U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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Saturated Zone Testing Highlights—2005 to 2006

Presented to:
Nuclear Waste Technical Review Board

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Arlington, Virginia

Predecisional—Preliminary

Outline

- **New Nye County Early Warning Drilling Program (EWDP) wells (Phase V)**
- **Hydrostratigraphic framework model (HFM) update**
- **Summary of hydraulic and tracer test results at Nye County Site 22**
- **Innovative methods of identifying flowing intervals and measuring ambient flow velocities in Nye County wells**

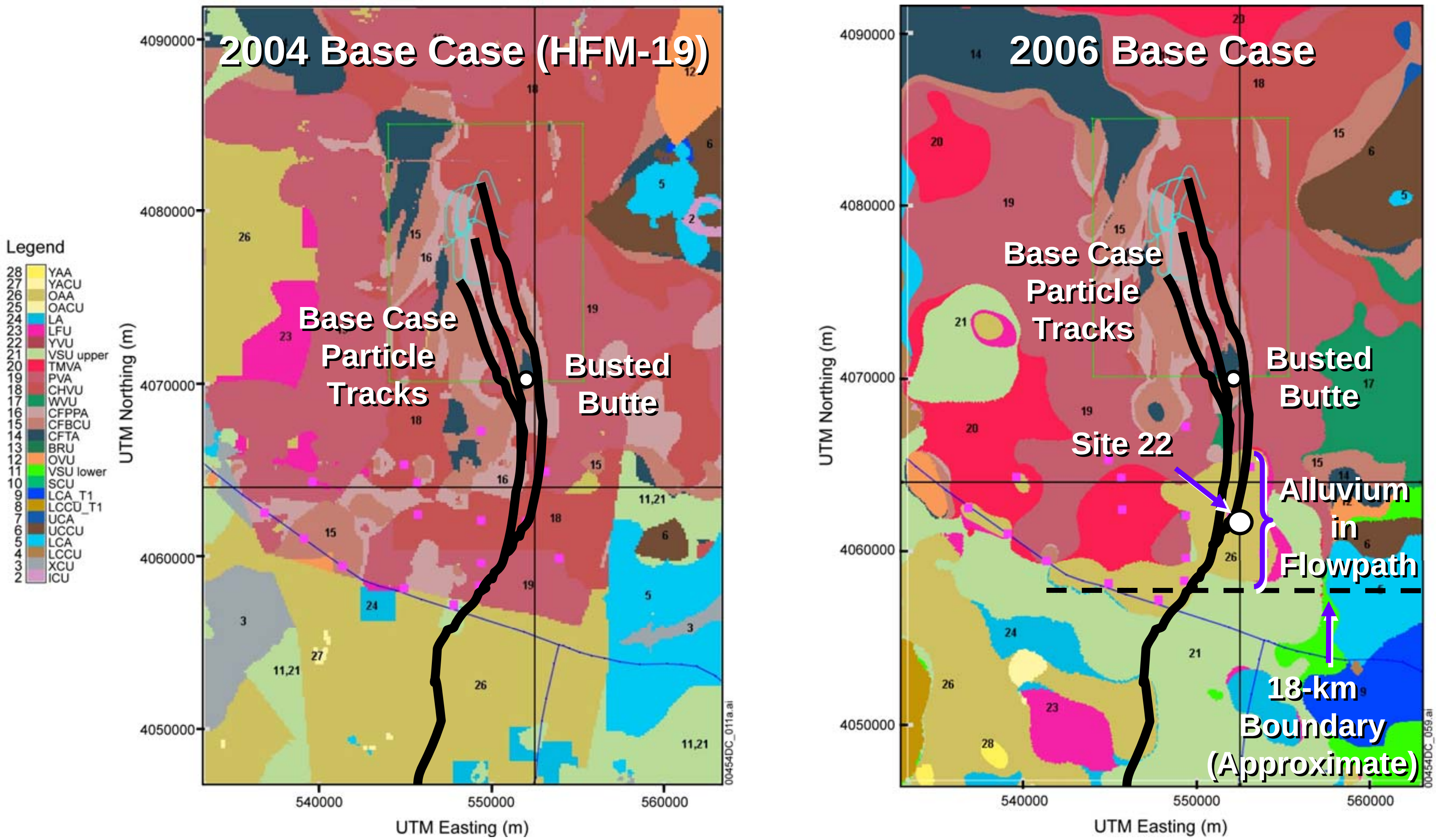
All of these activities have benefited from or been a result of close cooperation between the DOE-funded Nye County Department of Natural Resources EWDP, the DOE-University of Nevada Cooperative Agreement, and Yucca Mountain Project (YMP) scientists

New Nye County Wells

Nye County Early Warning Drilling Program (Phase I, II, III, IV, and V Wells)

Phase V Well **Location of Tests Detailed in this Presentation**

HFM Comparisons at Water Table



Differences mainly attributable to

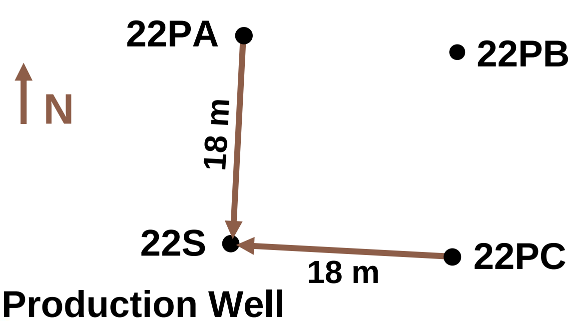
- **Nye County EWDP Wells (updates south and west of Busted Butte)**
- **2002 and 2004 USGS Regional Models (boundaries, other changes)**

