resolve vertical distance between inflow and outflows (not shown)
  - 1 m vertical grid for both models

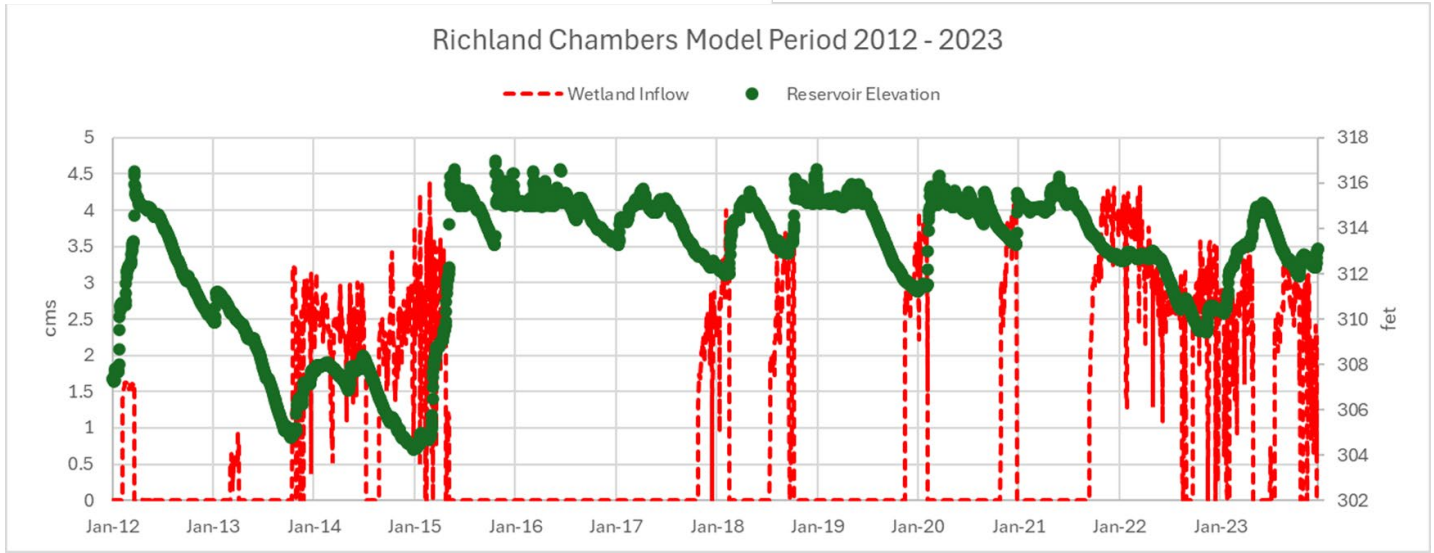




Locations Approximate
Each pixel represents a surface cell

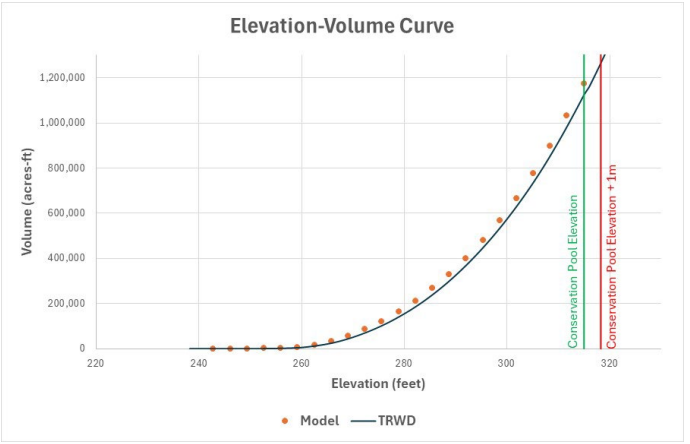
Reservoir Inflows

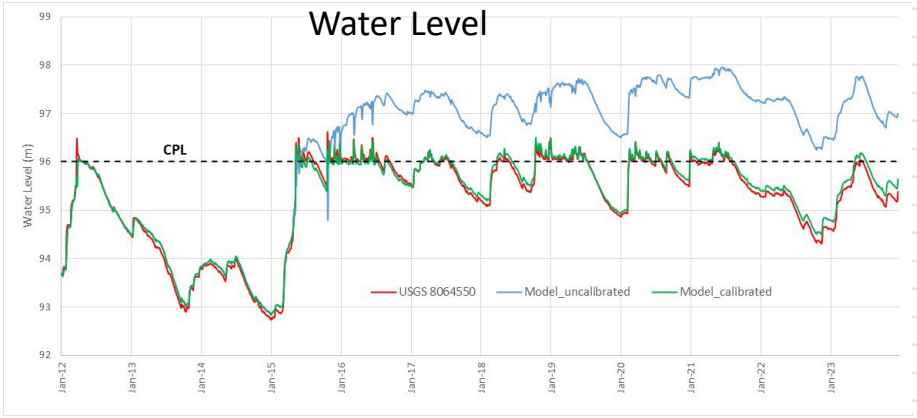


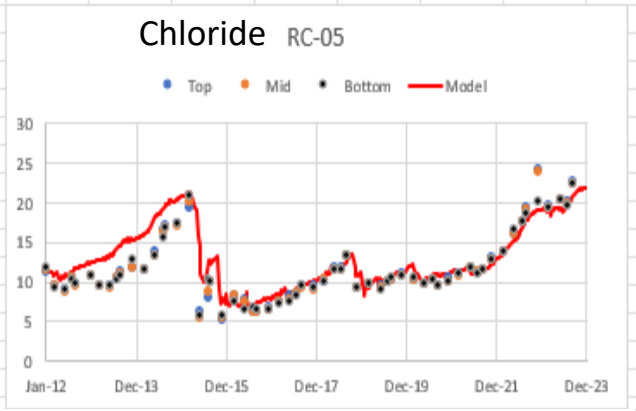


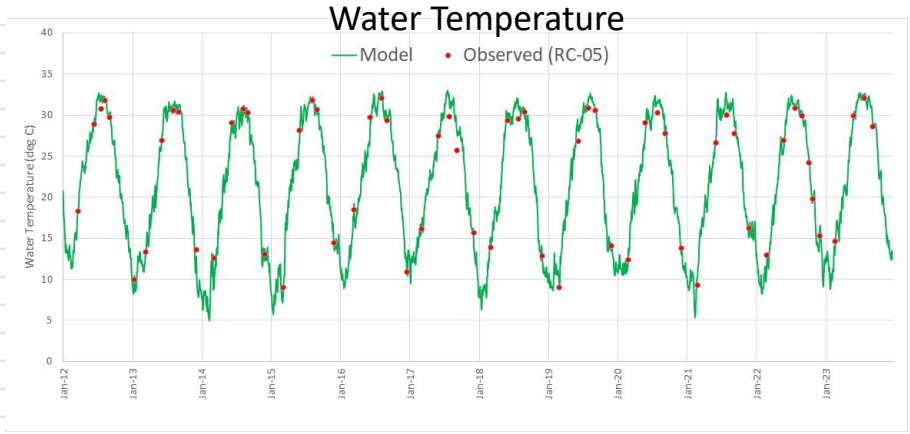
CE-QUAL-W2 Calibration

- MAE (Water Surface Elevation): 0.09 m.
- Temperature MAE: <1°C across 5 key stations.
- Chloride and conductivity within 15% error margin.
- Accurately captured thermocline depth and seasonal stratification.



