LA-UR-14-21253
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Intended for: arXiv
NGWA Conference on Hydrology and Water Scarcity in the Rio Grande Basin, 2014-02-25/2014-02-26 (Albuquerque, New Mexico, United States)
Web

Issued: 2014-02-27

Structure of Groundwater Flow in the Espanola Basin near Rio Grande and Buckman Wellfield

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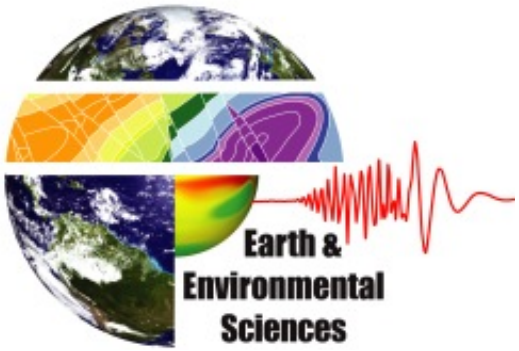
NGWA Conference
Hydrology and Water Scarcity in the Rio Grande Basin (#5034)
February 25, 2014
Albuquerque, NM



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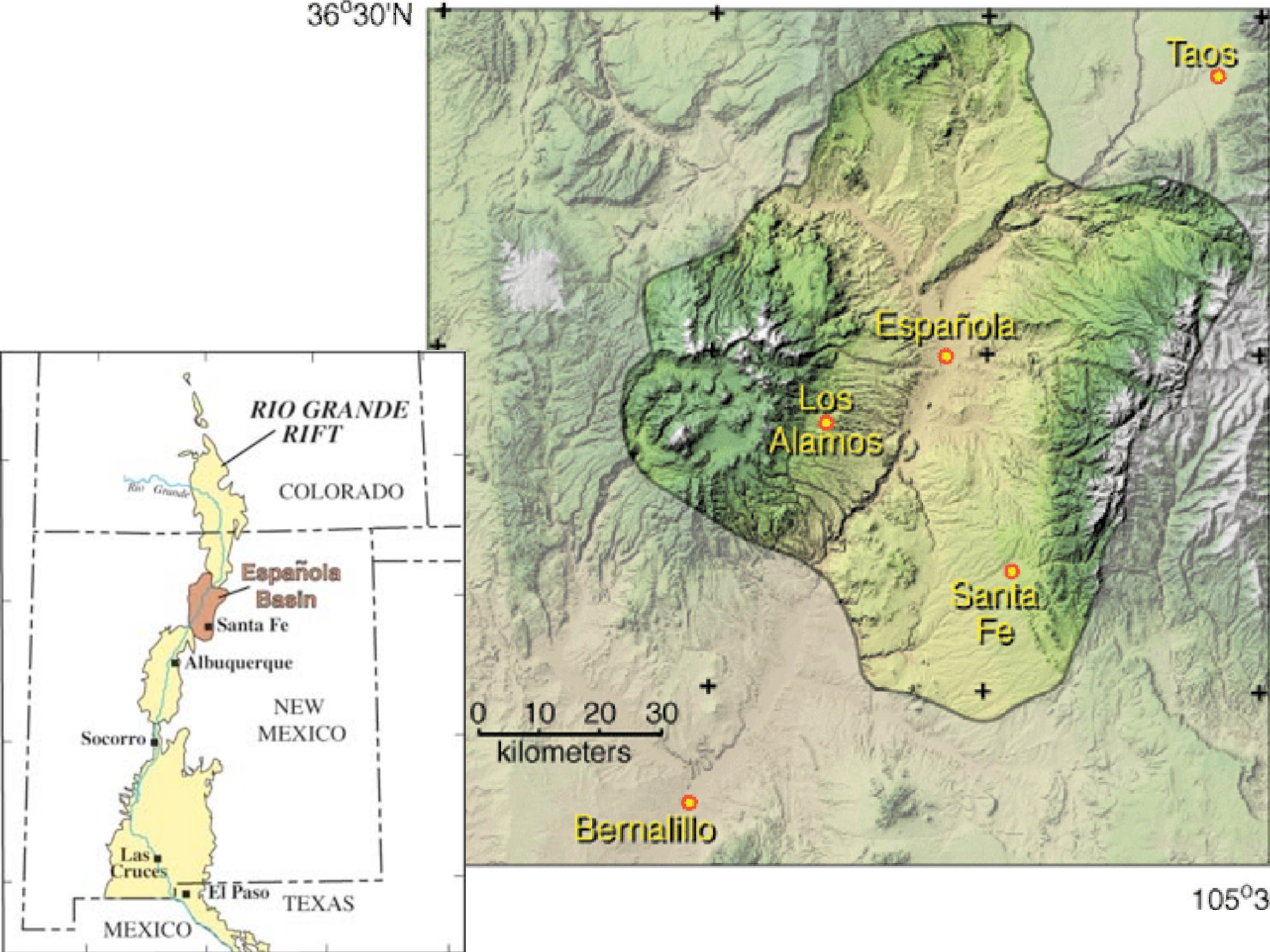
36°30'N
Taos
Española
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0 10 20 30
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105°3
RIO GRANDE RIFT
COLORADO
Río Grande
Española Basin
Santa Fe
Albuquerque
NEW MEXICO
Socorro
Las Cruces
El Paso
TEXAS
MEXICO