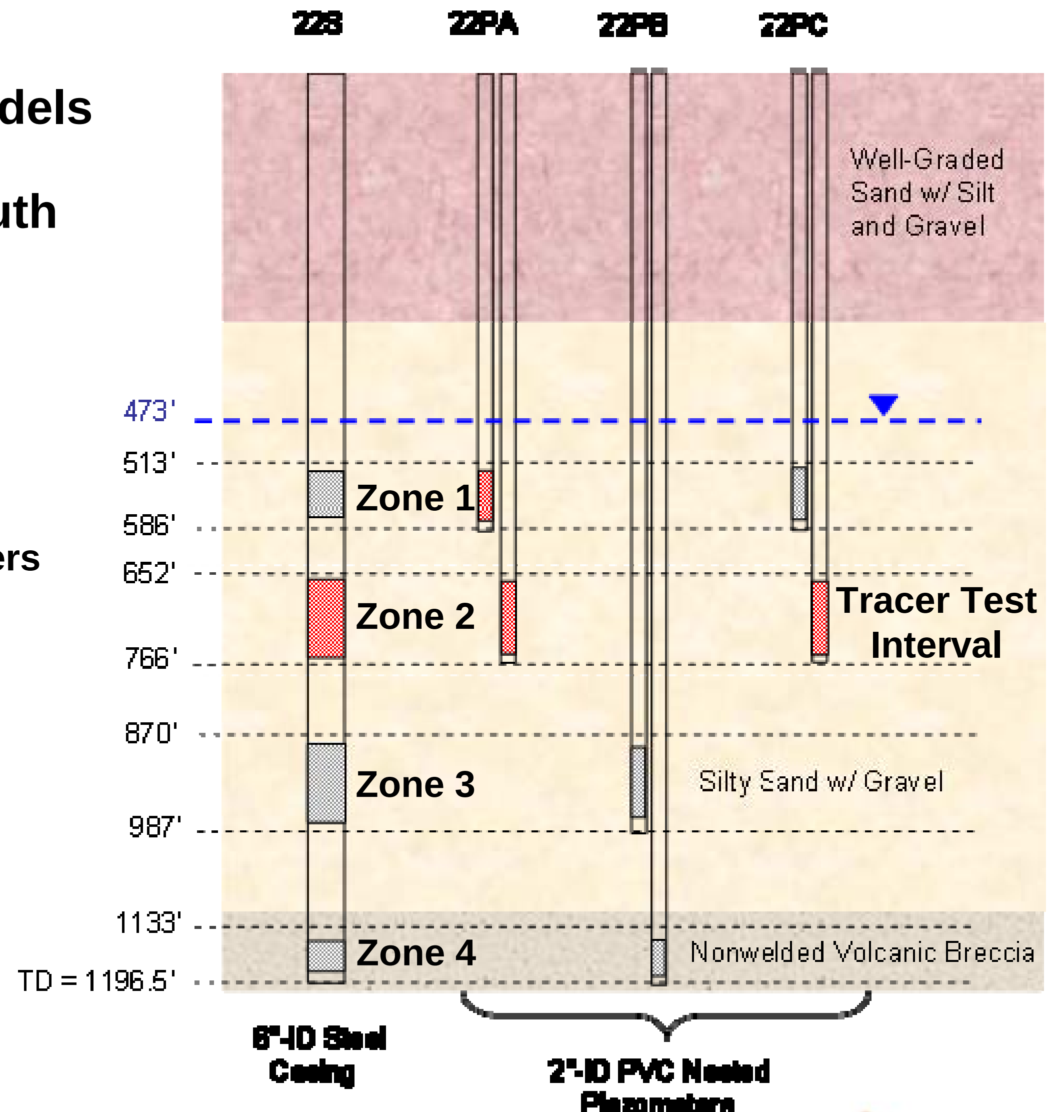
Testing at Nye County Site 22

Objective

- **Test/validate conceptual models of flow and radionuclide transport in the alluvium south of Yucca Mountain**
- **Obtain estimates of**
  - **Hydraulic conductivity**
  - **Groundwater velocity and flow direction**
  - **Effective porosity**
  - **Diffusive mass-transfer parameters**
  - **Reactive transport properties**
  - **Colloid transport parameters**

Site Layout





Site 22 Hydraulic Test Interpretations

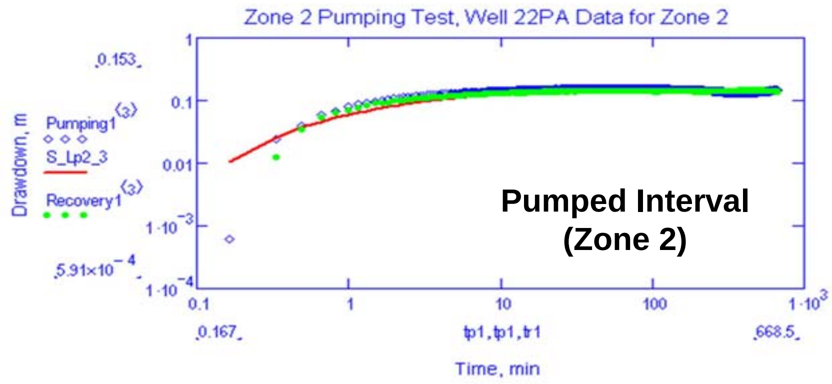
- **Analyzed observation well drawdowns/recoveries in pumped zone and in zones above and below pumped zone**
- **Three-aquifer semi-analytical solution:**

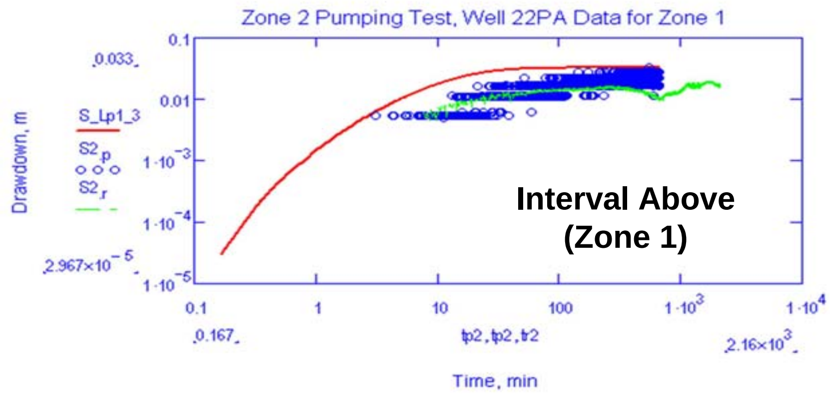
$$s_1 p\tilde{S}_1 = T_1 \nabla \tilde{S}_1 + \chi_{1-2}(\tilde{S}_2 - \tilde{S}_1) - \chi_0 \tilde{S}_1$$

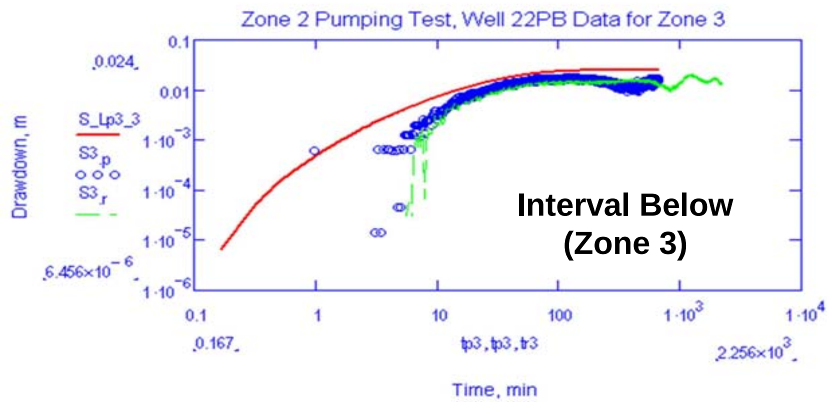
$$s_2 p\tilde{S}_2 = T_2 \nabla \tilde{S}_2 + \chi_{1-2}(\tilde{S}_1 - \tilde{S}_2) + \chi_{2-3}(\tilde{S}_3 - \tilde{S}_2)$$

$$s_3 p\tilde{S}_3 = T_3 \nabla \tilde{S}_3 + \chi_{2-3}(\tilde{S}_2 - \tilde{S}_3)$$

