U.S. DEPARTMENT *of* ENERGY

Office of Environmental Management

Hanford Field Office

Barometric Pressure Corrections in Support of Hydrologic Characterization Testing at a Hanford Pump and Treat System

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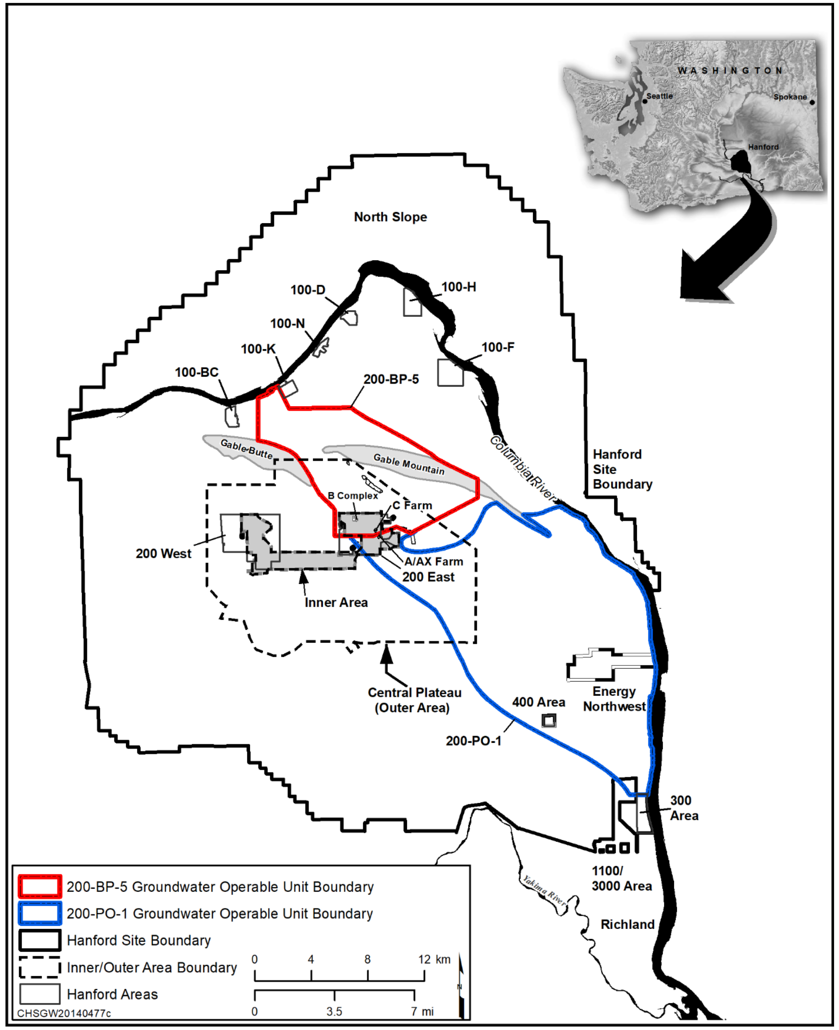
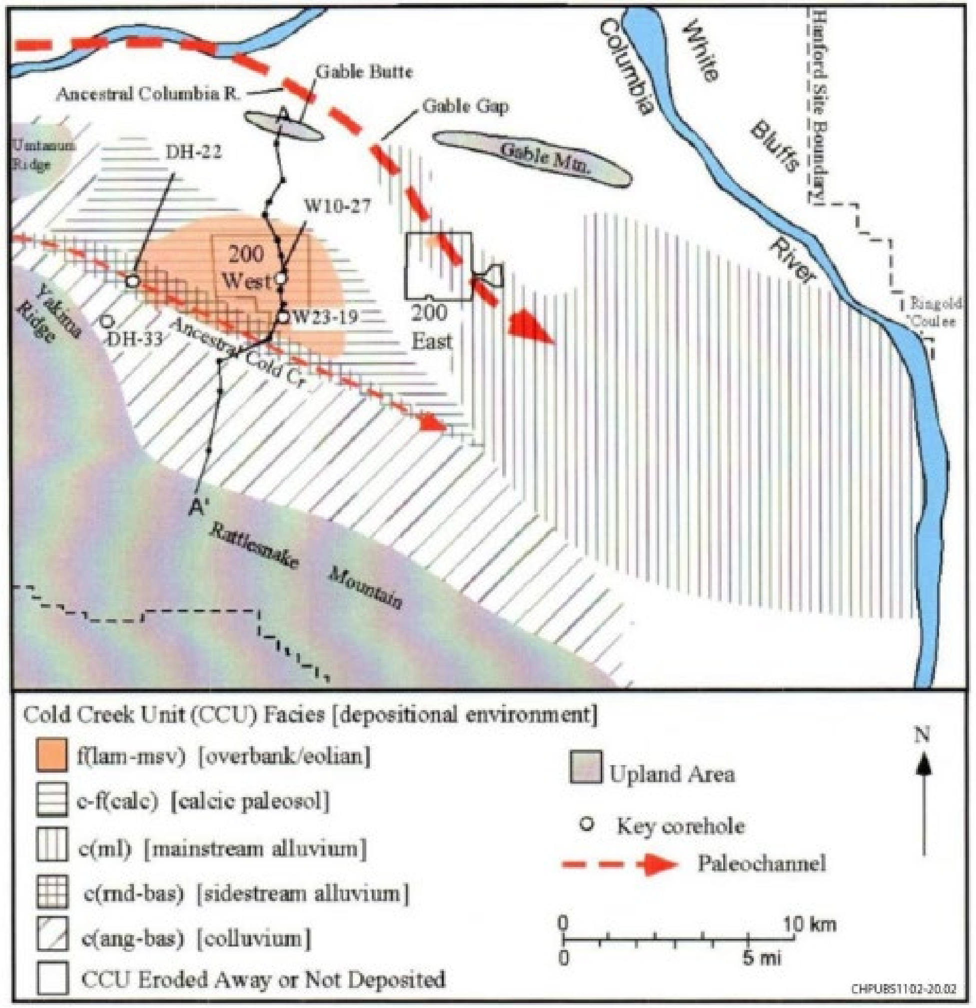
Introduction

- Hanford Site located in southeastern Washington State
- 200-BP-5 and 200-PO-1 Groundwater Operable Units encompass the 200-East Area of the Central Plateau on the Hanford Site
- Columbia River bounds the Hanford Site to the north and east