Introduction

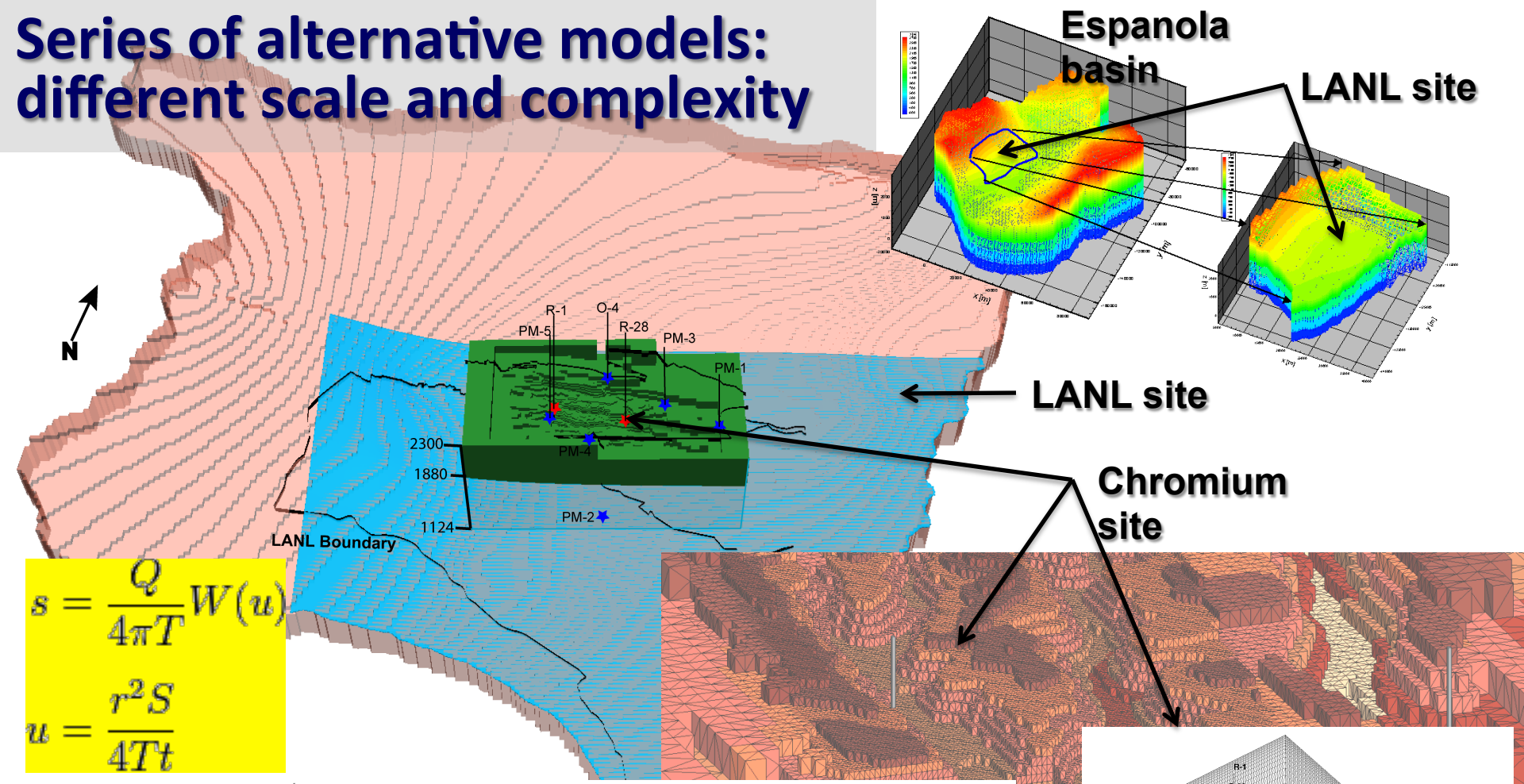
- Groundwater flow within Espanola Basin:
  - West of Rio Grande (LANL), it is generally eastward (towards Rio Grande)
  - East of Rio Grande (Pojoaque), it is generally westward (towards Rio Grande)
- This suggests that the Rio Grande is a discharge boundary for the groundwater in the basin
- However, this may not be exactly the case

Introduction

Understanding of the hydraulic connection between the Rio Grande and the regional aquifer near the Buckman Wellfield can be deduced from existing information:

- **Water-level data (pre- and post- development, pumping drawdowns; spring-discharge rates)**
- **Basin geology and hydrostratigraphy**
- **Ground-surface subsidence**
- **Isotope data**

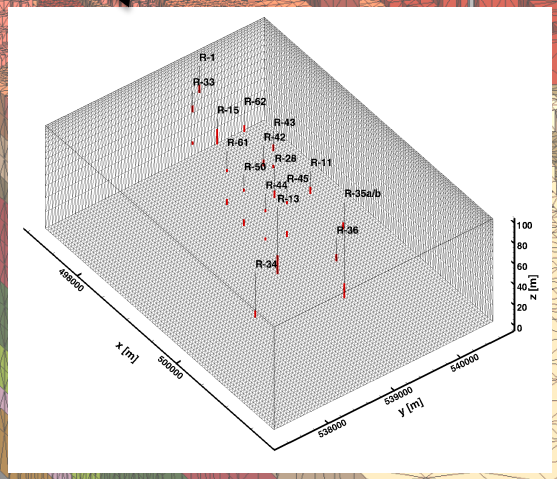
Series of alternative models: different scale and complexity



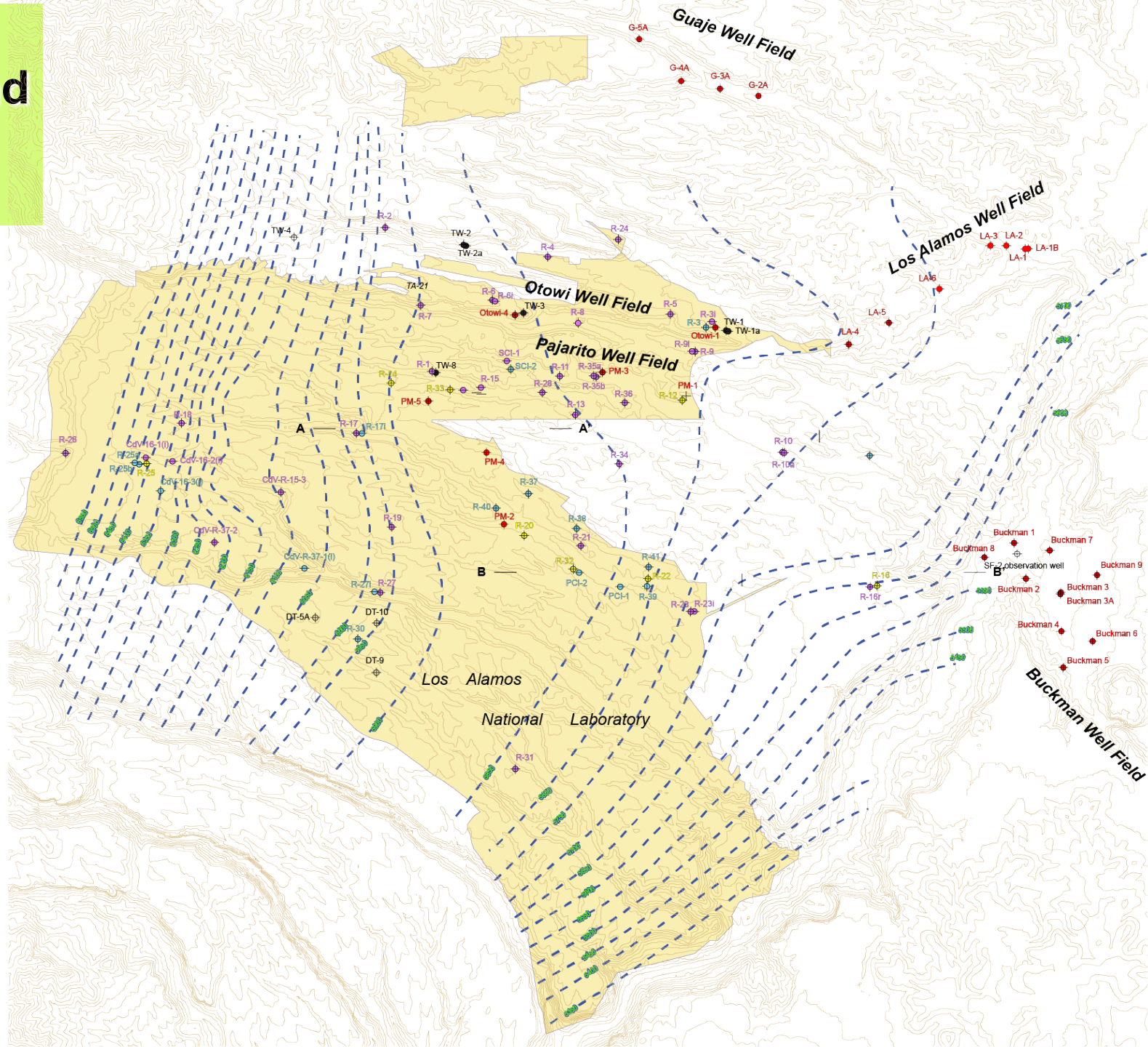
$$s = \frac{Q}{4\pi T} W(u)$$

$$u = \frac{r^2 S}{4Tt}$$

$$c(x,y,z,t) = \frac{1}{8\pi\theta x_S y_S z_S} \int_0^t I(t-\tau)\exp(-\lambda\tau)\left[erfc\left(\frac{x-\frac{1}{2}x_S-v\tau}{2\sqrt{\alpha_L v\tau}}\right) - erfc\left(\frac{x+\frac{1}{2}x_S-v\tau}{2\sqrt{\alpha_L v\tau}}\right)\right]$$
$$\times\left[erfc\left(\frac{y-\frac{1}{2}y_S-v\tau}{2\sqrt{\alpha_{TH} v\tau}}\right) - erfc\left(\frac{y+\frac{1}{2}y_S-v\tau}{2\sqrt{\alpha_{TH} v\tau}}\right)\right]$$