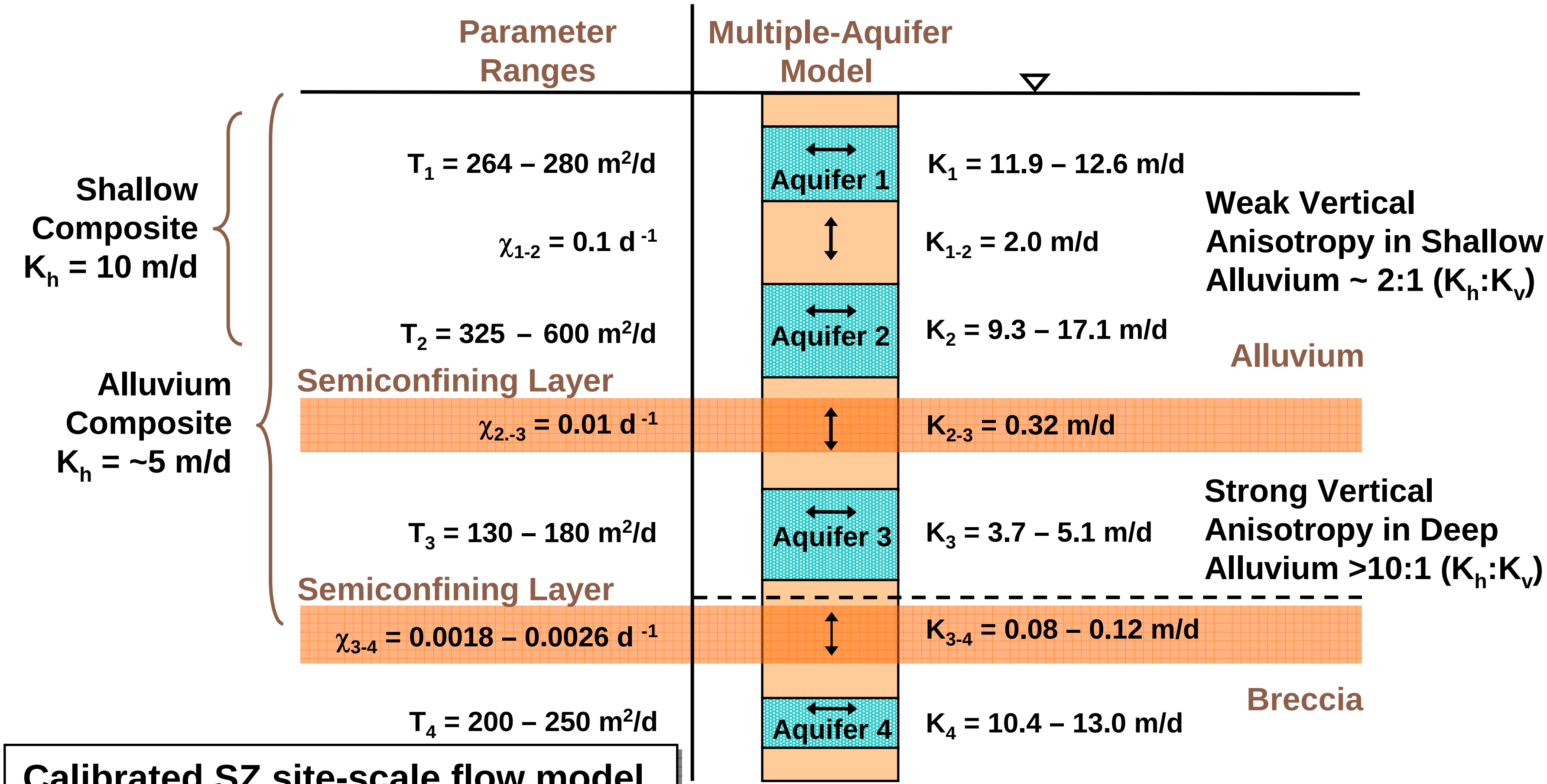
- **Obtain estimates of storativity (s) and transmissivity (T) in all three "aquifers", and χ (vertical hydraulic parameter) in intervening layers use two-aquifer solution for top and bottom zones**







Alluvium Flow Conceptualization and Parameters from Hydraulic Tests

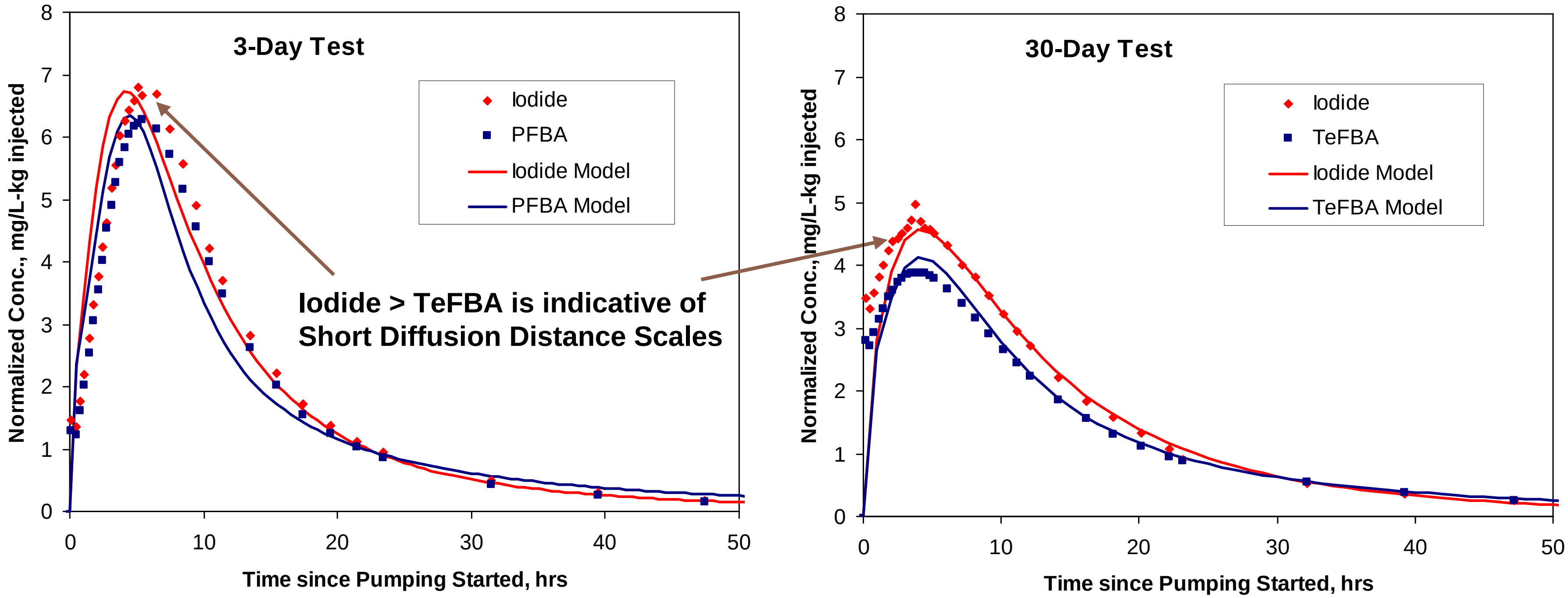


Calibrated SZ site-scale flow model has K_h = 17 m/d at Site 22 and 10:1 alluvium vertical anisotropy

⟷ Flow Directions of Conductivity Estimates

Note: Drawing not to scale

22S Single-Well Tracer Tests—Dual-Porosity Behavior with Short Diffusion Distances