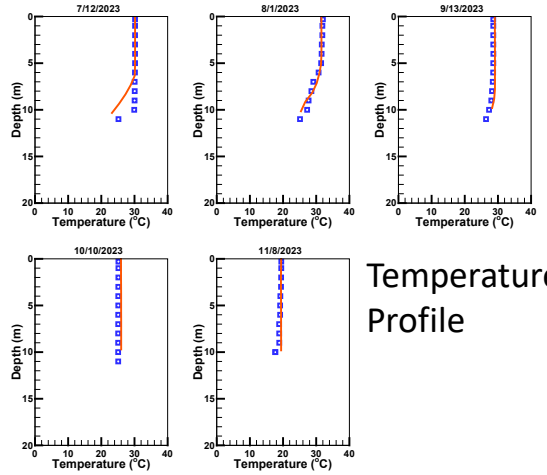






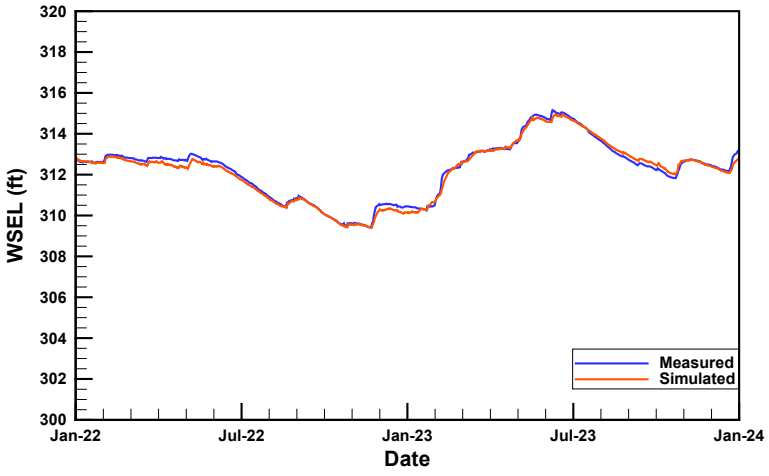
AEM3D Calibration

- MAE: <0.1 m (water level), <1°C (temperature).
- Chloride RAE: <20% across all stations.
- Captured stratification, lateral mixing, and circulation accurately.
- Validated against field data (2021–2023).