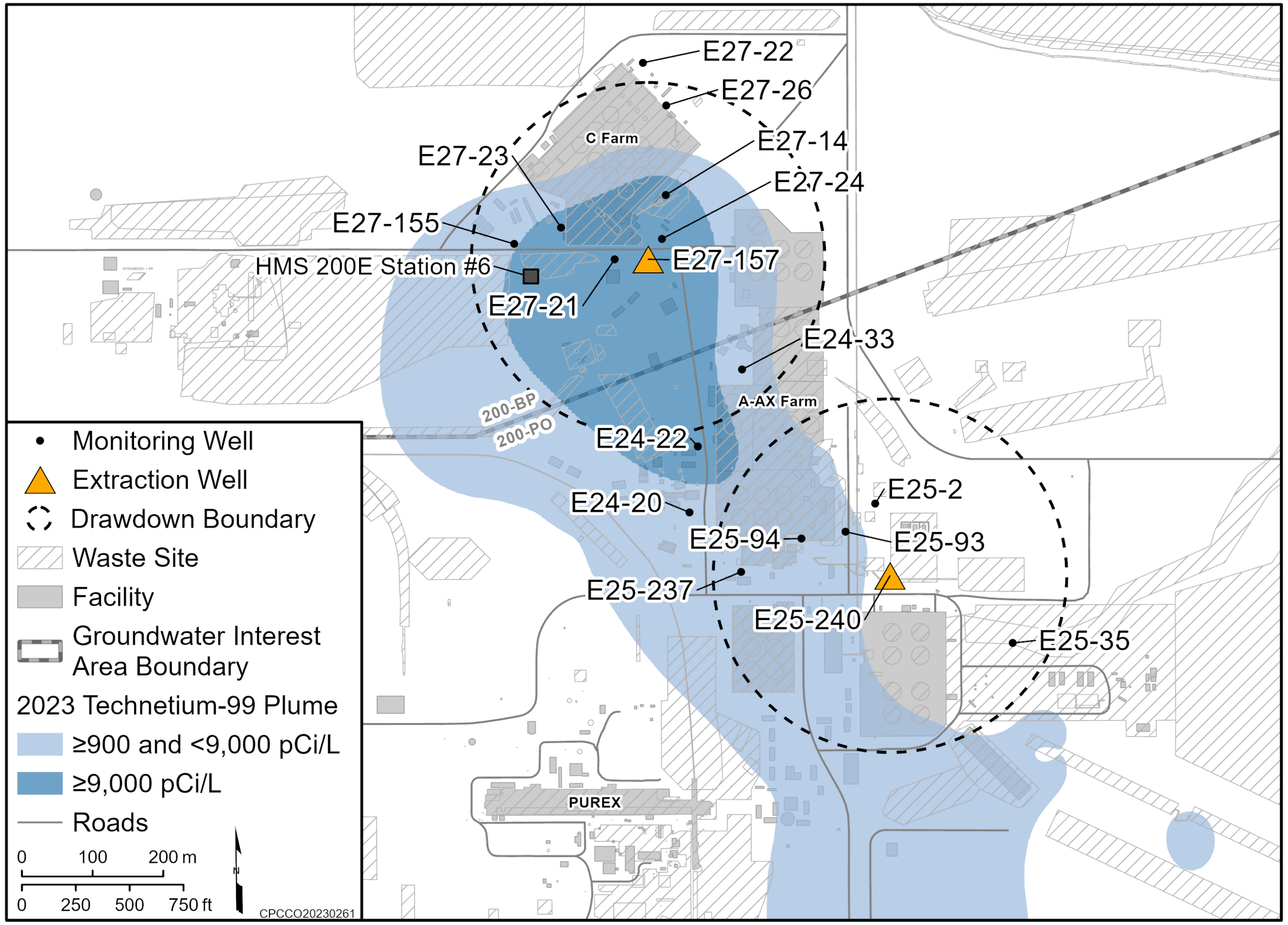
Introduction

- Paleochannel filled with highly conductive/ transmissive sedimentary deposits
- Hydraulic conductivity = 10^1 to 10^3 m/day
- Suprabasalt glaciofluvial and lacustrine deposits consist predominantly of sands and gravels



Introduction

- Technetium-99 concentrations in groundwater range up to ~25,000 pCi/L (DWS = 900 pCi/L)
- Extremely low hydraulic gradient conditions (10^{-5} to 10^{-6} m/m)
- Two new extraction wells 299-E25-240 and 299-E27-157: locations based on capture zone analysis for the technetium-99 plume
- Criteria for selecting monitor well locations
  - Saturated well-screen section of ≥1.5 m
  - Well distance of ≤250 m from the extraction well, based on the predicted radius to the predicted drawdown of 0.1 m



Hydrologic Testing Objectives

- **Completed Phase 1 Hydrologic Testing Activities (FY25)**
  - **Baseline water-level and barometric pressure characterization**
    - Development of barometric response functions (BRF) profiles at each monitoring well for:
      - Removal of extraneous barometric pressure effects from well pressure responses during Phase 2 long-duration hydrologic characterization tests
      - General site specific and areal hydrogeologic assessment of vadose zone hydraulic properties
- **Planned Phase 2 Hydrologic Testing Activities (FY26)**
  - **Modified Step-Drawdown Pumping Tests**
  - **Extended Constant-Rate Pumping Tests**
  - **Multi-Well Extended Constant-Rate Pumping Test**

Support Design of a Pump and Treat System

- **Hydrologic Testing Information Used to:**
  - Improve the conceptual site model
  - Update the fate and transport model to validate the capture zone and mass removal and determine time to cleanup
  - **Determine optimum approach to remediate technetium-99 in groundwater**
  - Optimize pump and treat flow rates to maximize mass recovery
  - Treat minimum volume of clean (i.e., <DWS) groundwater
  - Maintain contaminant concentrations within the effluent limits of the 200-West P&T facility

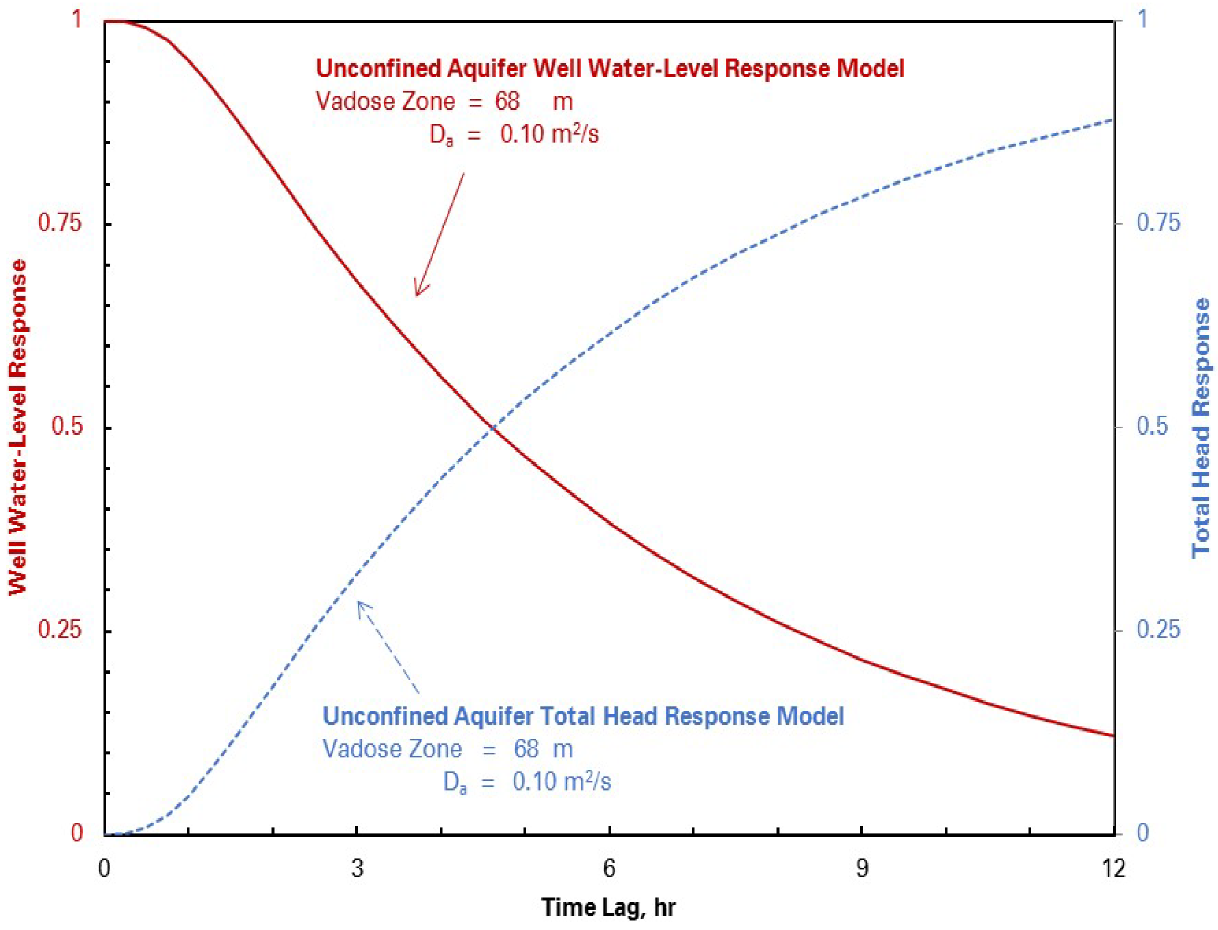
Barometric Response Function Development