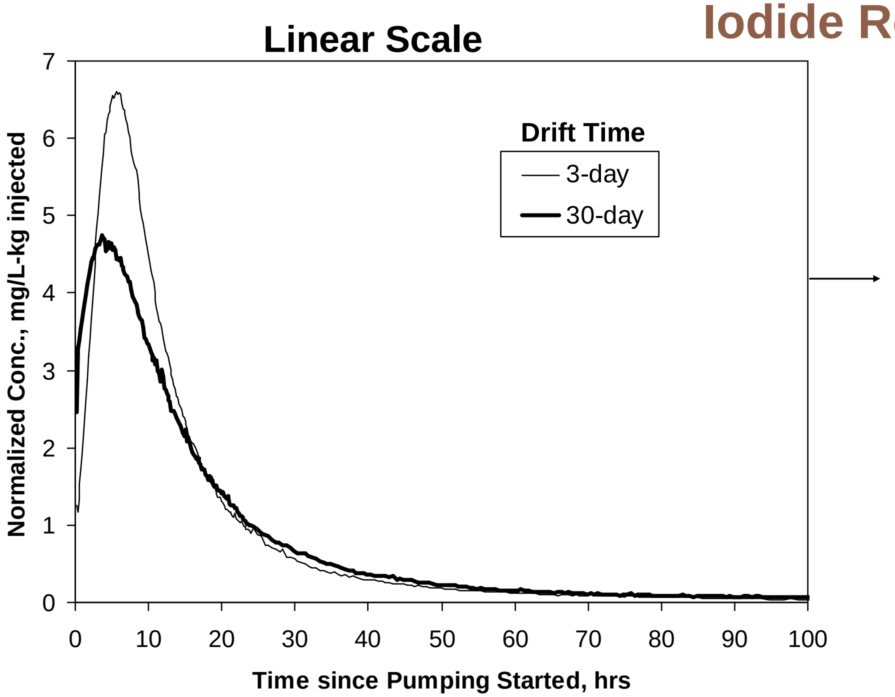


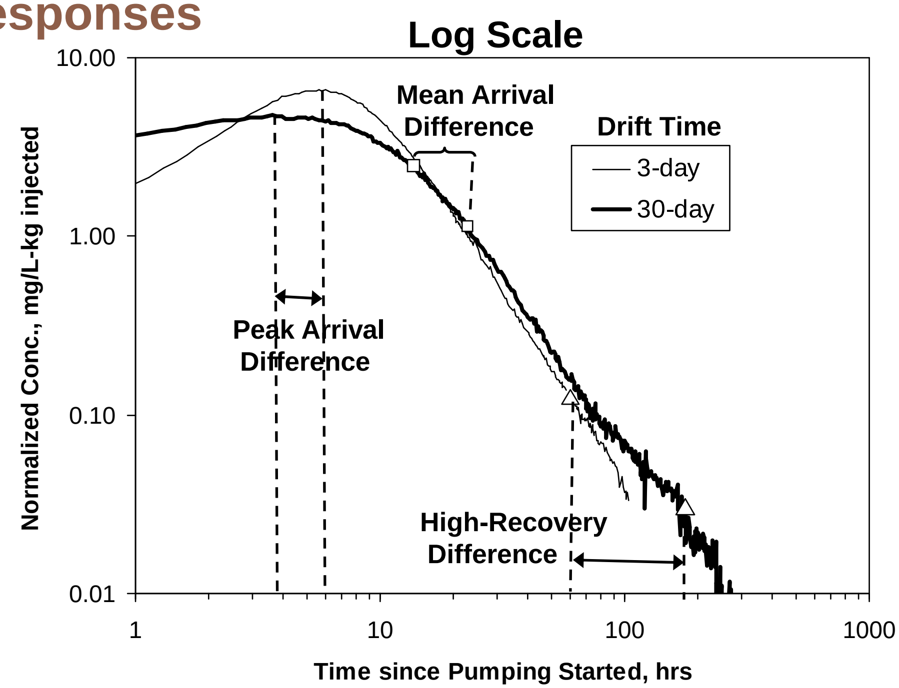
3-Day Recovery: ~100%
30-Day Recovery: 96.5%

- **Single set of diffusion parameters used to fit both tracer test responses**
- **Dual-porosity behavior observed, but system should exhibit single porosity behavior over longer time and length scales**

Single-Well Tracer Tests Yield Estimates of Alluvium Specific Discharge at Site 22

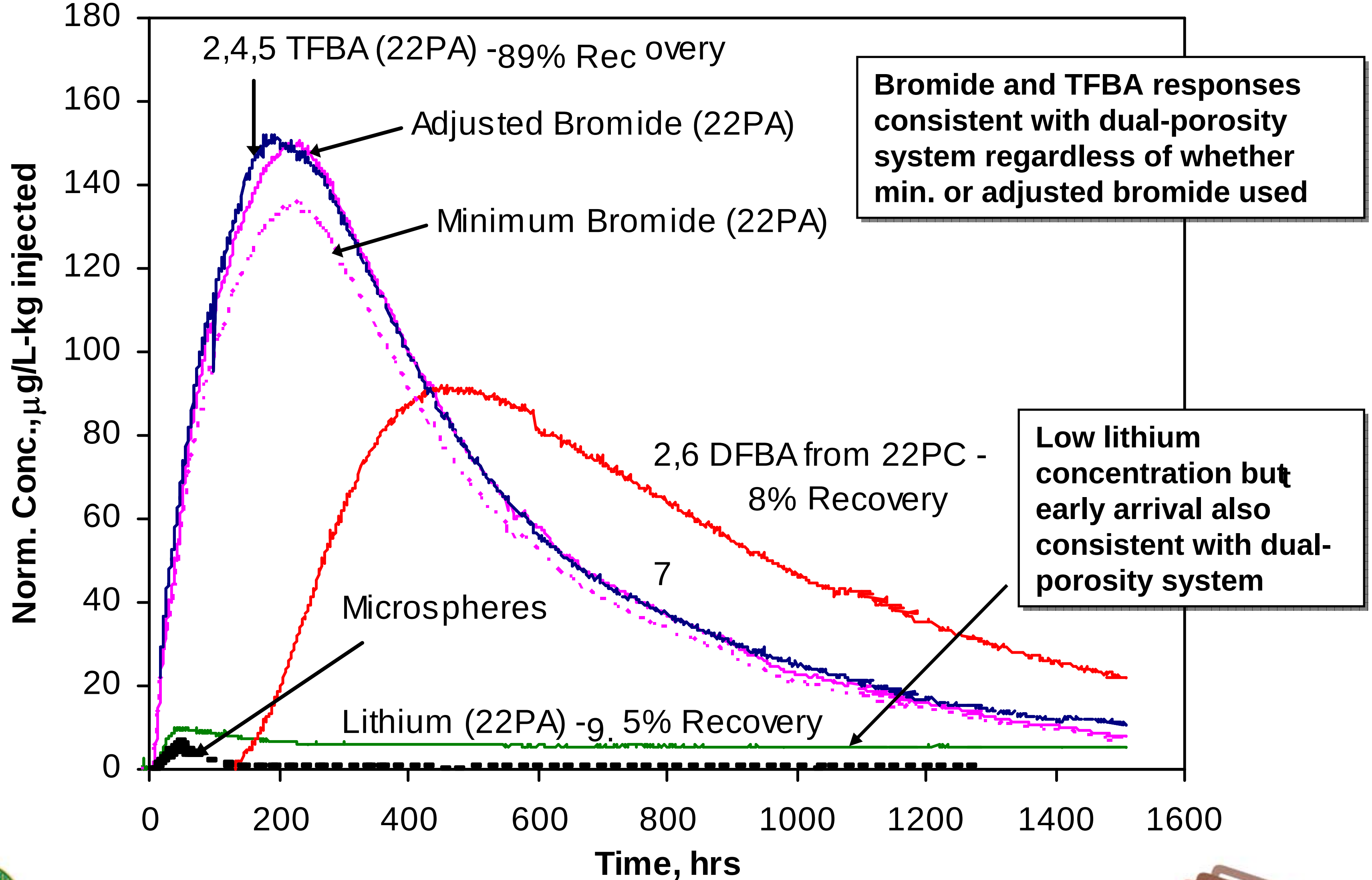
Iodide Responses





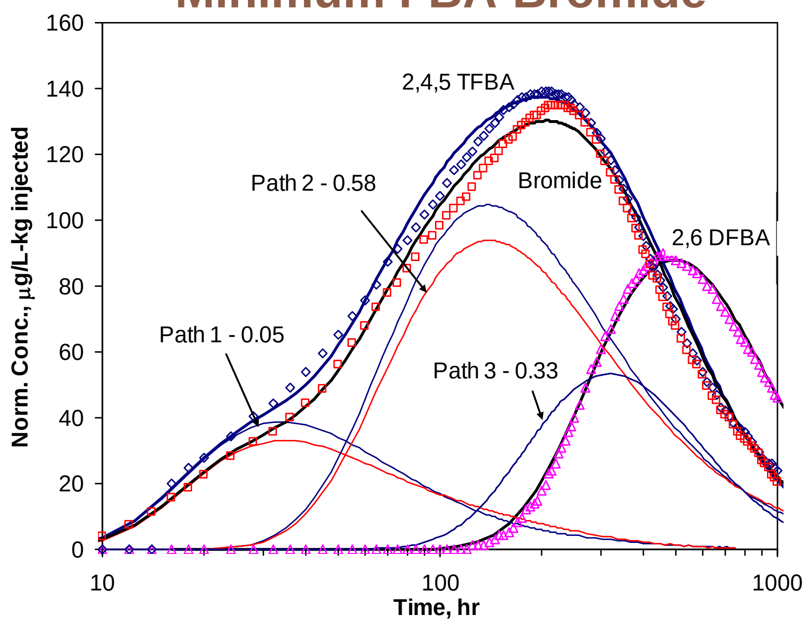
- **Specific discharge estimated from tracer responses as function of drift period**
  - **From difference in peak arrival times—0.5 to 1.2 m/yr**
  - **From difference in high-recovery times—2.2 to 5.4 m/yr**
  - **Range from single-well tests in 19D (at 18-km boundary) —1.2 to 9.4 m/yr**
- **Other specific discharge estimates**
  - **Independently estimated from head/conductivity data—3 to 12 m/yr**
  - **From calibrated SZ site-scale flow model— ~21 m/yr**