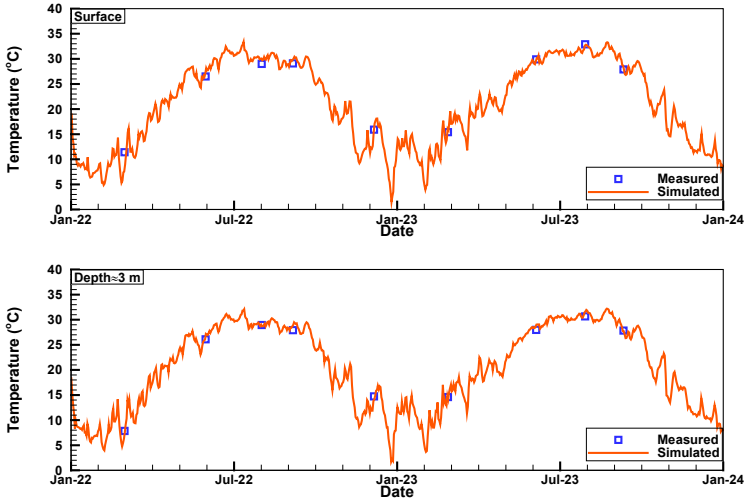


Temperature Profile

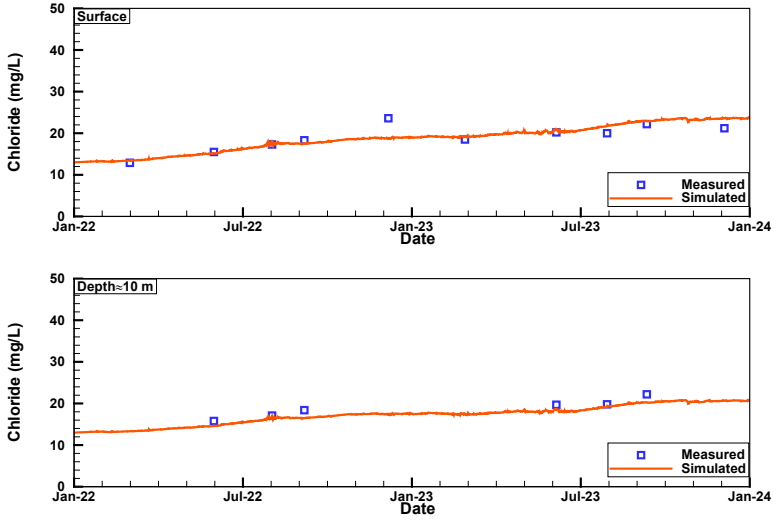
Water Level



Surface and Bottom Temperature

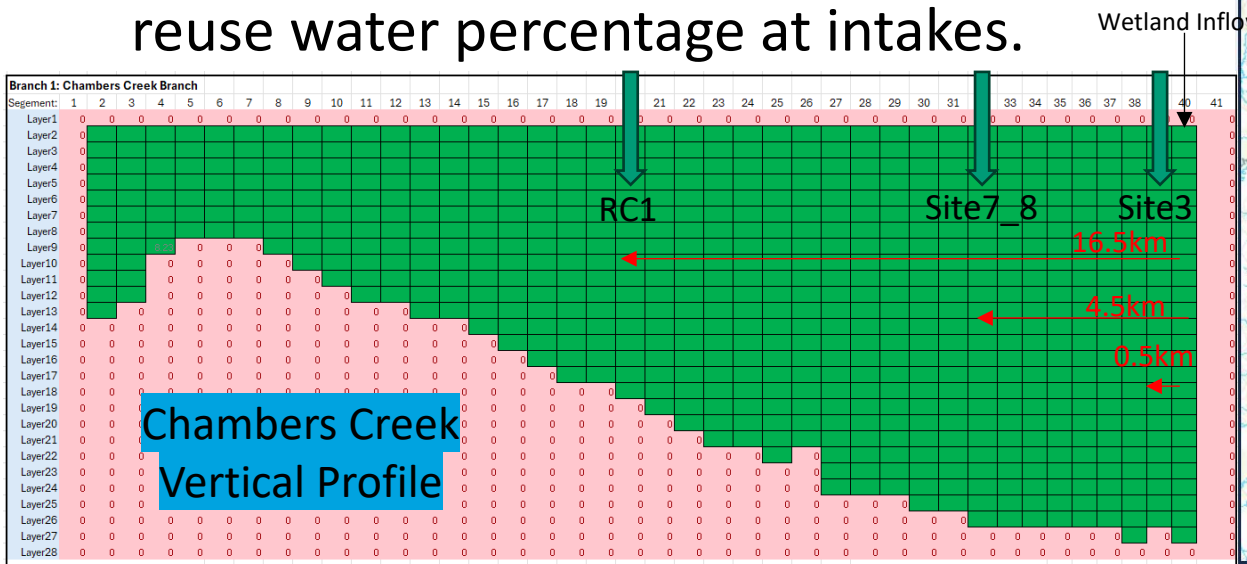


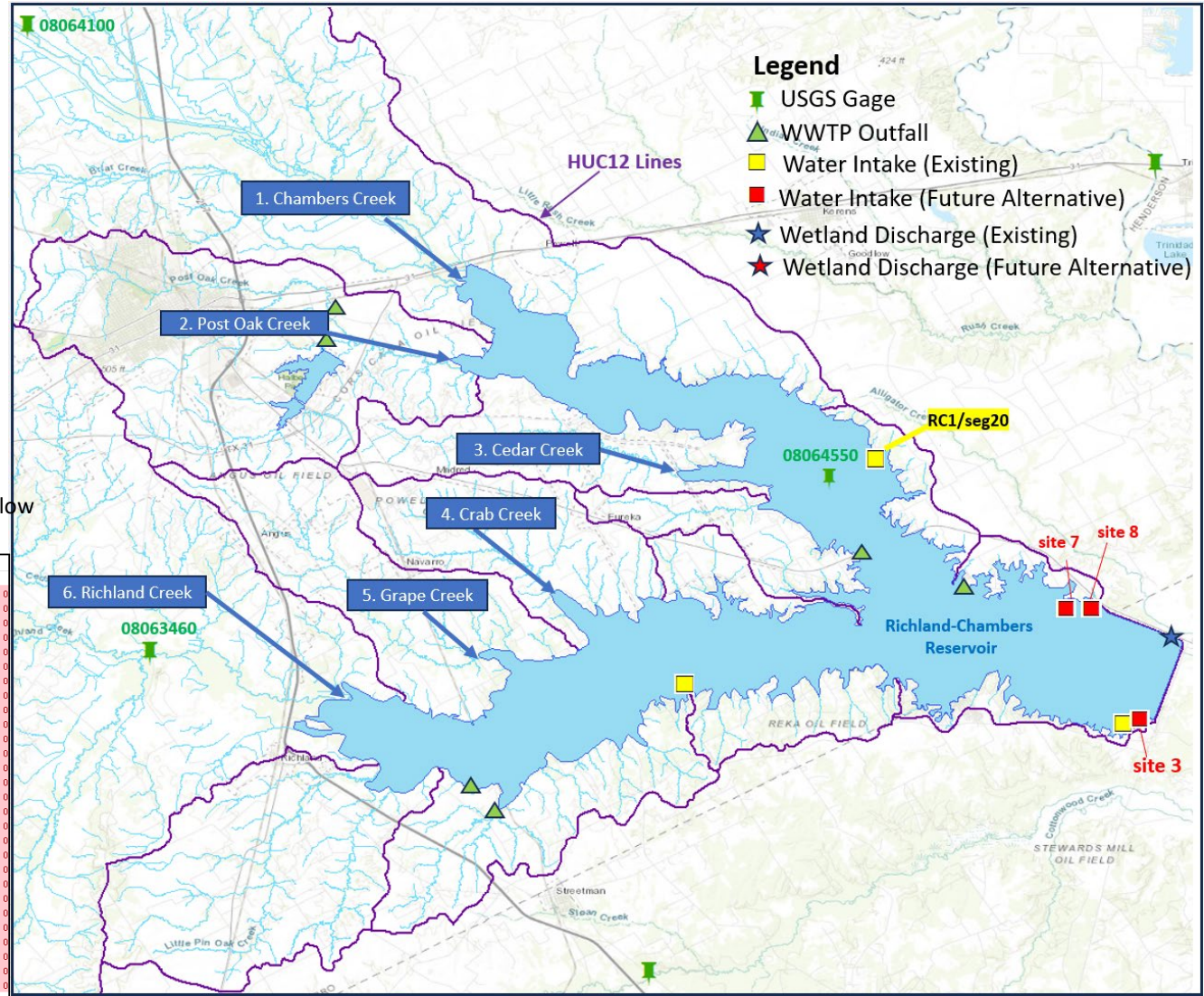
Surface and Bottom Chloride



Tracer Simulation Design

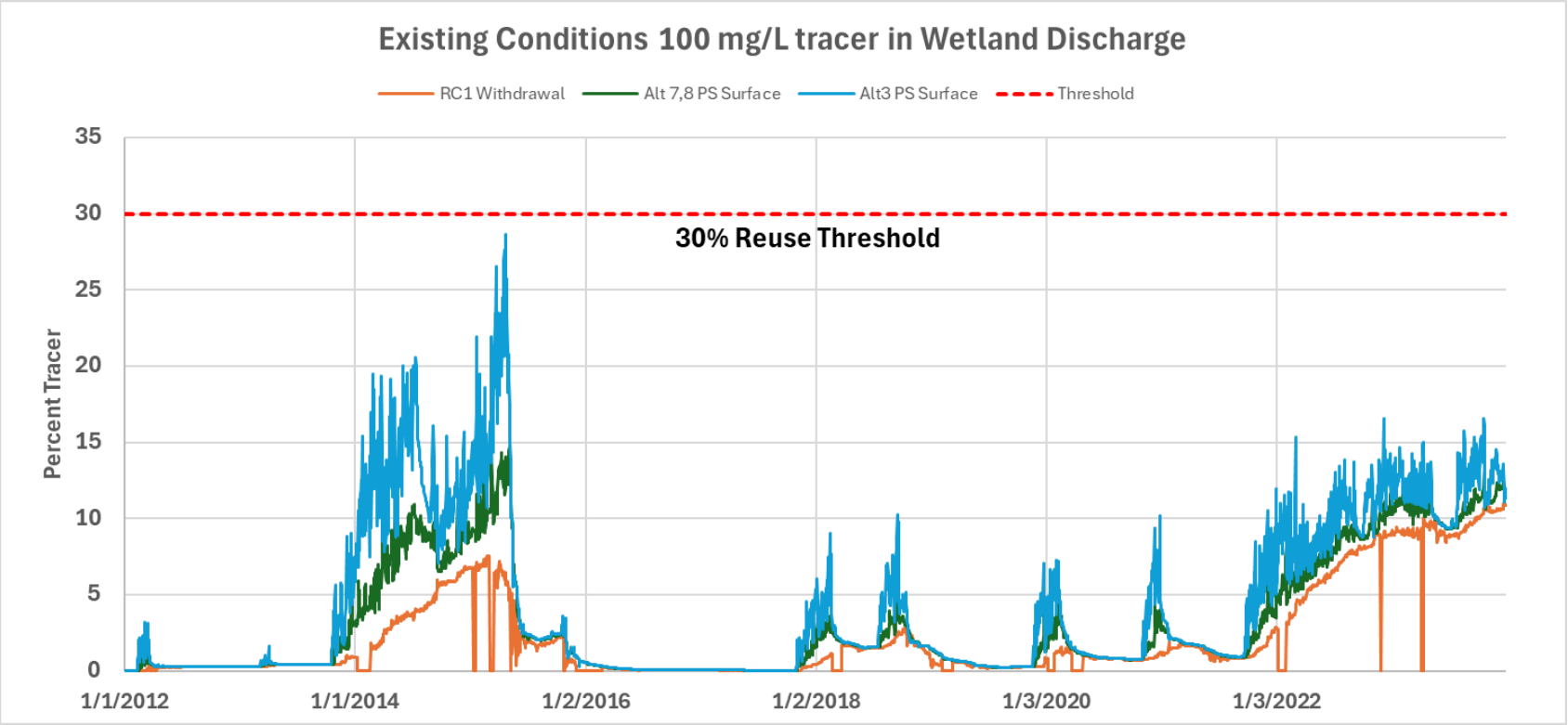
- Tracer types: Chloride, Specific Conductance, TDS.
- Applied 100 mg/L virtual tracer to Chambers Creek and Wetlands inflows.
- Ran both 24-hour pulse and continuous release simulations.
- Metrics: Travel time, dilution, and reuse water percentage at intakes.