- Removal of barometric pressure effects facilitates the analysis of hydrologic tests
  - Particularly where the barometric pressure changes > imposed hydrologic test responses
- Unconfined aquifers typically exhibit variable time-lagged water-level responses to barometric pressure fluctuations
  - ➢ Time delay for barometric pressure change to transmit through the vadose zone
  - ➢ A function of
    - ➢ vertical pneumatic diffusivity
    - ➢ moisture content
    - ➢ gas compressibility
    - ➢ vadose zone thickness

References: PNNL-18732, Spane 2002

Barometric Response Function Development

- Assuming wellbore storage effects are insignificant, then BRF relationships can be developed from either:
  - Well water-level responses to barometric pressure change, or
  - **Total pressure head responses to barometric pressure change**
- Total pressure head generally provides better BRFs in 200-East Area wells



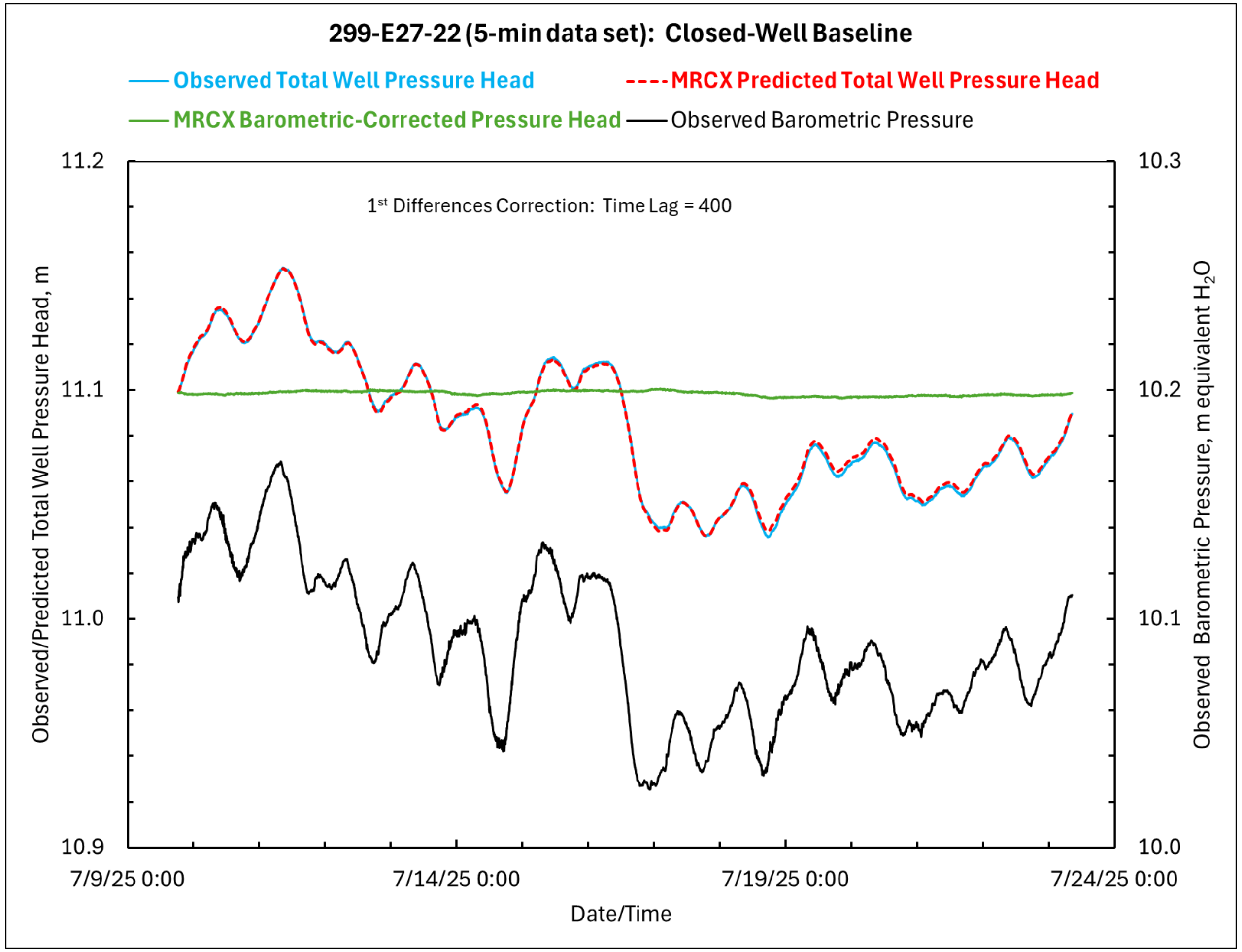
References: PNNL-13078, Spane 2002, and McDonald 2024

Baseline Monitoring Conditions for Developing BRFs

- Open-Well Condition
  - Wellhead open to the atmosphere
  - Transmission effects of barometric pressures directly to the water table through the unsaturated section of the well screen
  - Time-lagged transmission of barometric pressures propagates through the vadose zone
  - 15-day baseline period in June 2025
- Closed-Well Condition
  - Wellhead sealed to eliminate transmission effects through the unsaturated section of the well screen
  - Minimizes the effect of well bore storage
  - 15-day baseline period in July 2025

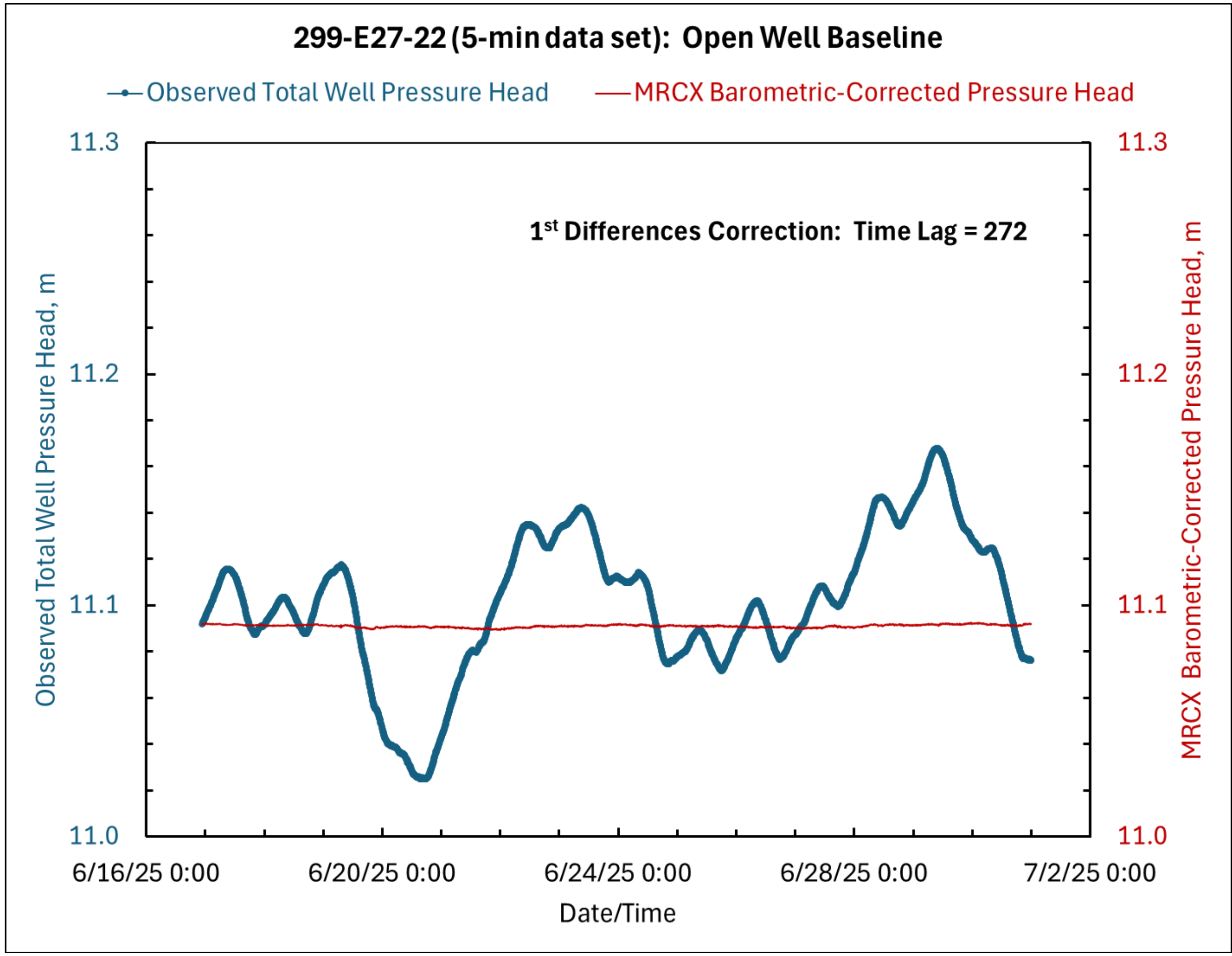
Barometric Response Function Analysis Method