$$\times\left[erfc\left(\frac{z-(z_0+z_S)}{2\sqrt{\alpha_{TV} v\tau}}\right) - erfc\left(\frac{z-z_0}{2\sqrt{\alpha_{TV} v\tau}}\right) + erfc\left(\frac{z+(z_0+z_S)}{2\sqrt{\alpha_{TV} v\tau}}\right)\right.$$
$$\left. - erfc\left(\frac{z+z_0}{2\sqrt{\alpha_{TV} v\tau}}\right)\right] d\tau\alpha_L$$



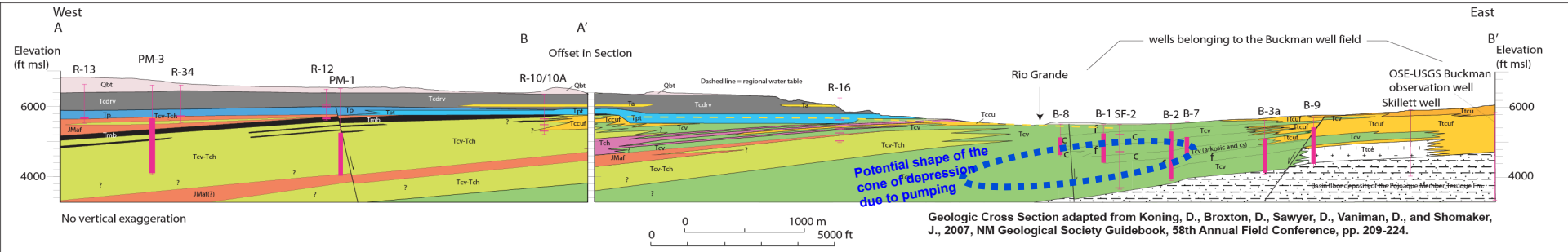
LANL, Rio Grande and Buckman wellfield



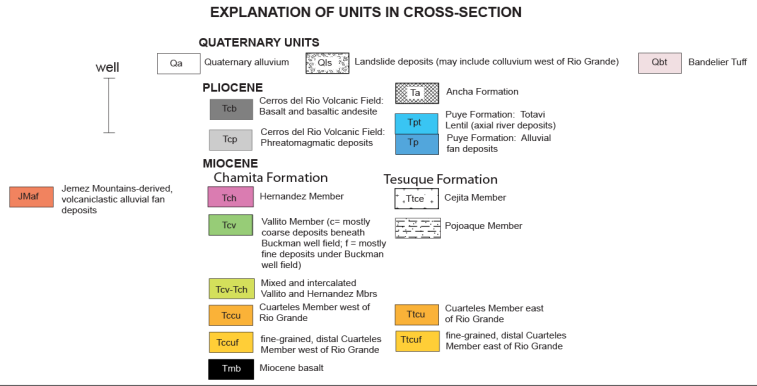
Regional Hydrostratigraphy

- Hydrostratigraphy is expected to have a control on the spatial propagation of the cone of depression caused by Buckman pumping
- Santa Fe group is stratified, and the layering is generally dipping to the West

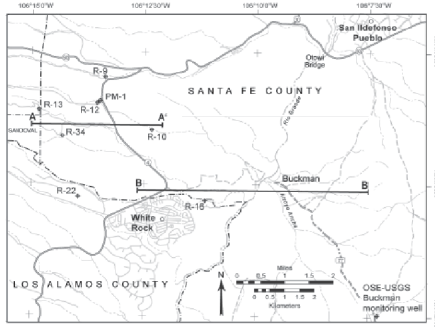
West **Buckman** **East**



Geologic Cross Section adapted from Koning, D., Broxton, D., Sawyer, D., Vaniman, D., and Shomaker, J., 2007, NM Geological Society Guidebook, 58th Annual Field Conference, pp. 209-224.