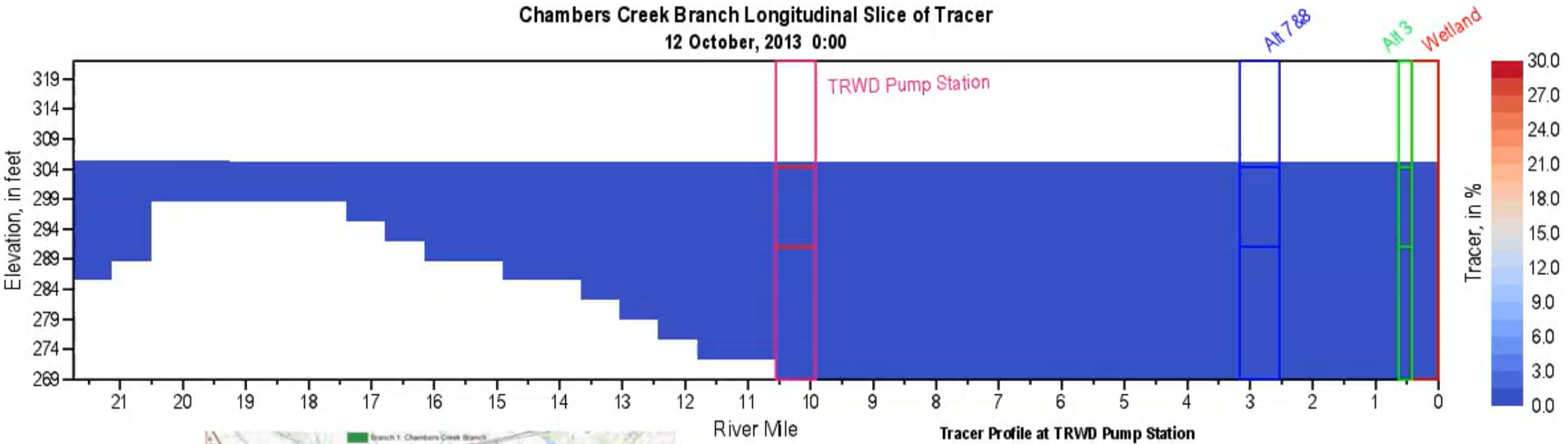


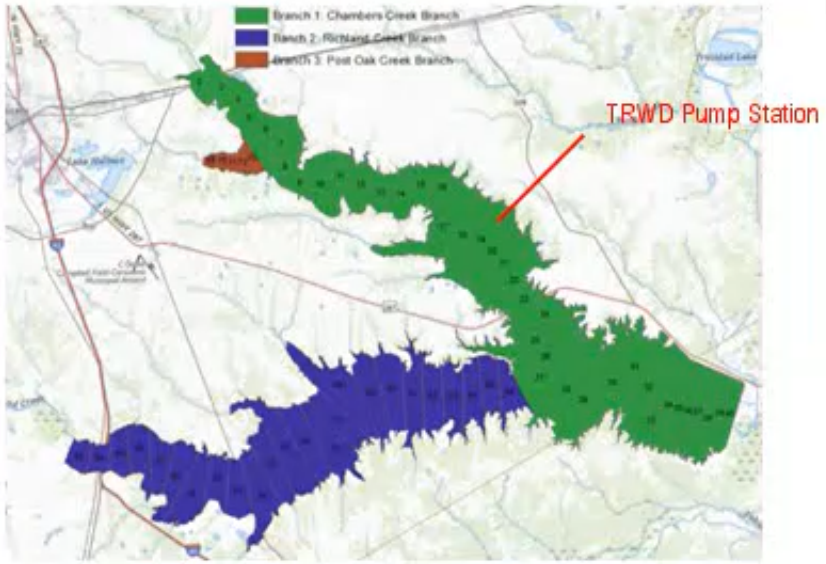
2D Model Results for Wetland Tracer Injection

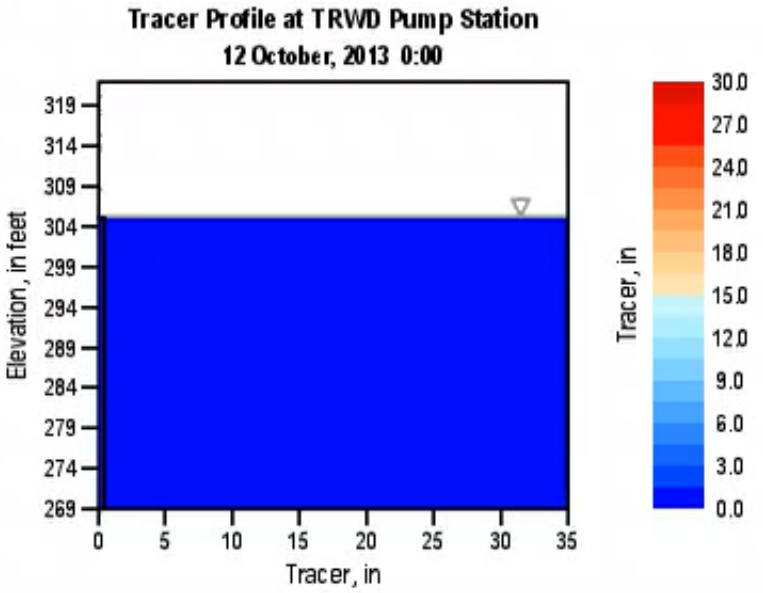
- Scenarios simulated using 2012-2023 historical data