- Multiple-regression deconvolution method to correct for barometric pressure effects
  - ➢ Step 1 (convolution): linear regression of time-lagged barometric pressure and observed total pressure head to predict the total pressure head response
  - ➢ Step 2 (deconvolution): predicted total pressure head responses removed from the observed total well pressure head responses to produce corrected well pressure head responses
  - ➢ Multiple Regression Correction in Excel (MRCX) software used to calculate the BRFs and corrected well response



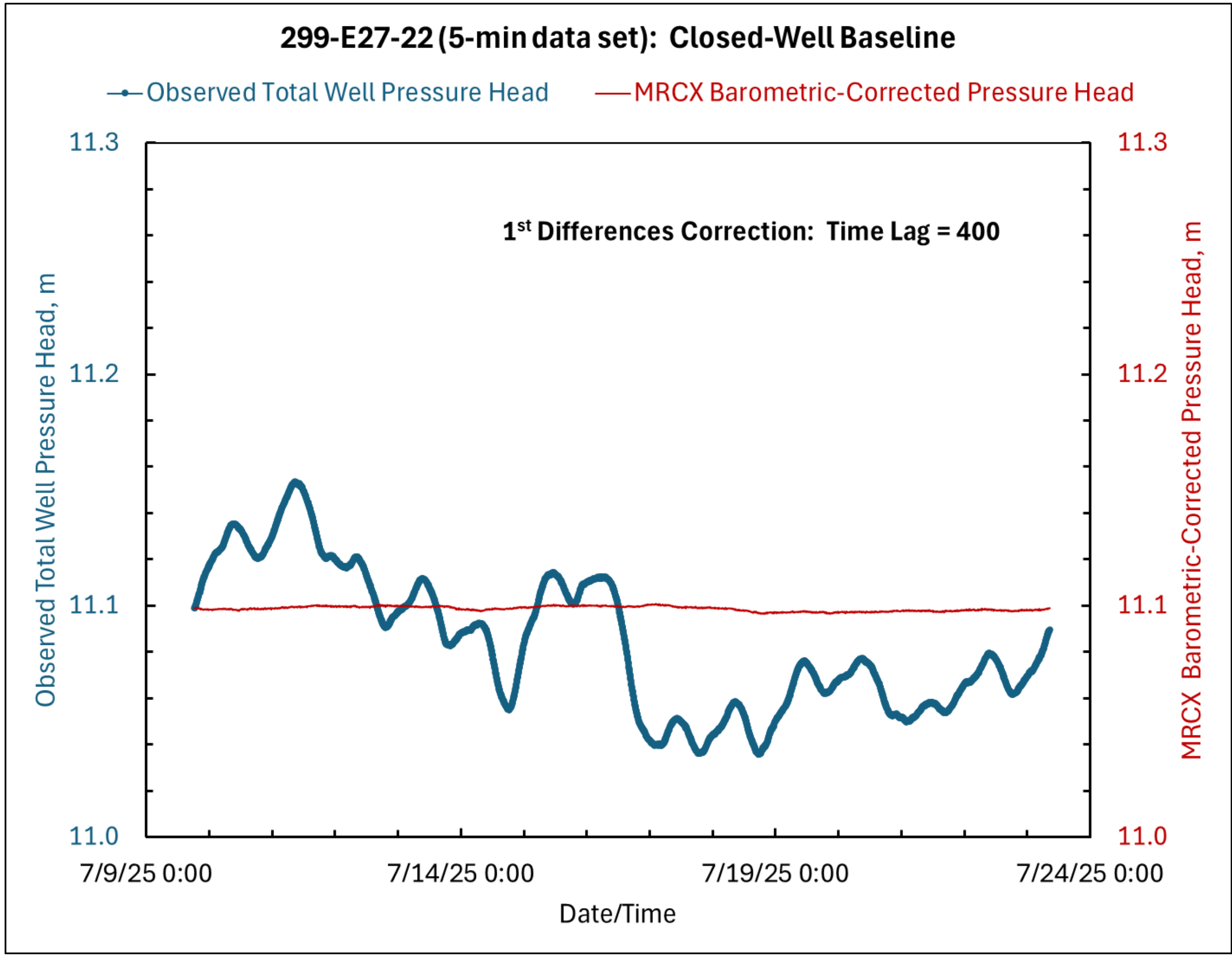
BRF Correction for Open-Well Conditions

- **MW 299-E27-22 is an example of a high level of open-well barometric correction**
- Time lag of 272 (5-min frequency) equates to 22.7 hr



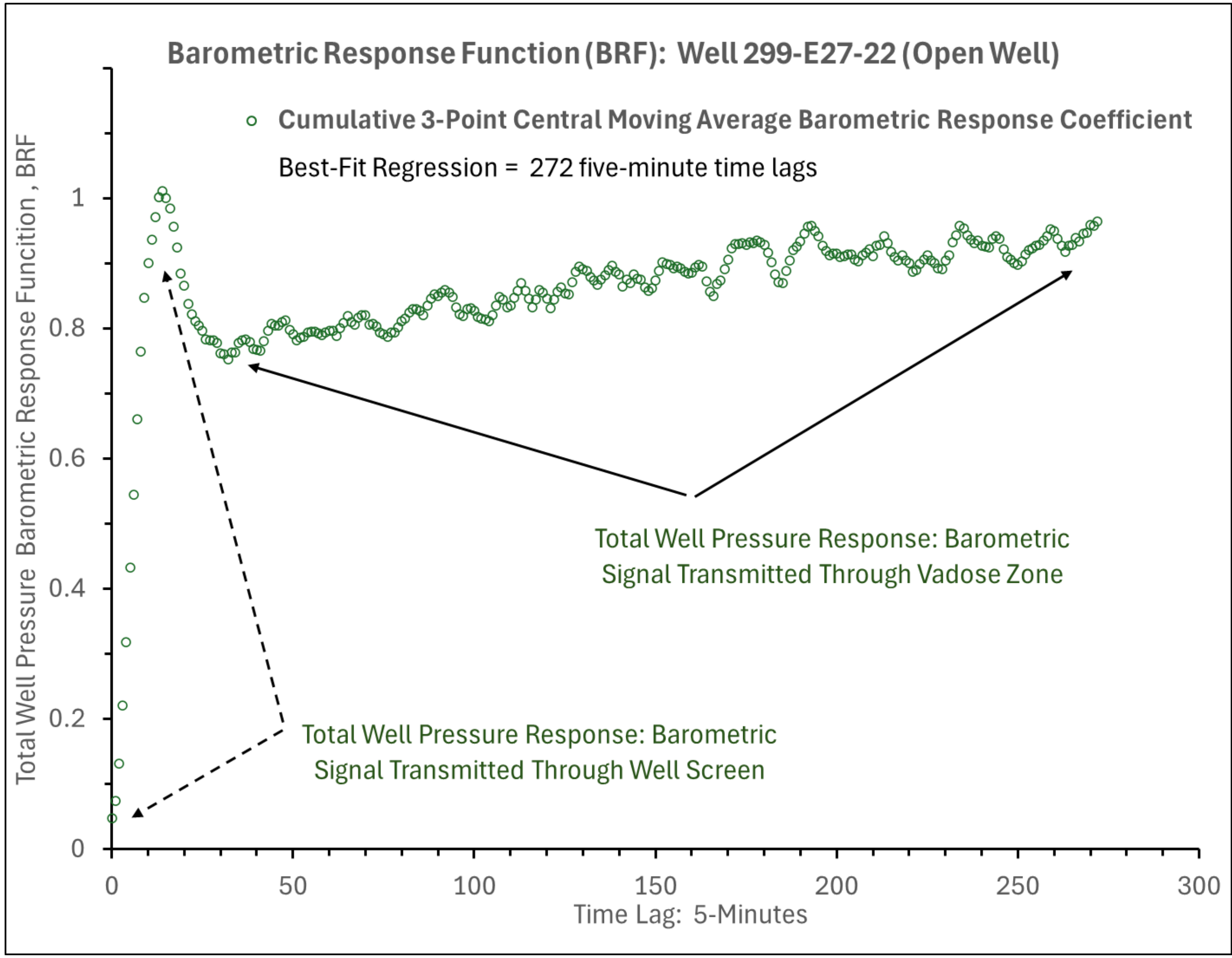
BRF Correction for Closed-Well Conditions