No vertical exaggeration



Pumping drawdowns

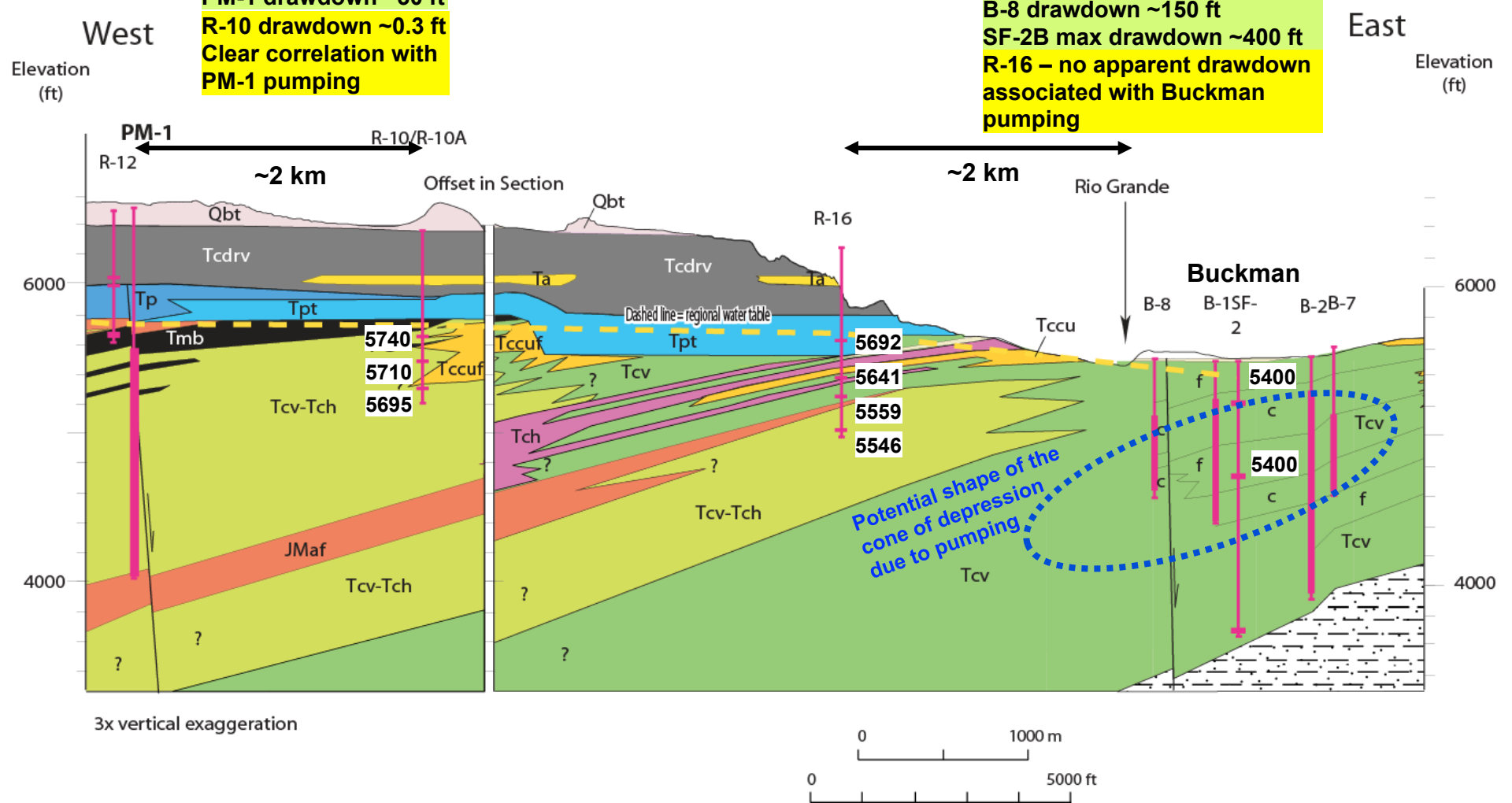
No apparent drawdown associated with Buckman pumping is observed west of Rio Grande in the existing monitoring wells