Cross-Hole Tracer Test 1 Results

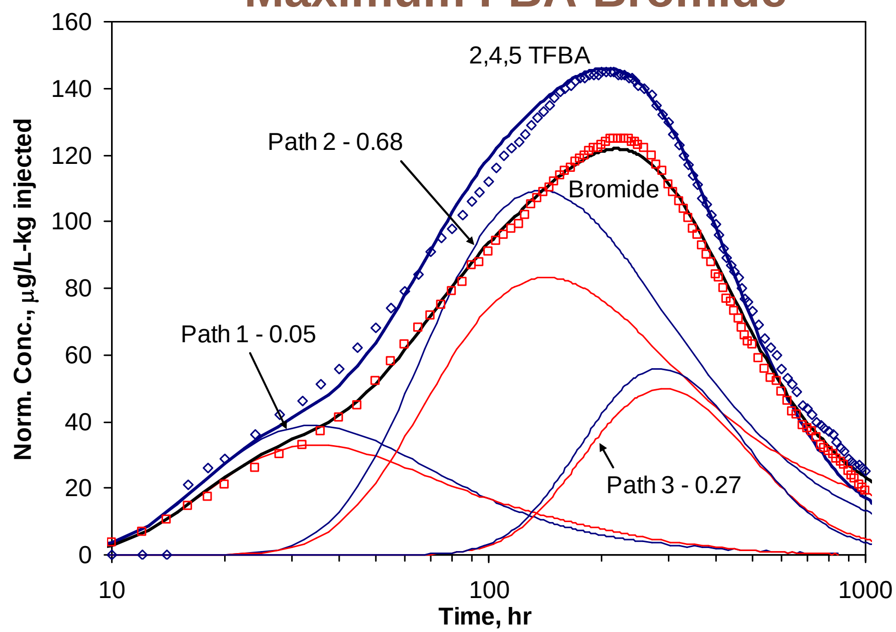


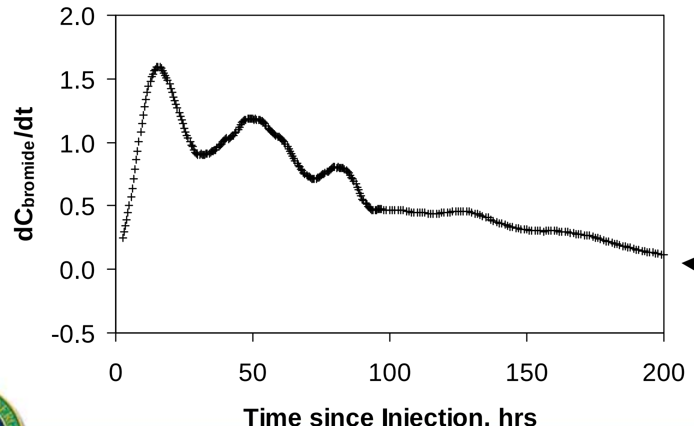
Cross-Hole Test 1—Dual Porosity, Multiple Pathway Interpretations

Minimum FBA-Bromide



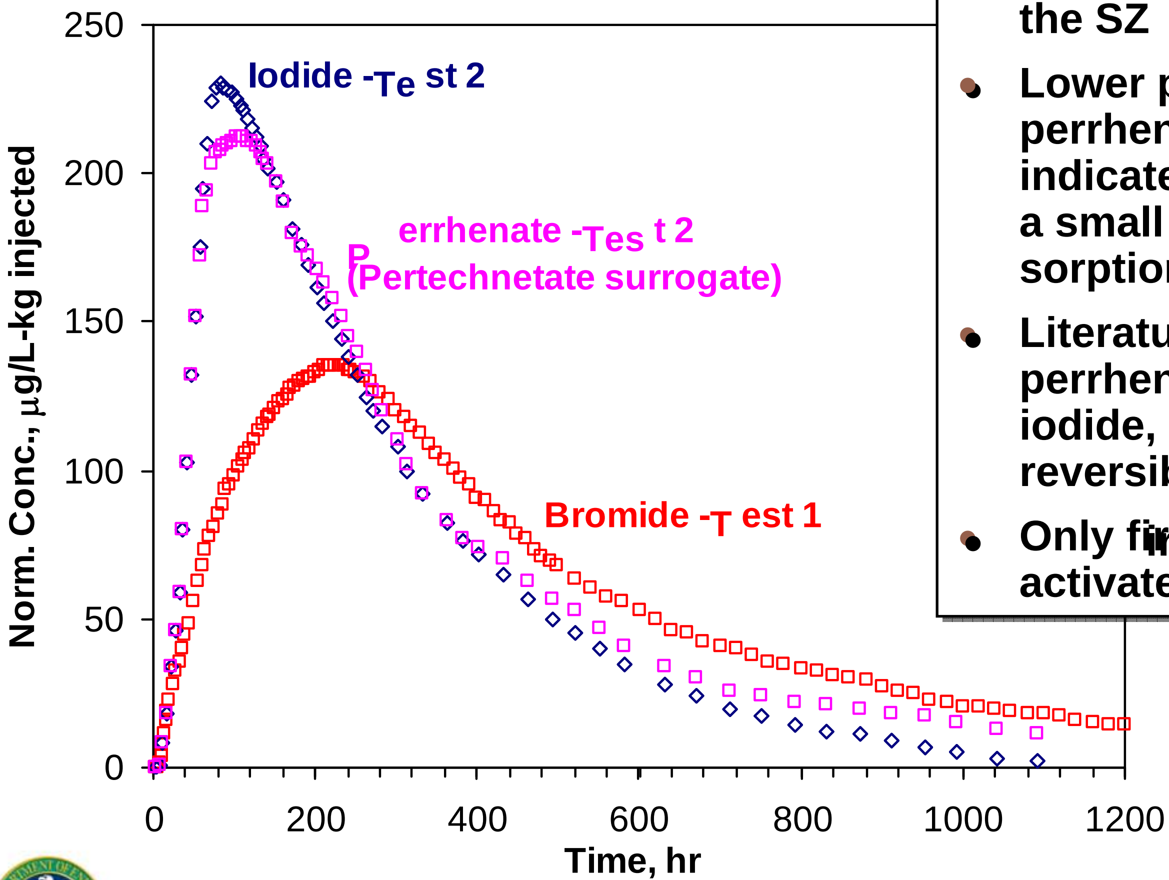
Maximum FBA-Bromide





- **Both interpretations involve 3 flow pathways with dual-porosity behavior in at least 2 of the pathways**
- **Evidence for multiple flow pathways apparent from derivative of bromide and TFBA responses**

Cross-Hole Test 2 Tracer Responses



- Tc-99 is predicted to be a significant contributor to dose and is expected to be in the form of pertechnetate in the SZ
- Lower peak and longer tail of perrhenate relative to iodide indicates either greater diffusion or a small amount of reversible sorption of perrhenate
- Literature diffusion coefficient of perrhenate is ~0.7 times that of iodide, so responses suggest some reversible sorption of perrhenate
- Only first two flow pathways activated in Test 2