- **MW 299-E27-22 is an example of a high level of closed-well barometric correction**
- Time lag of 400 (5-min frequency) equates to 33.3 hr



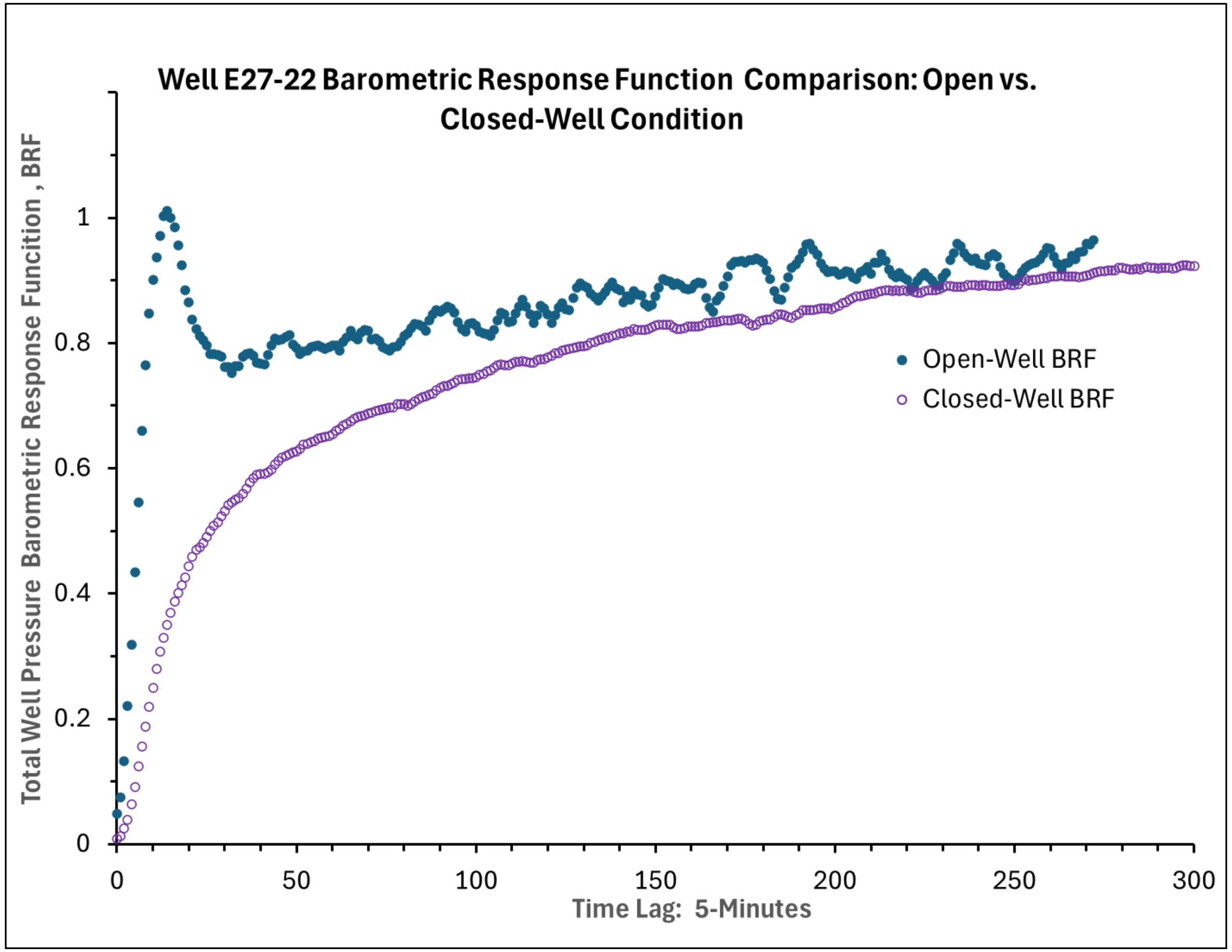
Barometric Pressure Transmission for Open-Well Conditions

- BRF analysis indicate competing, interfering affects of barometric pressure at many of the monitor wells
  - through the unsaturated well-screen section (early-time lag response)
  - vertically through the vadose zone (later-time lag response)



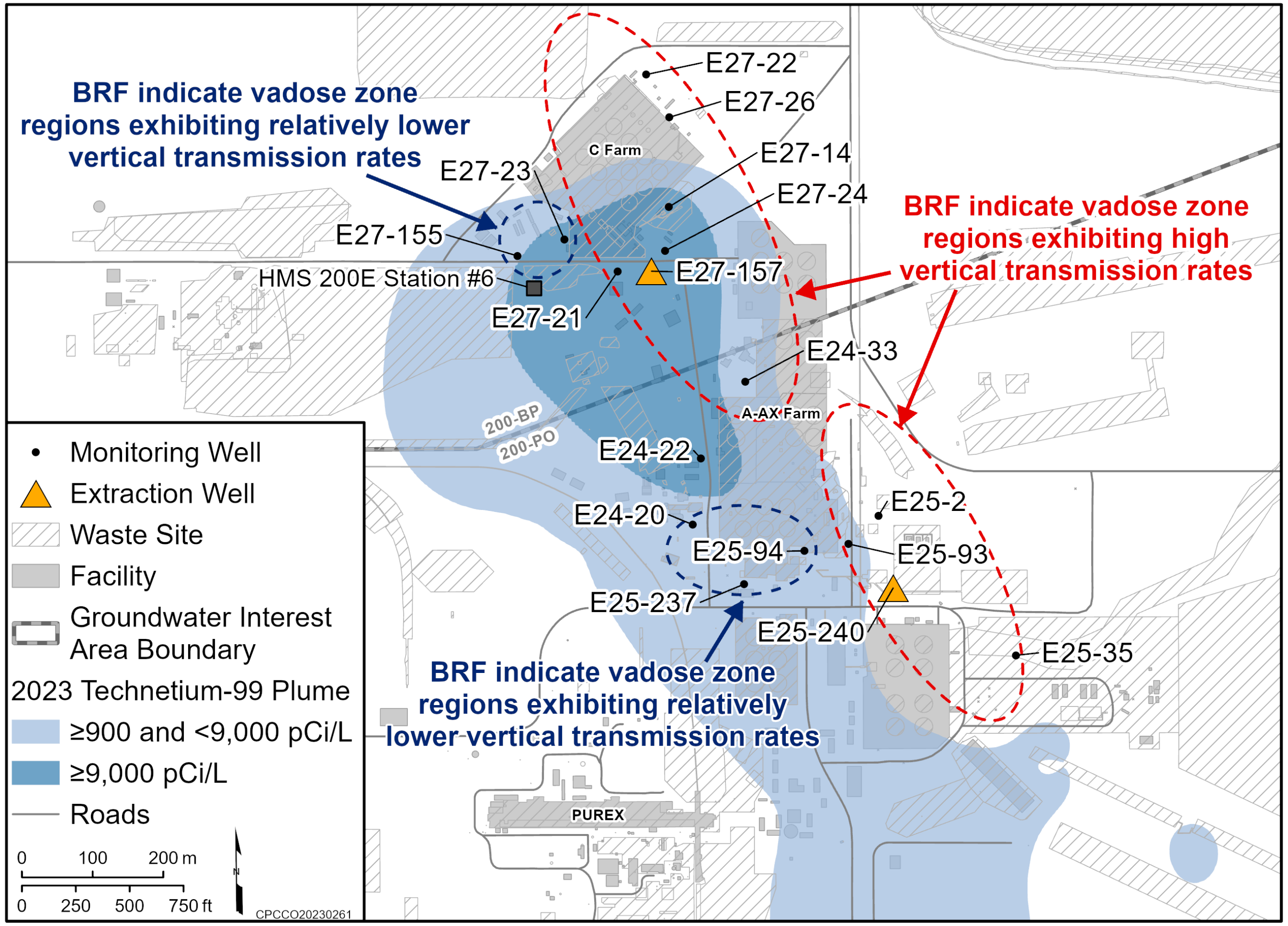
Open- vs. Closed-Well Barometric Pressure Transmission Comparison