PM-1 pumps ~150,000 gpd

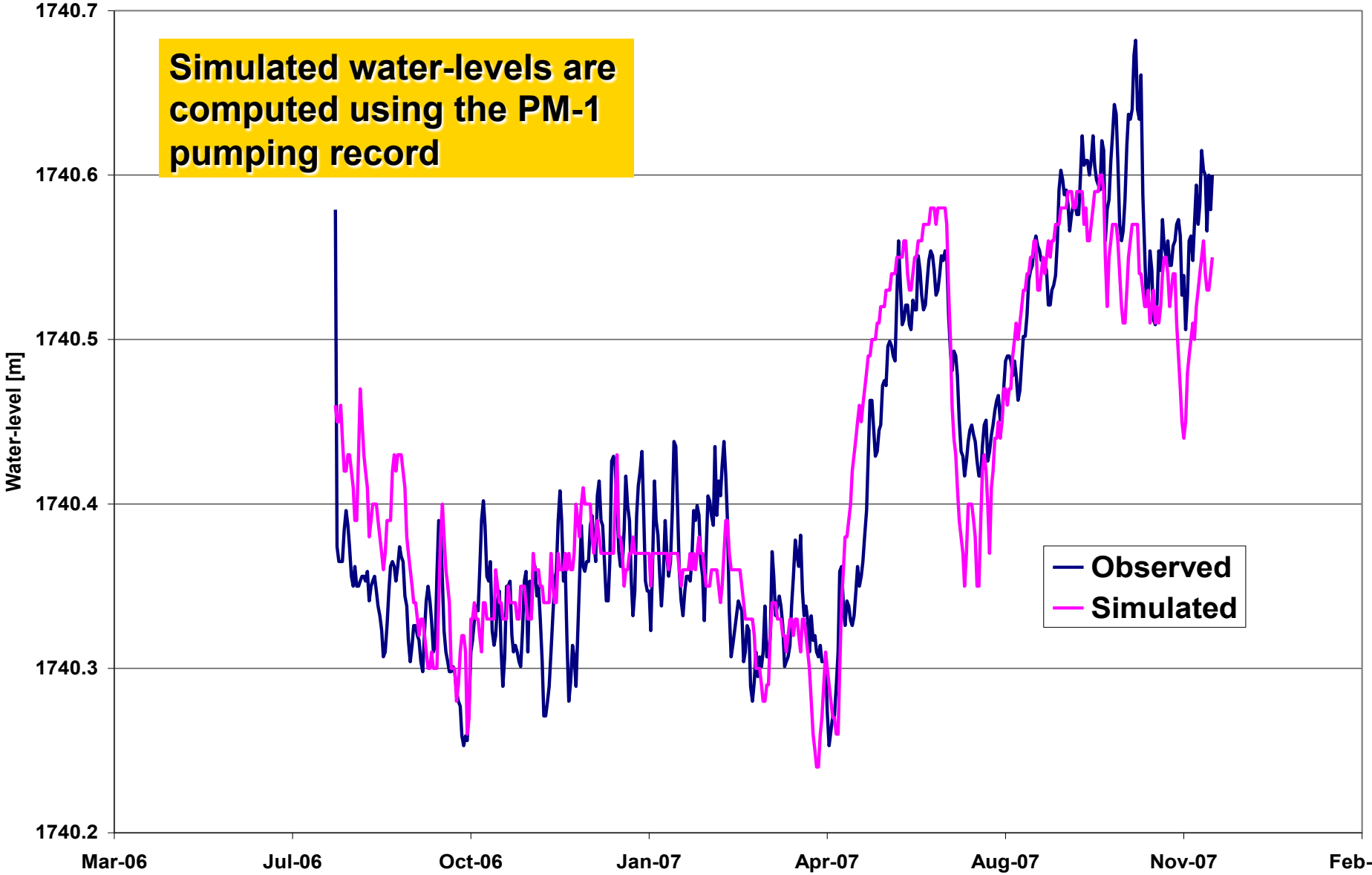
PM-1 drawdown ~30 ft
R-10 drawdown ~0.3 ft
Clear correlation with PM-1 pumping

Buckman pumps ~4,500,000 gpd
B-8 pumps ~800,000 gpd

B-8 drawdown ~150 ft
SF-2B max drawdown ~400 ft
R-16 – no apparent drawdown associated with Buckman pumping

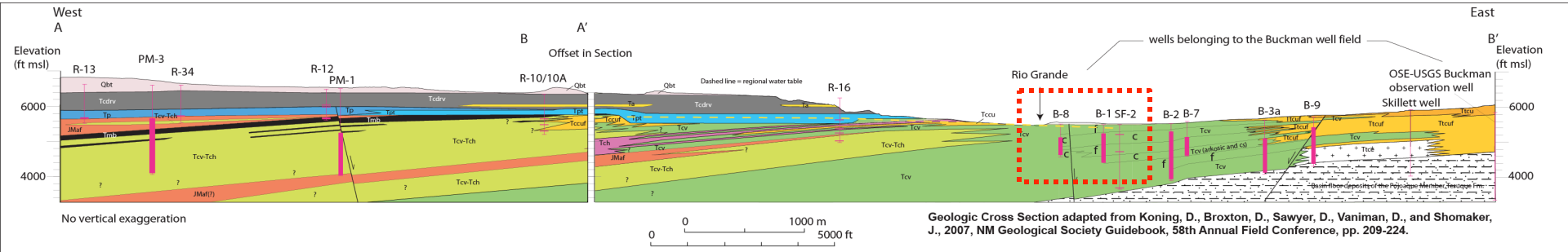


PM-1 water-supply pumping affects R10, Screen 1 water levels. There are no Buckman influences



Regional Hydrostratigraphy

West **Buckman** **East**



Geologic Cross Section adapted from Koning, D., Broxton, D., Sawyer, D., Vaniman, D., and Shomaker, J., 2007, NM Geological Society Guidebook, 58th Annual Field Conference, pp. 209-224.