Transport Parameter Estimates from Site 22 Tracer Tests

Parameter	Lower Bound	Best Estimate	Upper Bound
Effective flow porosity	0.036	0.121	0.187
Specific discharge, m/yr*	0.5	–	5.4
Longitudinal dispersivity, m	1.6	5	10
Horizontal flow anisotropy ratio (N-S principal axis)	2.5	3.1	10.7
Characteristic diffusion time scale, $(L^2/8D_m)$, hr	0 (14.1)	–	1125
Ratio of stagnant to flowing water volumes	0 (0.3)	–	1.9
Microsphere filtration rate constant, hr^{-1}	0.04	–	0.16
Microsphere detachment rate constant, hr^{-1}	0.00034	–	0.0011

*Estimate of ~2 m/yr and southerly direction from cross-hole Test 1 tracer responses at start of Test 2

SZ flow/transport models

- **Effective flow porosity—Normal distribution with mean = 0.18**
- **Horizontal anisotropy—Zone of enhanced permeability along Fortymile Wash**
- **Conceptual model—Alluvium as porous medium (single-porosity)**

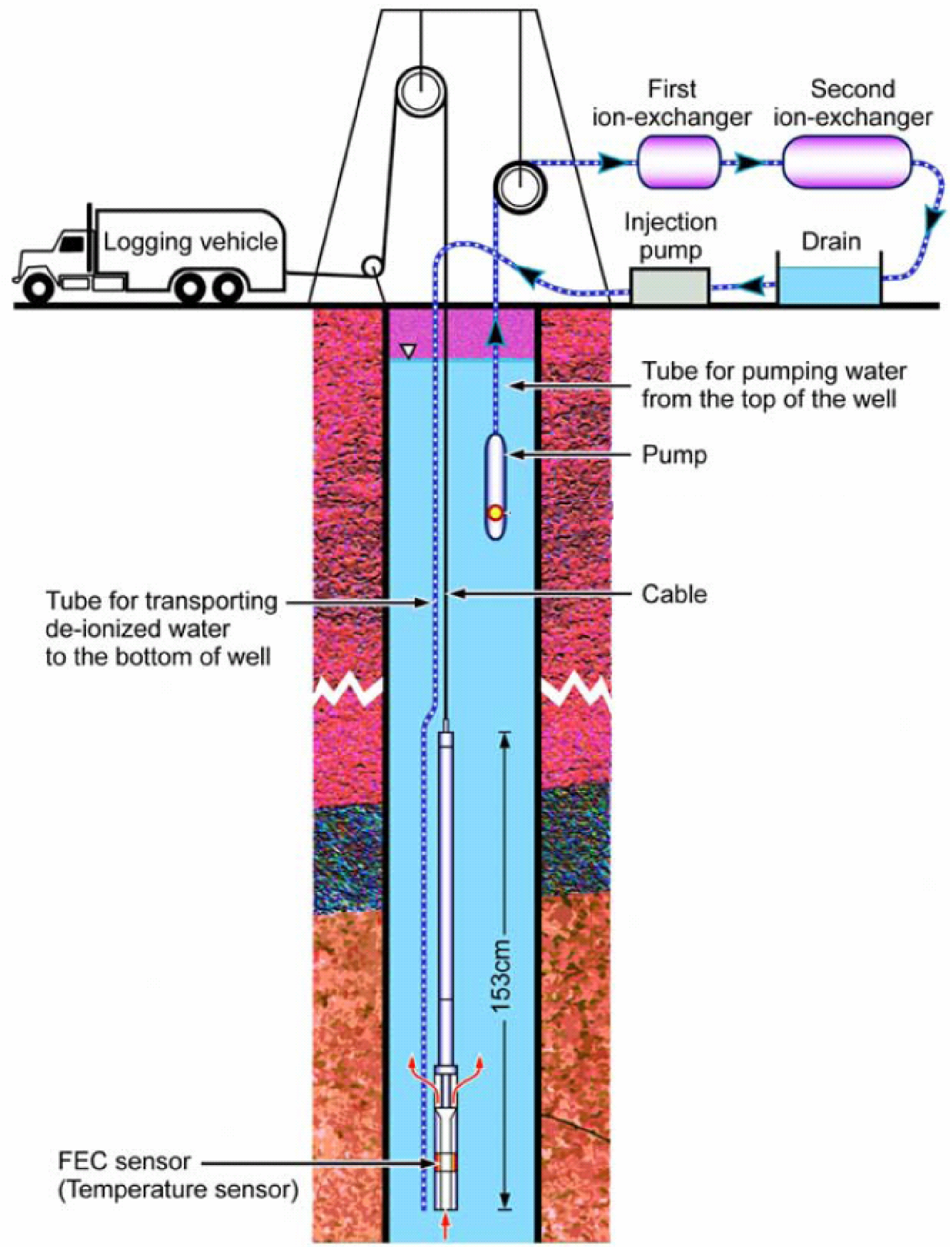
Outline Revisited

- New Nye County Early Warning Drilling Program (EWDP) wells (Phase V)
- Hydrostratigraphic framework model update
- Summary of hydraulic and tracer test results at Nye County Site 22
- **Innovative methods of identifying flowing intervals and measuring ambient flow velocities in Nye County wells**

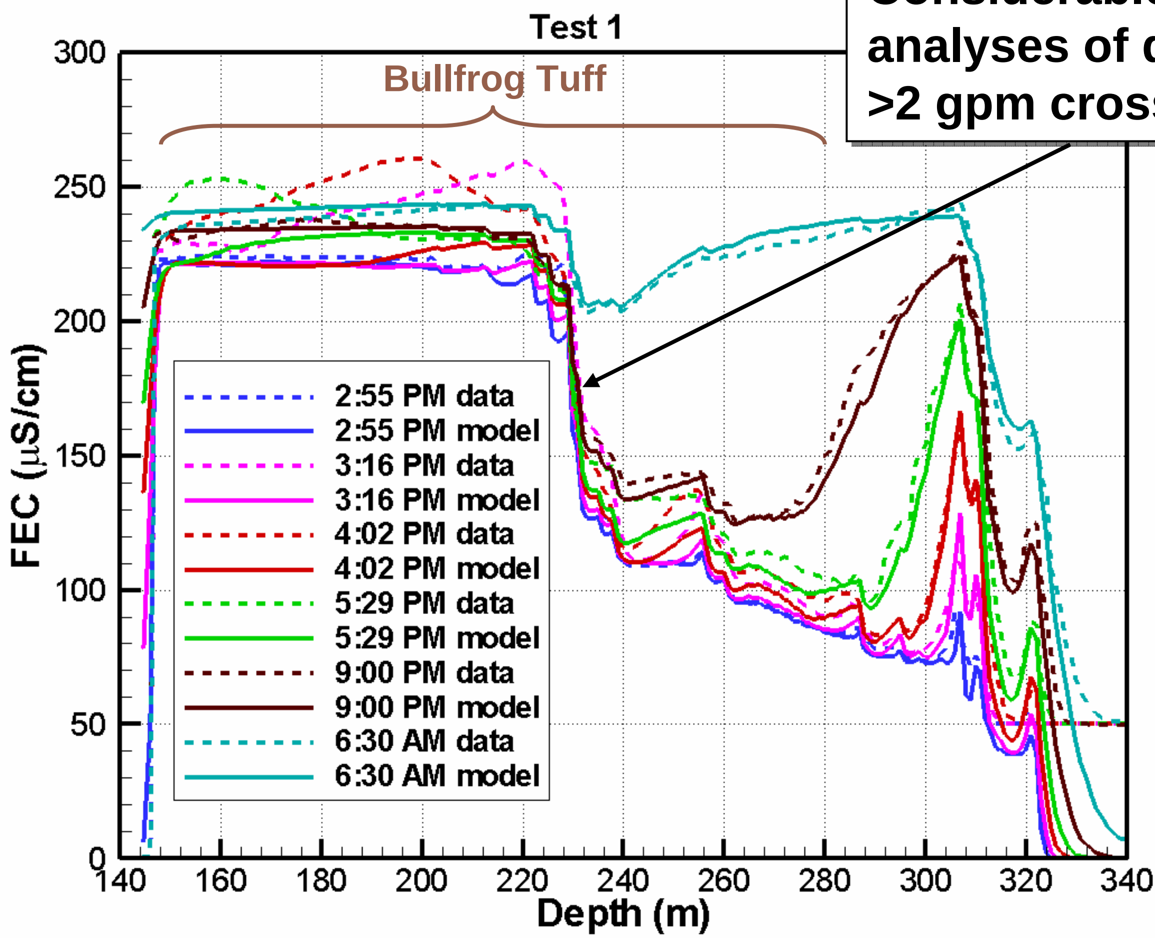
Flowing Electrical Conductivity (FEC) Logging