- BRF analysis comparisons indicate that closed-well conditions provide smoother profiles at all monitor well locations, due to the elimination of the competing/ interfering effects of barometric pressure through the unsaturated well-screen



Vadose Zone Barometric Pressure Transmission Characteristics

- BRF delineated vadose zone areas exhibit high barometric transmission characteristics
- Relatively slower, time-lagged BRFs indicate a change in vadose zone transmission characteristics
- Supports a NW-SE trending paleochannel



Phase 1 Characterization Summary

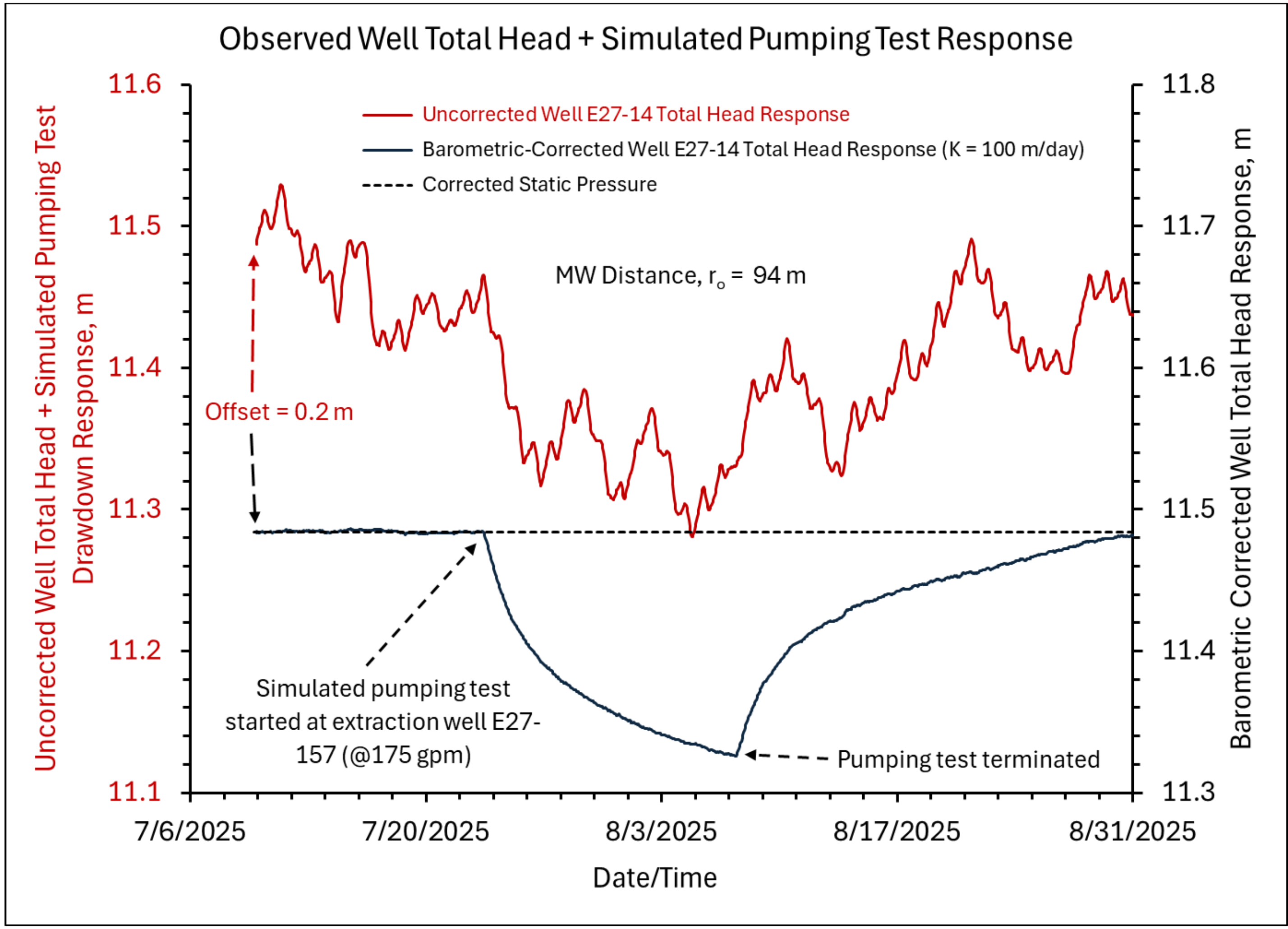
- Both open- and closed-well derived BRFs show a high level of barometric pressure correction at most monitor well locations
  - ➢ Closed-well monitor well conditions provide the best BRF profiles at all monitor well locations
  - ➢ A high level of BRF derived barometric correction is expected to be used to discern imposed low drawdown responses (e.g., 0.1 m) up to distances of 250 m from the extraction wells
- Vadose zone diagnostic characterization
  - ➢ Potential for identifying areas of high barometric pressure transmission rates

Phase 2: Simulated Pumping Test Response

- Calculated test response based on predicted aquifer hydraulic/storage properties:

K	**=**	**100 m/day**
K_D	=	0.33
S	=	2.5e-3
S_y	=	0.25
b	=	14.8 m
r_o	=	94 m

- Simulated test response indicates that a high level of BRF derived barometric correction can be used to discern imposed low drawdown responses (e.g., 0.1 m) up to distances of 250 m from the extraction wells



Additional Slides

Barometric Response Function Method

Barometric response function defined as:

$$\Delta H_t = \alpha + \beta_0 \Delta B_t + \beta_1 \Delta B_{t-1} + \beta_2 \Delta B_{t-2} + \cdots + \beta_n \Delta B_{t-n} + \varepsilon$$

where:

ΔH_t = change in well hydraulic head between successive times = $H_t - H_{t-1}$

ΔB_t = change in barometric pressure between successive times = $B_t - B_{t-1}$

ΔB_{t-1} = change in barometric pressure at one time step (lag) previously

ΔB_{t-n} = change in barometric pressure n time steps (lags) previously

n = maximum time lag (indexed at zero)

α = regression intercept (linear trend term)

$\beta_0 \dots \beta_n$ = regression coefficients corresponding to time lags of 0 to n

ε = residual error term

$$BRF_n = \sum_{i=0}^{n} \beta_i$$

where:

BRF_n = barometric response function for n number of time lags

β_i = regression coefficients corresponding to time lags of 0 to n

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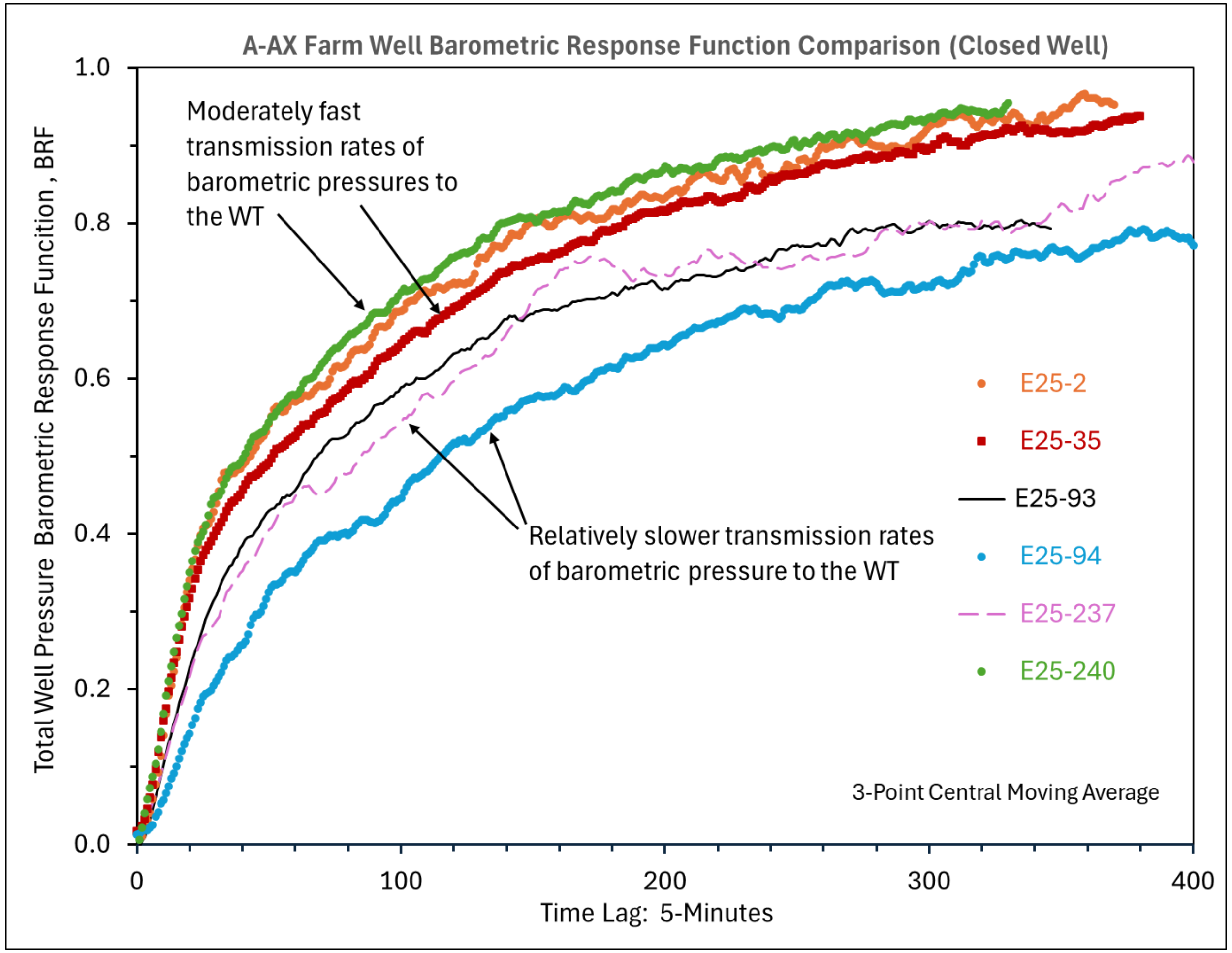
Areal BRF Comparisons for A-AX Farm (Closed Well)

- Three of the A-AX Farm wells (299-E25-2, 299-E25-35, and 299-E25-240) exhibit similar, moderately fast transmission of surface barometric pressures to the water table
  - barometric signal transmitted to the water table within 28 to 32 hours
- Well 299-E25-93 shows a transmission rate of 29 hr, but has a less smooth BRF
- Two wells (299-E25-94 and 299-E25-237) exhibiting relatively slower lagged transmission rates are located together in A-AX Farm northwest of extraction well 299-E25-240
  - barometric signal transmitted to the water table within 38 to 43 hours

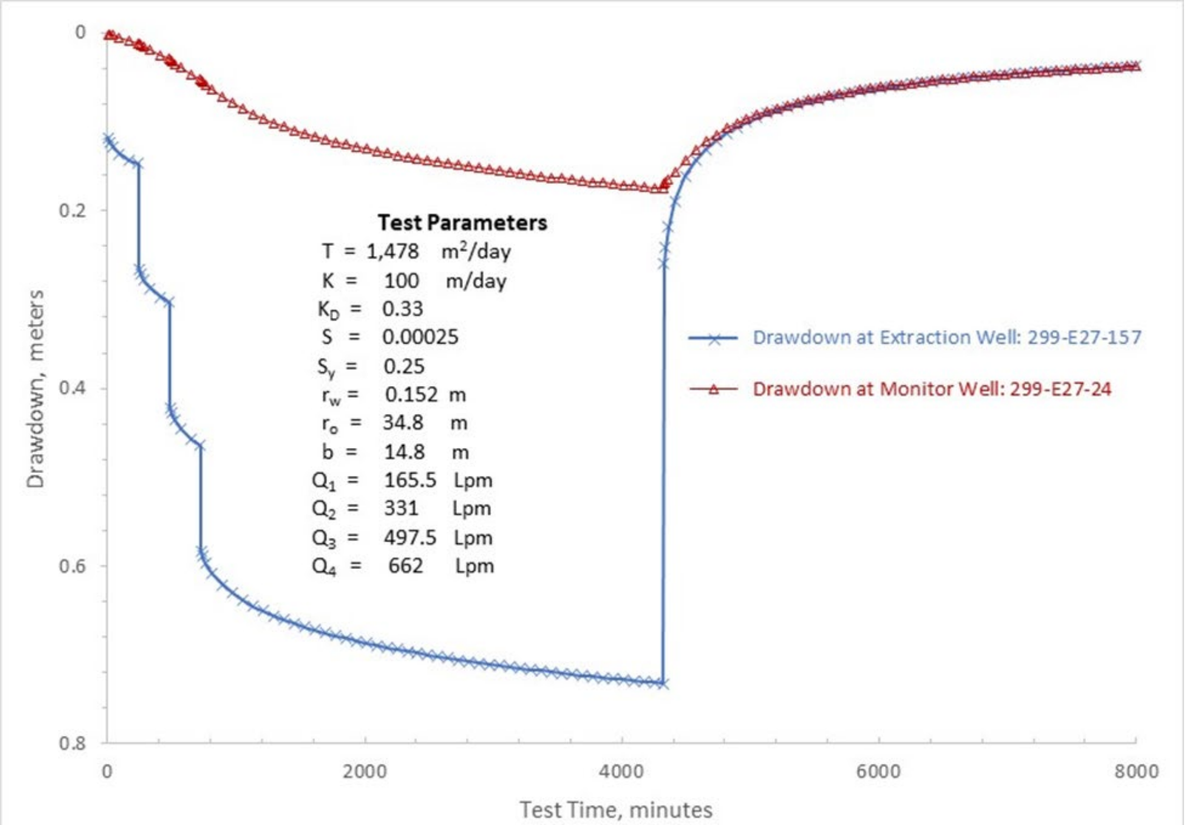


Phase 2: Recommended Monitoring Well Conditions

- **Open-Well or Closed-Well Conditions for Phase 2 Activities?**
  - Closed-well condition generally provides smoother BRFs and a higher level of well head pressure correction
  - Barometric pressure will become more variable and with greater pressure changes during the fall and winter months
  - Closed-well condition preferred for the 15 monitoring wells
    - Requires periodic field checks to maintain wellhead seal
  - Open-well condition preferred for the two extraction wells
    - Accommodates Operations activities and is more practical
    - Drawdown test responses are much higher than at the monitor wells; therefore, the extraction wells are not as impacted by barometric pressure changes
    - BRFs indicated a higher level of well head pressure correction