EXPLANATION OF UNITS IN CROSS-SECTION

well

QUATERNARY UNITS

- Qa — Quaternary alluvium
- Qls — Landslide deposits (may include colluvium west of Rio Grande)
- Qbt — Bandelier Tuff

PLIOCENE

- Tcb — Cerros del Rio Volcanic Field: Basalt and basaltic andesite
- Tcp — Cerros del Rio Volcanic Field: Phreatomagmatic deposits
- Ta — Ancha Formation
- Tpt — Puye Formation: Totavi Lentil (axial river deposits)
- Tp — Puye Formation: Alluvial fan deposits

MIOCENE

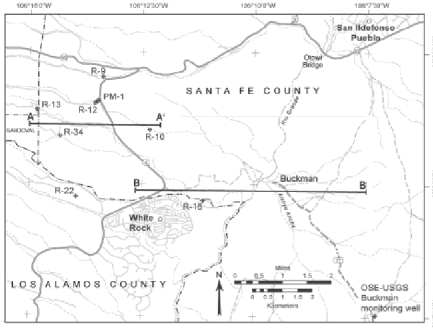
- JMaf — Jemez Mountains-derived, volcaniclastic alluvial fan deposits

Chamita Formation

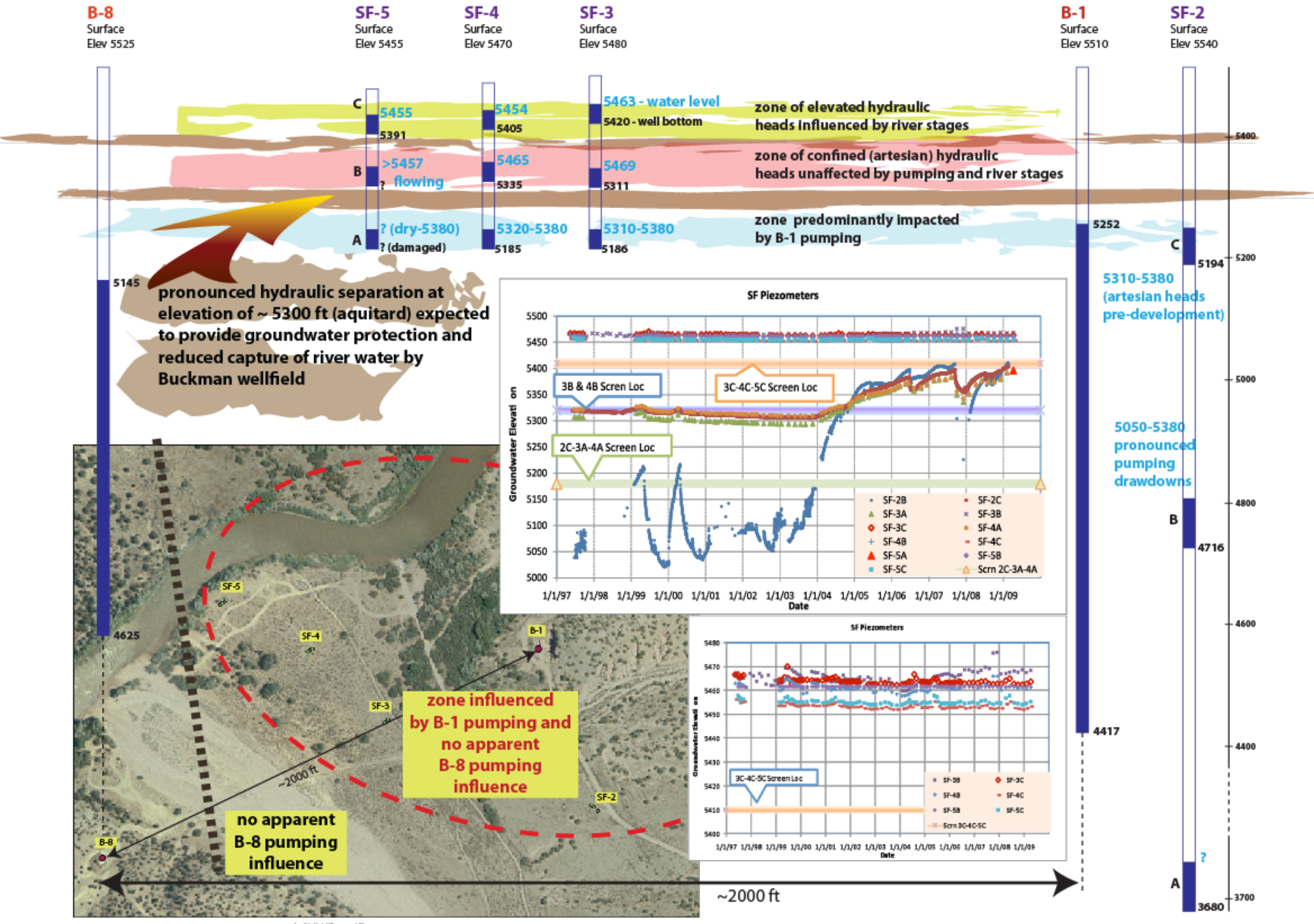
- Tch — Hernandez Member
- Tcv — Vallito Member (c= mostly coarse deposits beneath Buckman well field; f = mostly fine deposits under Buckman well field)
- Tcv-Tch — Mixed and intercalated Vallito and Hernandez Mbrs
- Tccu — Cuarteles Member west of Rio Grande
- Tccuf — fine-grained, distal Cuarteles Member west of Rio Grande
- Tmb — Miocene basalt