1. **Set pump above and injection tube below interval to be tested**
2. **Recirculate fluid**
3. **Log wellbore under ambient or pumped conditions**

DOE OSTI/S&T and Nye County EWDP Collaboration



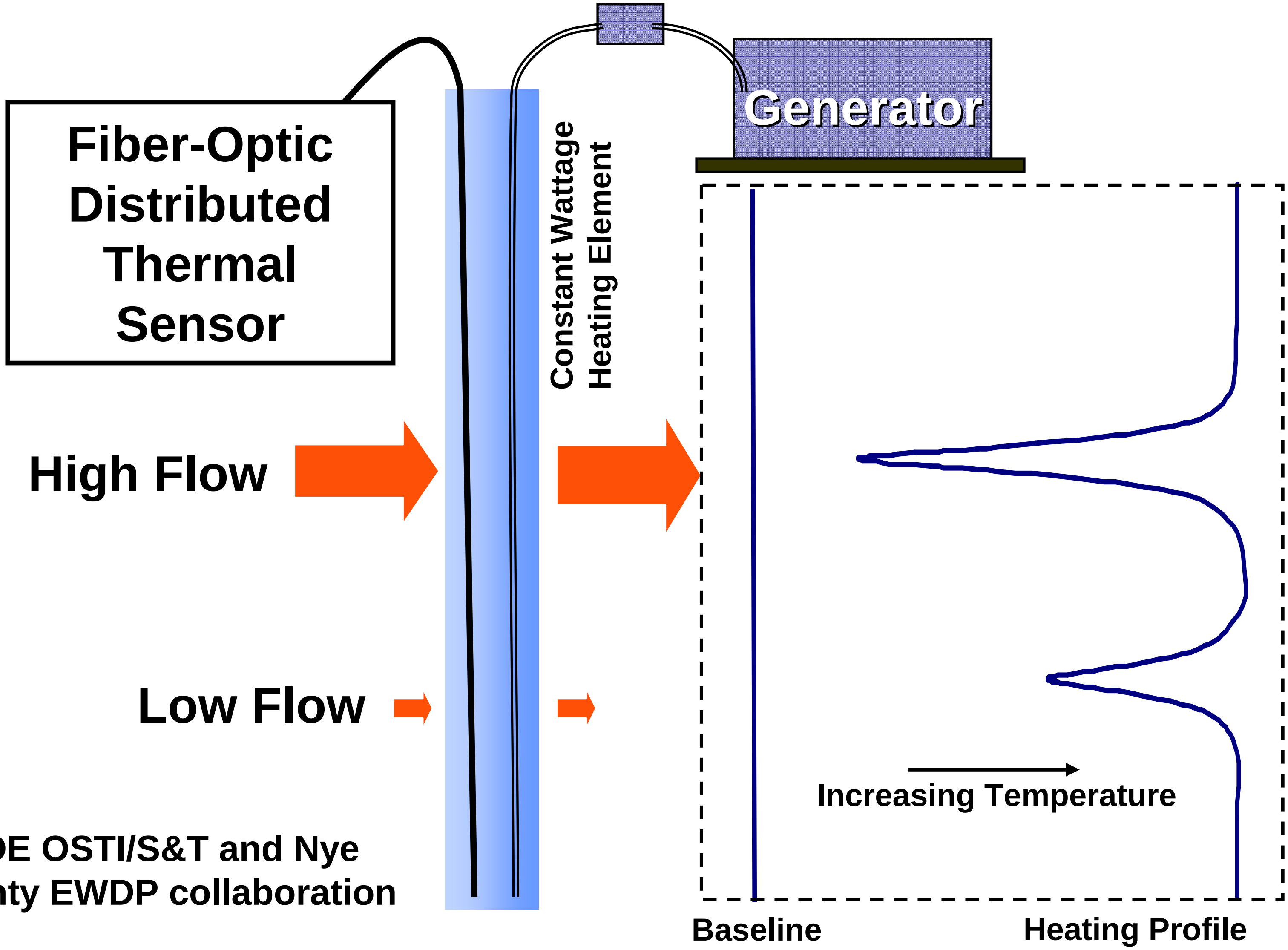
FEC Logs in 24PB Indicate High-Flow Zone at ~230 m below Surface in Bullfrog Tuff



Considerable uncertainty from analyses of different logs, but >2 gpm cross-flow

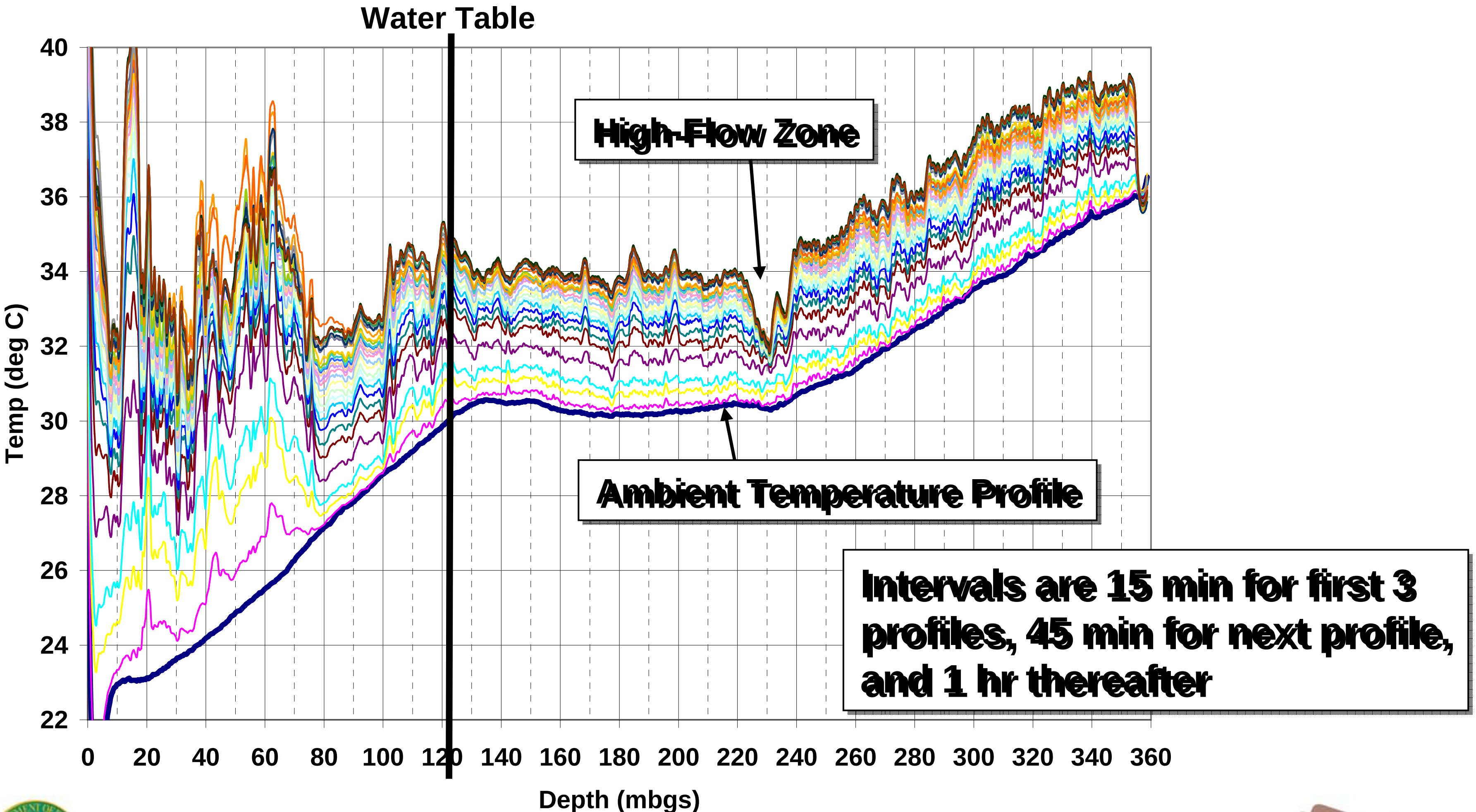
8 GPM recirculation; ambient flow after 2:55 pm