**30% threshold is TRWD's arbitrary reuse limit to protect reservoir and water supply for potential impacts.*



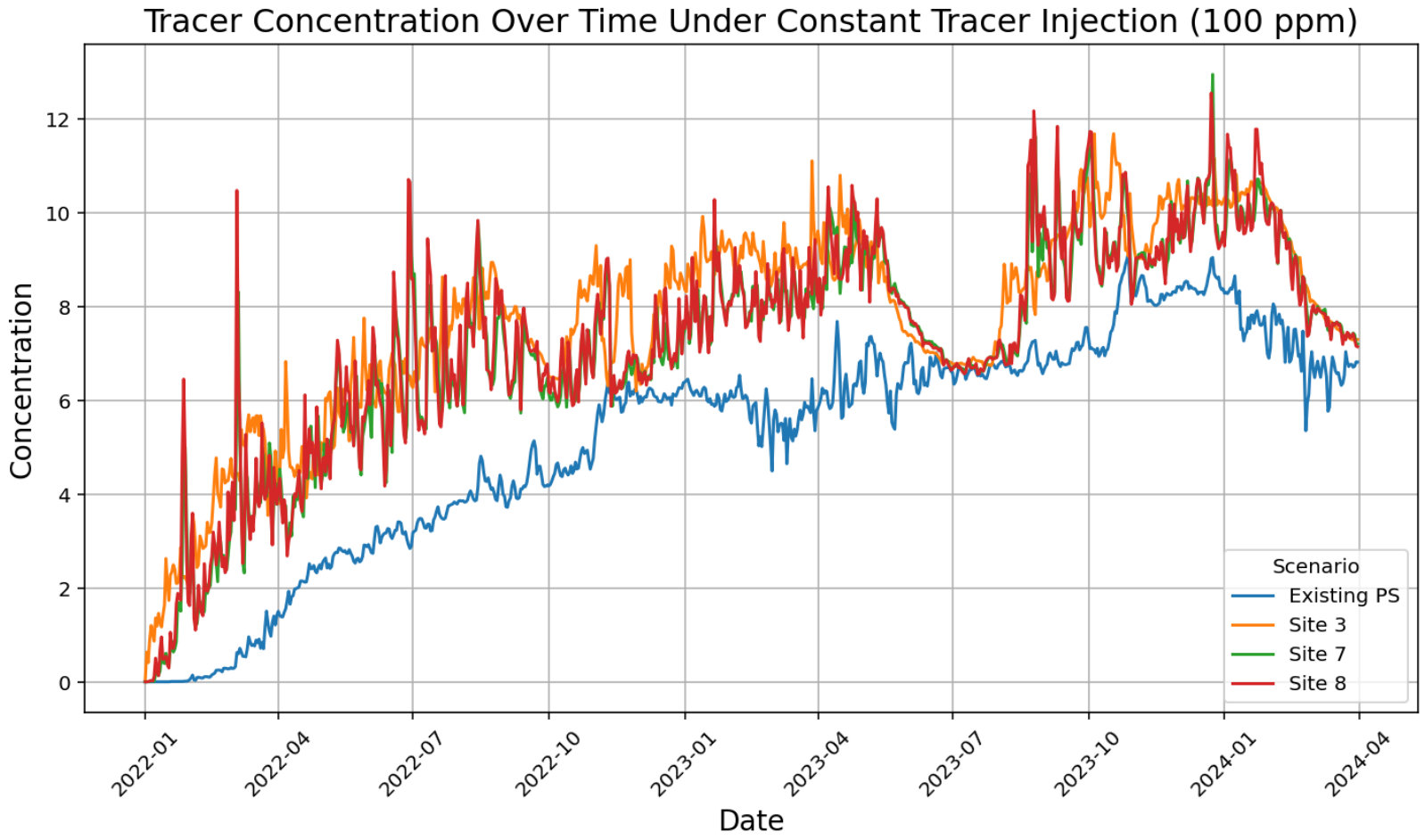




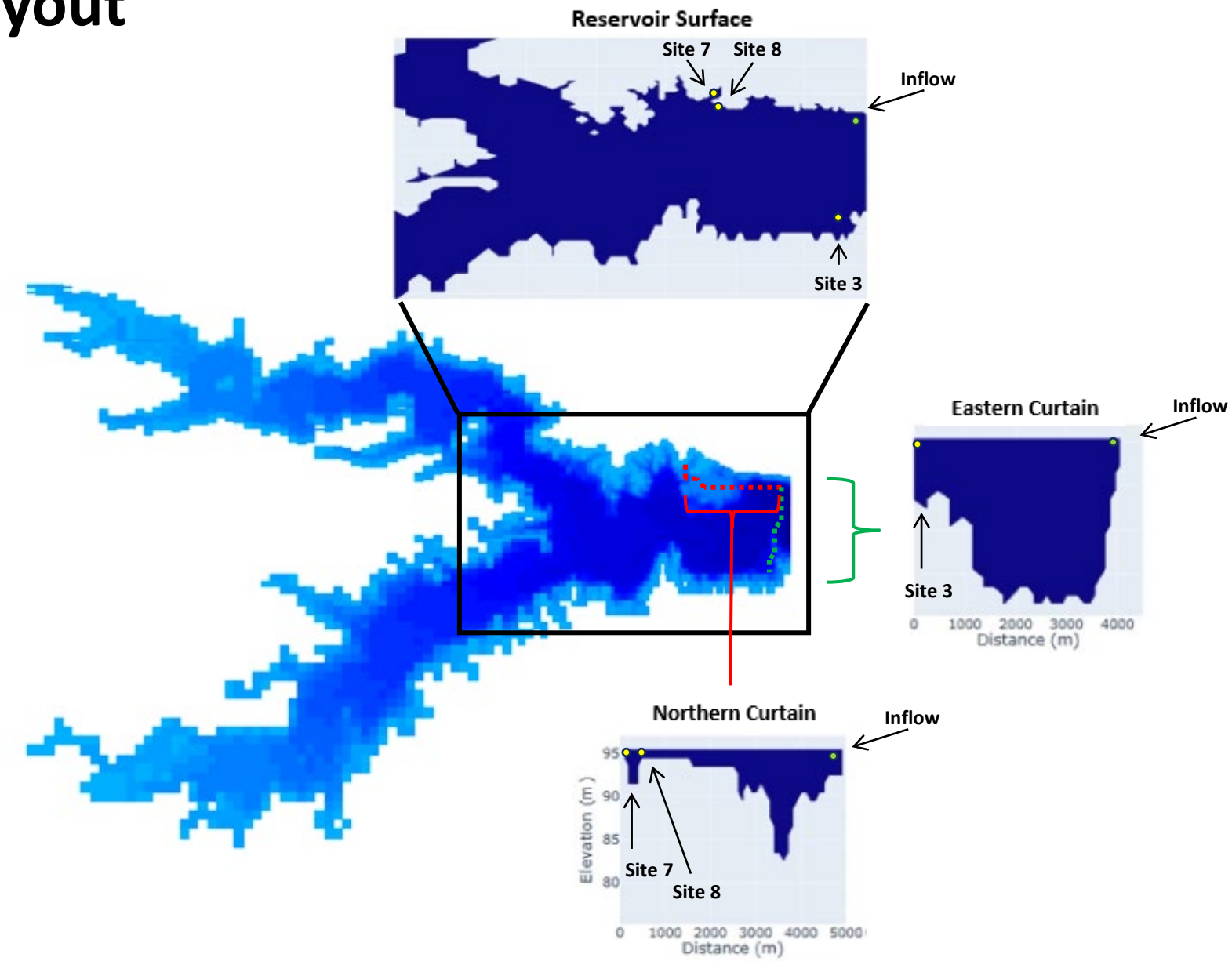
2D Model Animation

3D Model Results for Wetland Tracer Injection

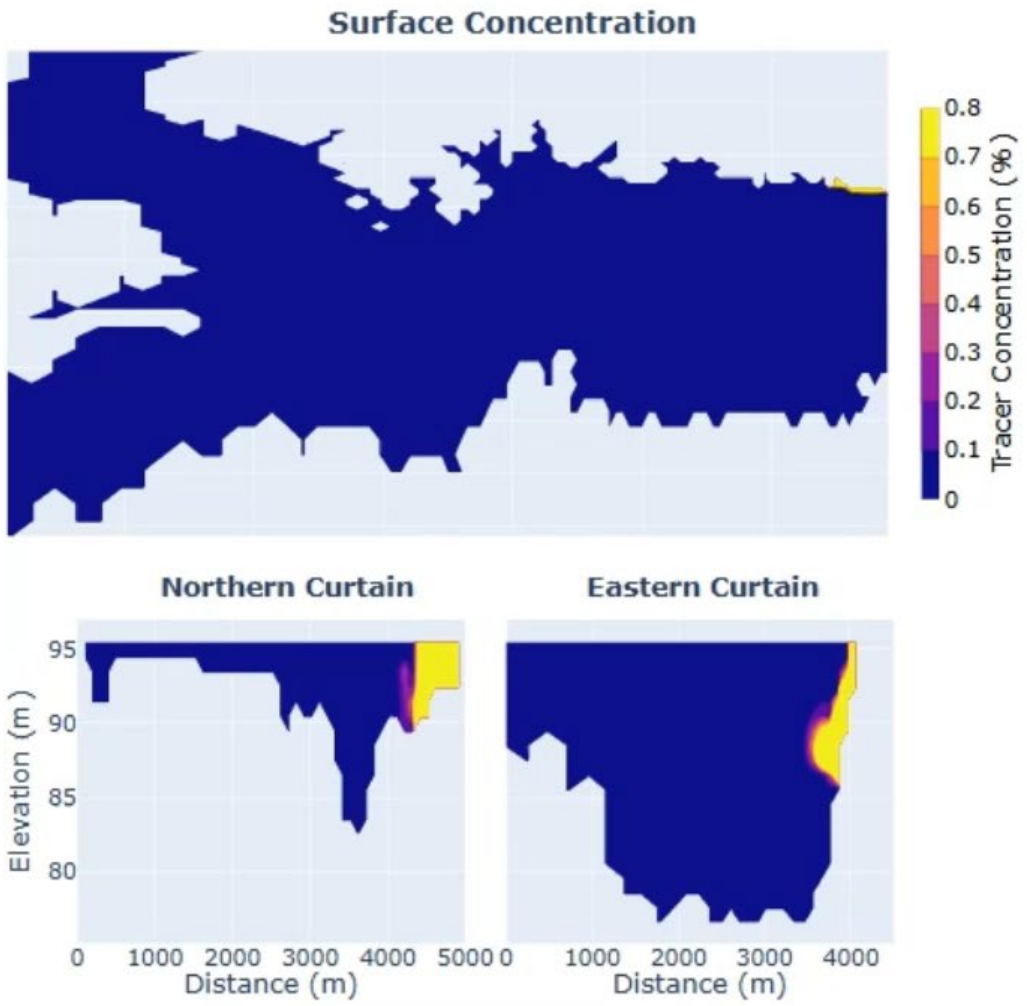