Phase 2 Hydrologic Test Plan Activities

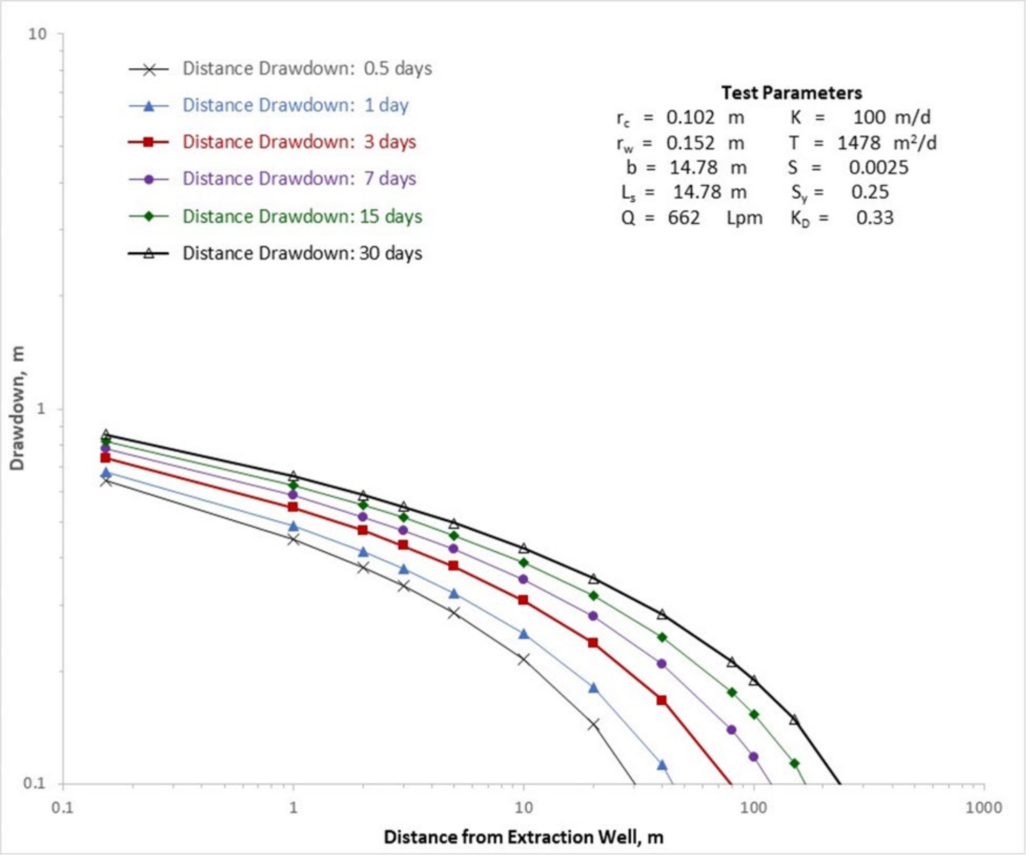
- Modified Step-Drawdown Pumping Test Design (FY26)
  - ➢ Step-drawdown test planned for each extraction well individually
    - 4-hour duration for each of the first three steps
    - 60-hour duration for the fourth step
    - Total pumping duration of 72 hours followed by 72 hours of recovery
    - Pumping rate steps of 44, 87, 143, and 175 gpm are anticipated
    - Estimate intermediate scale (≤100 m) hydraulic and storage properties
  - ➢ Samples collected during each step test



Predicted Well Water-Level Response During a Modified Step-Drawdown Test

Phase 2 Hydrologic Test Plan Activities

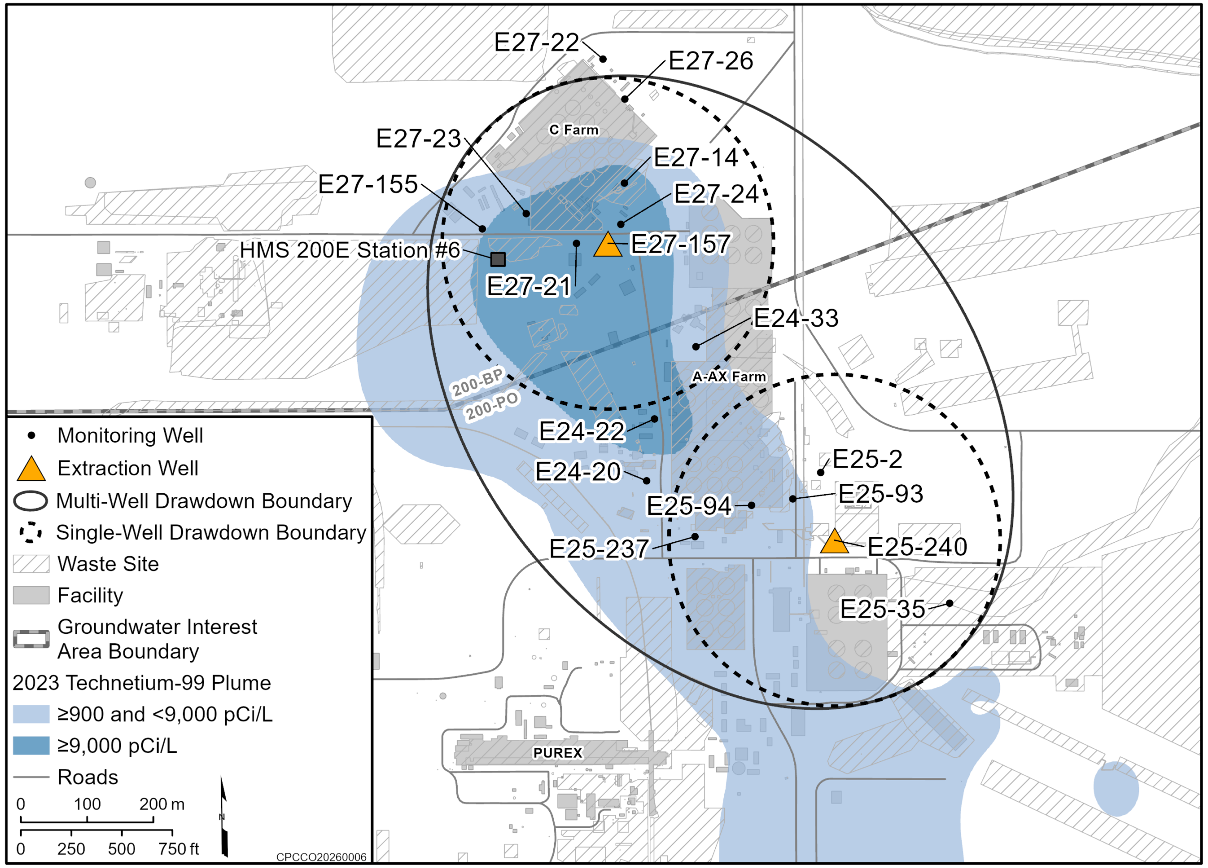
- Extended Constant-Rate Pumping Test Design (FY26)
  - ➢ Constant-rate test planned for each extraction well individually
    - A constant, uniform pumping rate of 175 gpm anticipated
    - Up to 30 days pumping duration followed by an equal duration of recovery
    - Estimate large-scale (≤250 m) hydraulic and storage properties
  - ➢ Samples collected during each constant-rate test to observe contaminant concentration changes during pumping



Predicted Well Water-Level Response Versus Distance During a Constant-Rate Pumping Test

Phase 2 Hydrologic Test Plan Activities

- Multi-Well Constant-Rate Pumping Test Design (FY26)
  - ➢ Constant-rate test planned utilizing extraction wells pumped simultaneously
    - A constant, uniform pumping rate of 175 gpm from each well (combined total of 350 gpm) anticipated
    - 30-day pumping duration followed by 30 days of recovery
    - Increases imposed drawdown over inter-extraction well region
    - Possibly detect hydrologic barriers
  - ➢ Samples collected during the multi-well test to observe contaminant concentration changes during pumping



Predicted Areal Drawdown Boundary Around Extraction Wells at the end of Single- and Multi-Well Constant-Rate Pumping Tests