Distributed Thermal Sensor Logging

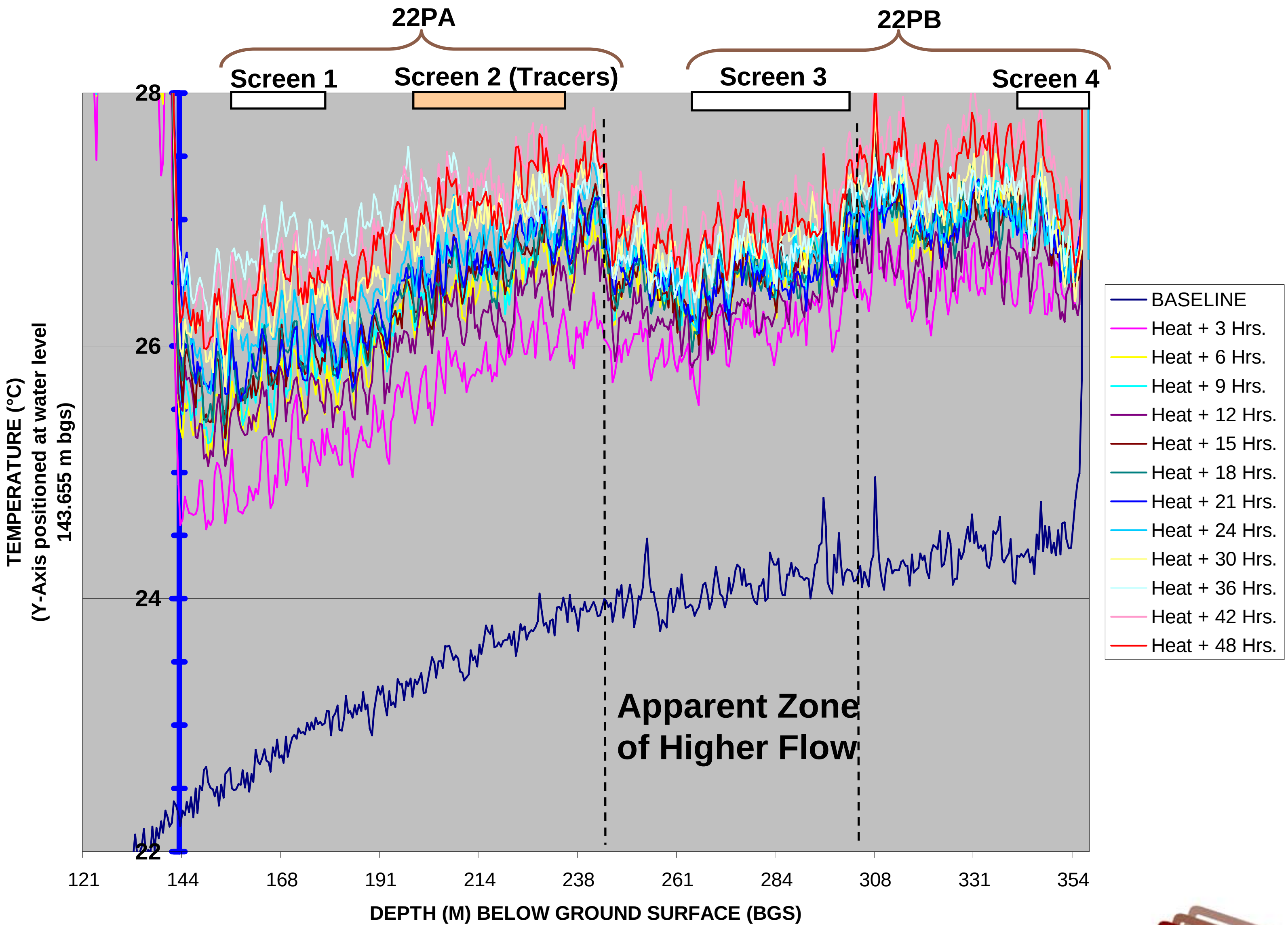


DOE OSTI/S&T and Nye County EWDP collaboration

High-Flow Zone in 24PB Confirmed by Thermal Logging in Grouted-In Borehole



Heating Profiles in 22PB



Summary and Conclusions

- **HFM updates based on (1) Nye County wells and (2) 2006 regional flow model result in greater predicted radionuclide transport through alluvium**
- **Site 22 hydraulic tests**
  - **Weak vertical anisotropy shallow (2:1); stronger vertical anisotropy deep (>10:1)**
  - **10:1 used in SZ site-scale flow model**
  - **Composite K_h = 5 to 10 m/d versus 17 m/d in SZ site-scale flow model**

Summary and Conclusions (continued)

- **Site 22 tracer tests**
  - **Dual-porosity system with short diffusion scales versus single-porosity system in SZ site-scale transport model**
  - **Effective flow porosity estimate = 0.12 versus 0.18 (mean) in SZ site-scale transport model**
  - **Specific discharge estimates = 0.5 to 5.4 m/yr (southerly direction) versus ~21 m/yr in SZ site-scale flow model**
- **FEC and DTPS logging results indicate high flow zone in Bullfrog Tuff at Site 24**

Key to Map Legend

Legend

28	YAA	=	Young Alluvial Aquifer
27	YACU	=	Young Alluvial Confining Unit
26	OAA	=	Older Alluvial Aquifer
25	OACU	=	Older Alluvial Confining Unit
24	LA	=	Limestone Aquifer
23	LFU	=	Lava flow Unit
22	YVU	=	Young Volcanic Units
21	VSU upper	=	Volcanic and Sedimentary Units
20	TMVA	=	Timber Mountain Volcanic Aquifer
19	PVA	=	Paintbrush Volcanic Aquifer
18	CHVU	=	Calico Hills Volcanic Unit
17	WVU	=	Wahmonie Volcanic Unit
16	CFPPA	=	Crater Flat – Prow Pass Aquifer
15	CFBCU	=	Crater Flat – Bullfrog Confining Unit
14	CFTA	=	Crater Flat – Tram Aquifer
13	BRU	=	Belted Range Unit
12	OVU	=	Older Volcanic Units
11	VSU lower	=	Volcanic and Sedimentary Units
10	SCU	=	Sedimentary Confining Unit
9	LCA_T1	=	Lower Carbonate Aquifer Thrust
8	LCCU_T1	=	Lower Clastic Confining Unit Thrust
7	UCA	=	Upper Carbonate Aquifer
6	UCCU	=	Upper Clastic Confining Unit
5	LCA	=	Lower Carbonate Aquifer
4	LCCU	=	Lower Clastic Confining Unit
3	XCU	=	Crystalline Confining Unit
2	ICU	=	Intrusive Confining Unit