Scenarios simulated using 2022-2023 historical data



3D Model Animation Layout



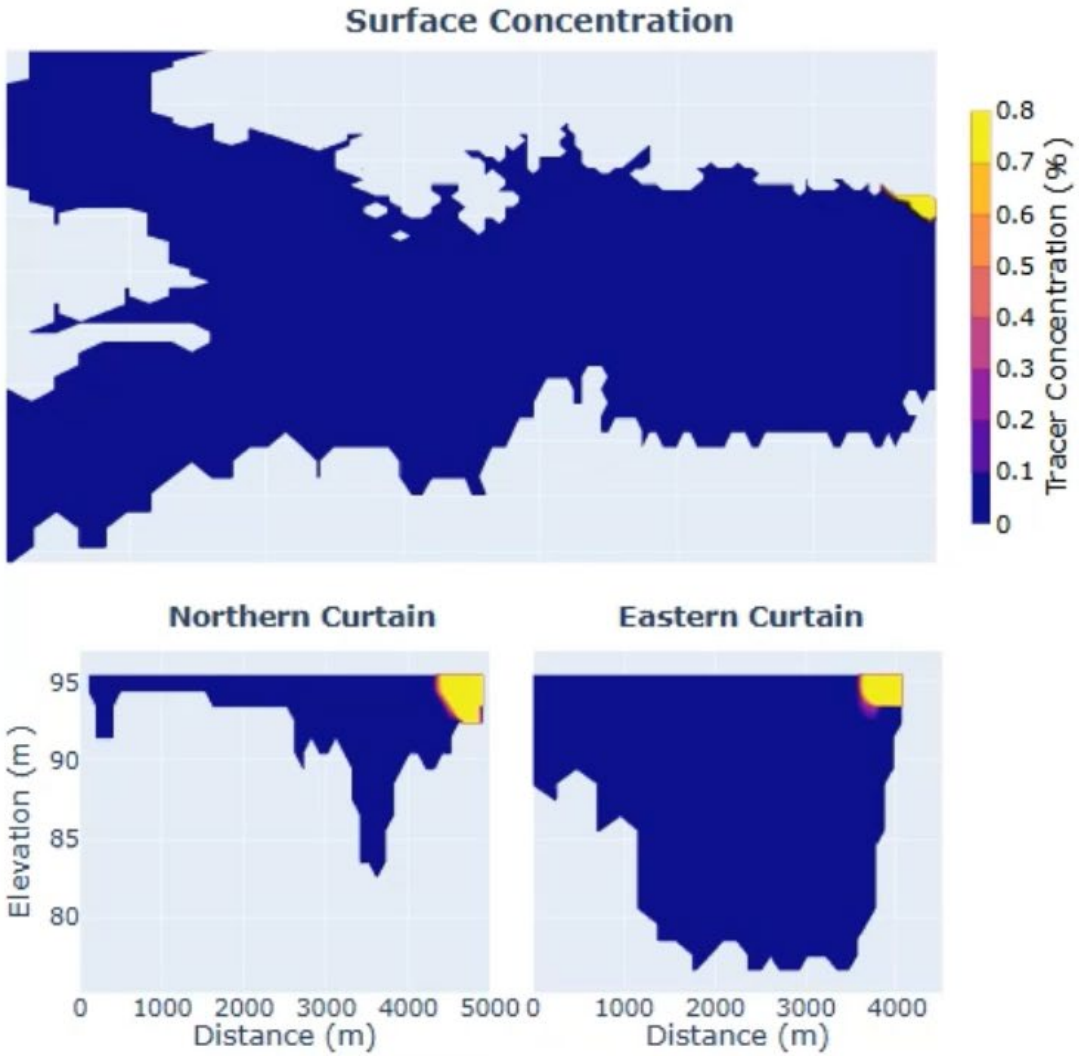
Typical Tracer Movement: Spring



- **Tracer Injection Date**: 05/25/2022
- 28th – 69th percentile max concentration; 75th percentile wetland flow.

DRAFT

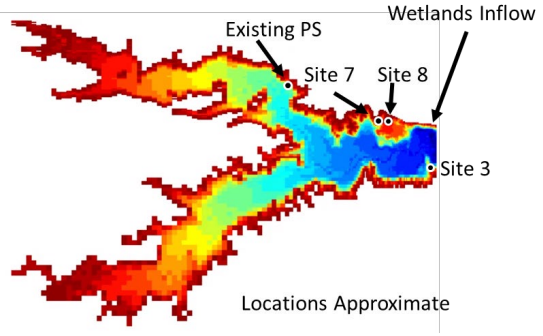
Low Dilution Tracer: Site 3 – Winter Short-Circuiting

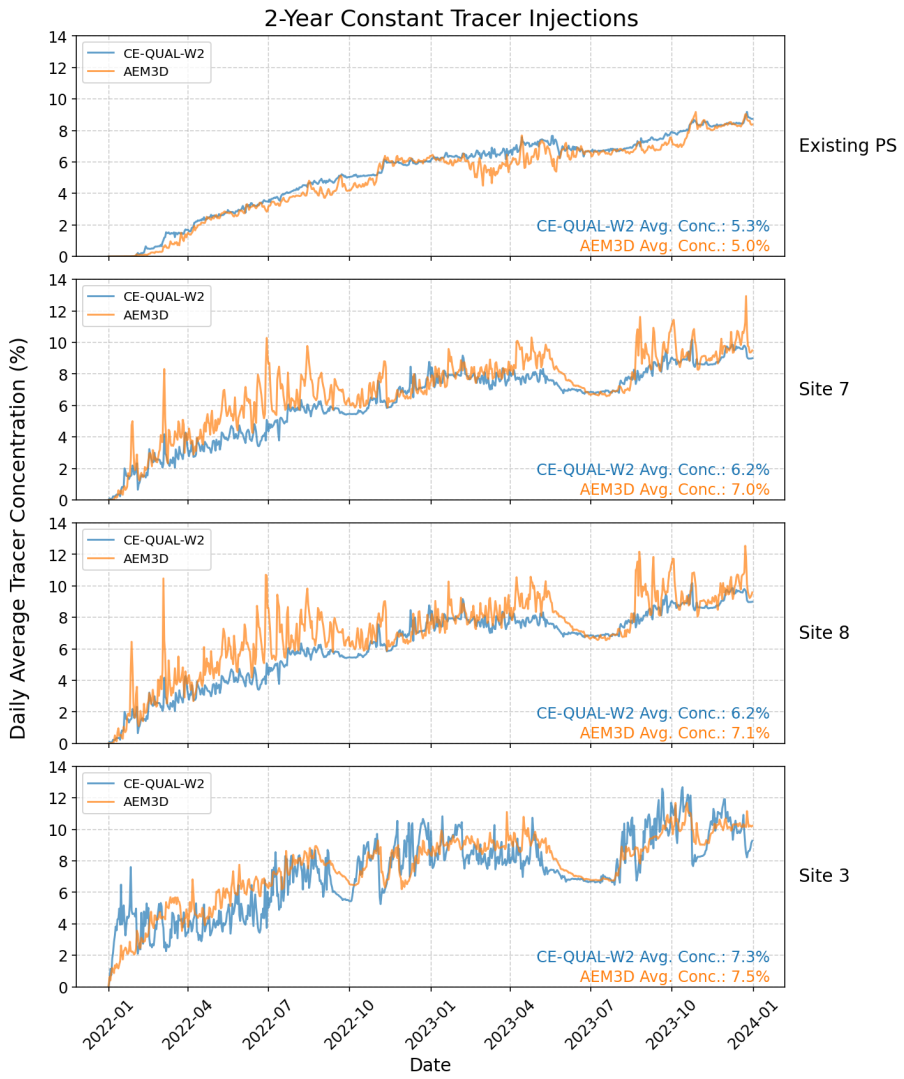


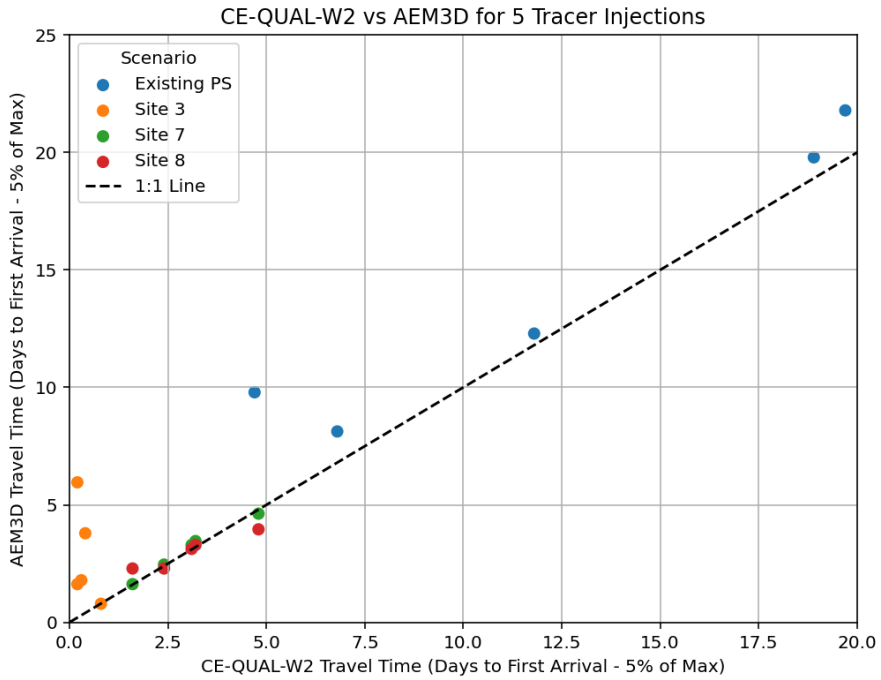
- **Tracer Injection Date:** 02/02/2022
- 98th percentile max concentration at site 3
- 92nd percentile wetland flow

DRAFT

2D vs 3D Model Comparaison for Wetland Tracer Injection:
Tracer Concentration & Travel Time

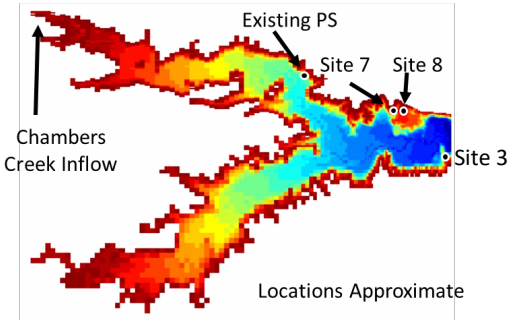


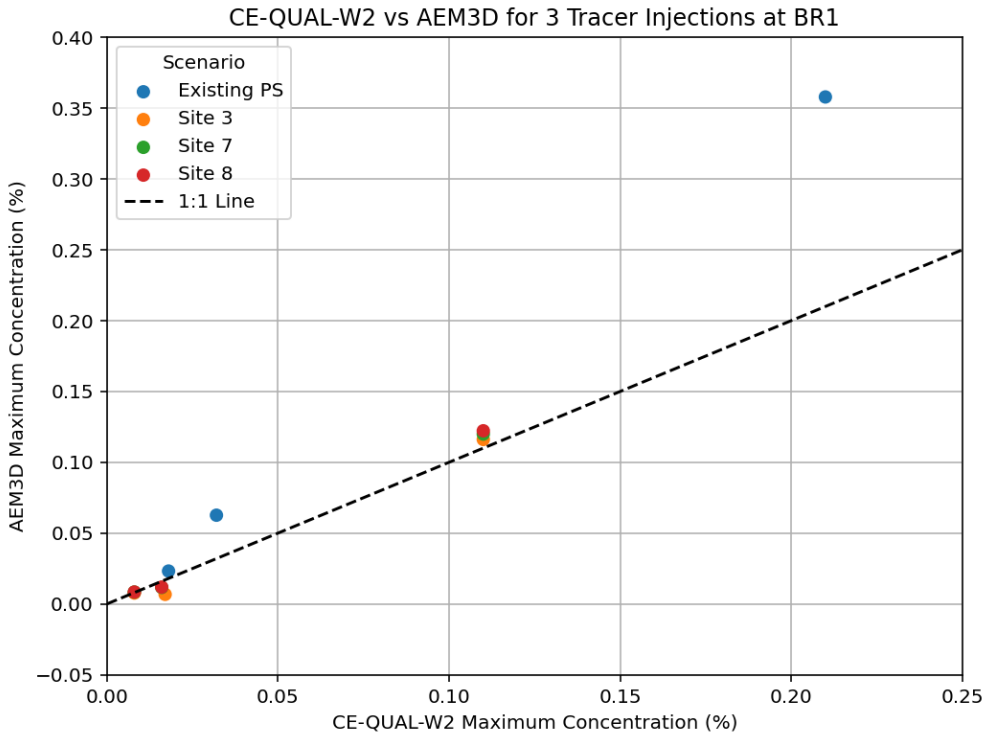


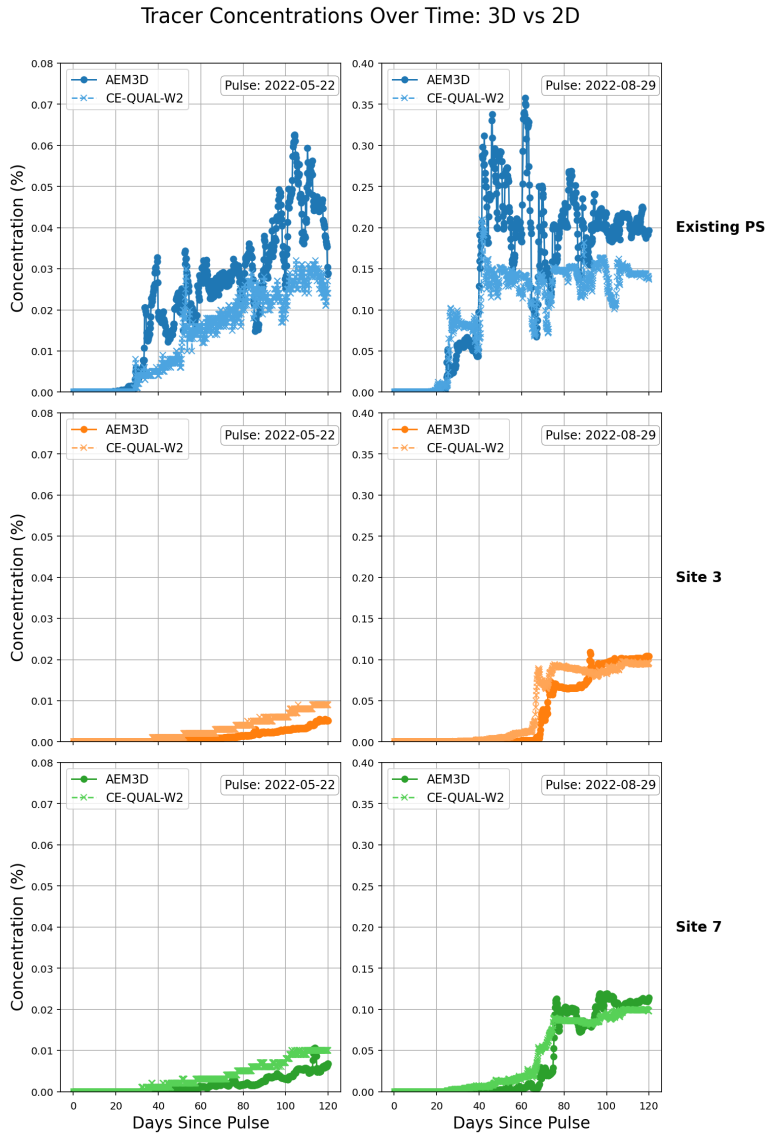


- Constant injection shows similar tracer concentrations with both models
  - 3D model captures more variability
- 3D model shows significantly longer travel times to Site 3

2D vs 3D Model Comparaison for Chambers Creek Tracer Injection: Tracer Concentration & Travel Time







- Chambers Creek inflow tracers show generally good agreement between 2D and 3D model

Model Computational Performance

- CE-QUAL-W2 for 12 years simulation time ~30 mins.
- AEM3D for 2 years simulation time ~48 hours.
- 3D model development cost ~ 1.5 times more than 2D model.
- 2D model ideal for planning-level studies.
- 3D model used for detailed event simulations (e.g., spills, droughts, near shore water quality modeling).

2D vs 3D Model Comparison: Summary

- Good agreement in travel time and dilution across sites.
- 2D overestimated dilution during low-mixing (stratified) conditions.
- 3D resolved lateral variability and localized mixing effects.
- Differences within ±1 day for travel time metrics.

Key Takeaways and Recommendations

- Both models capture key hydrodynamic and tracer processes effectively.
- Travel time and dilution generally agree within acceptable limits.
- 2D: cost-effective, fast, planning tool; 3D: detailed event simulation.
- Sites 7 & 8 are technically optimal for new pump station siting.

QUESTIONS?

PLUMMER

Nabin Basnet

nbasnet@plummer.com

Water Quality Solutions

Kareem Hannoun

khannoun@wqsinc.com

trwd Tarrant Regional Water District

Mark Ernst

Mark.Ernst@trwd.com

Management Implications

- Sites 7 & 8 show best dilution and travel time balance.
- 2D model sufficient for routine TRWD operations planning.
- 3D model recommended for targeted high-resolution event studies.
- Provides basis for reuse, diversion, and drought contingency modeling.