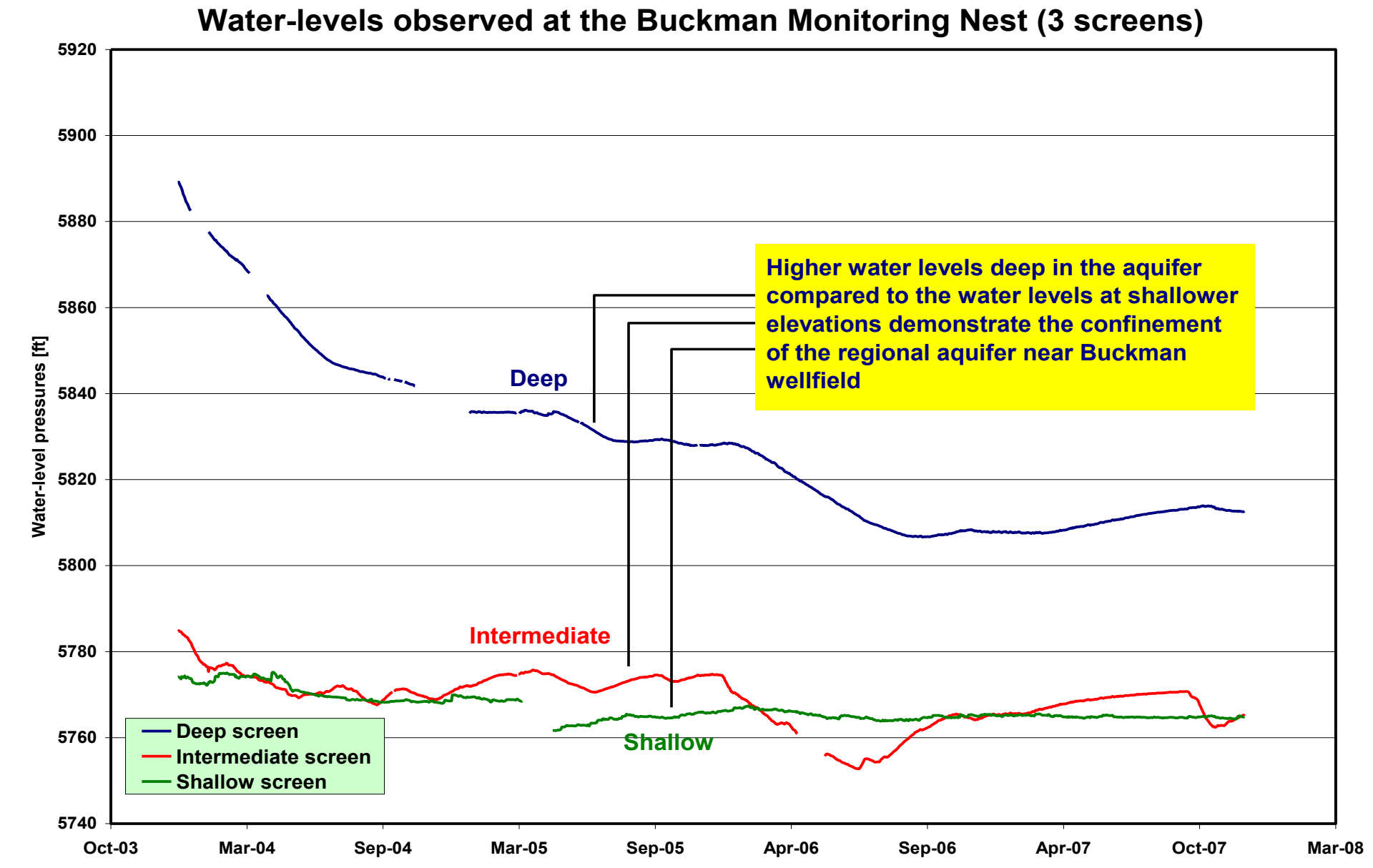
Tesuque Formation

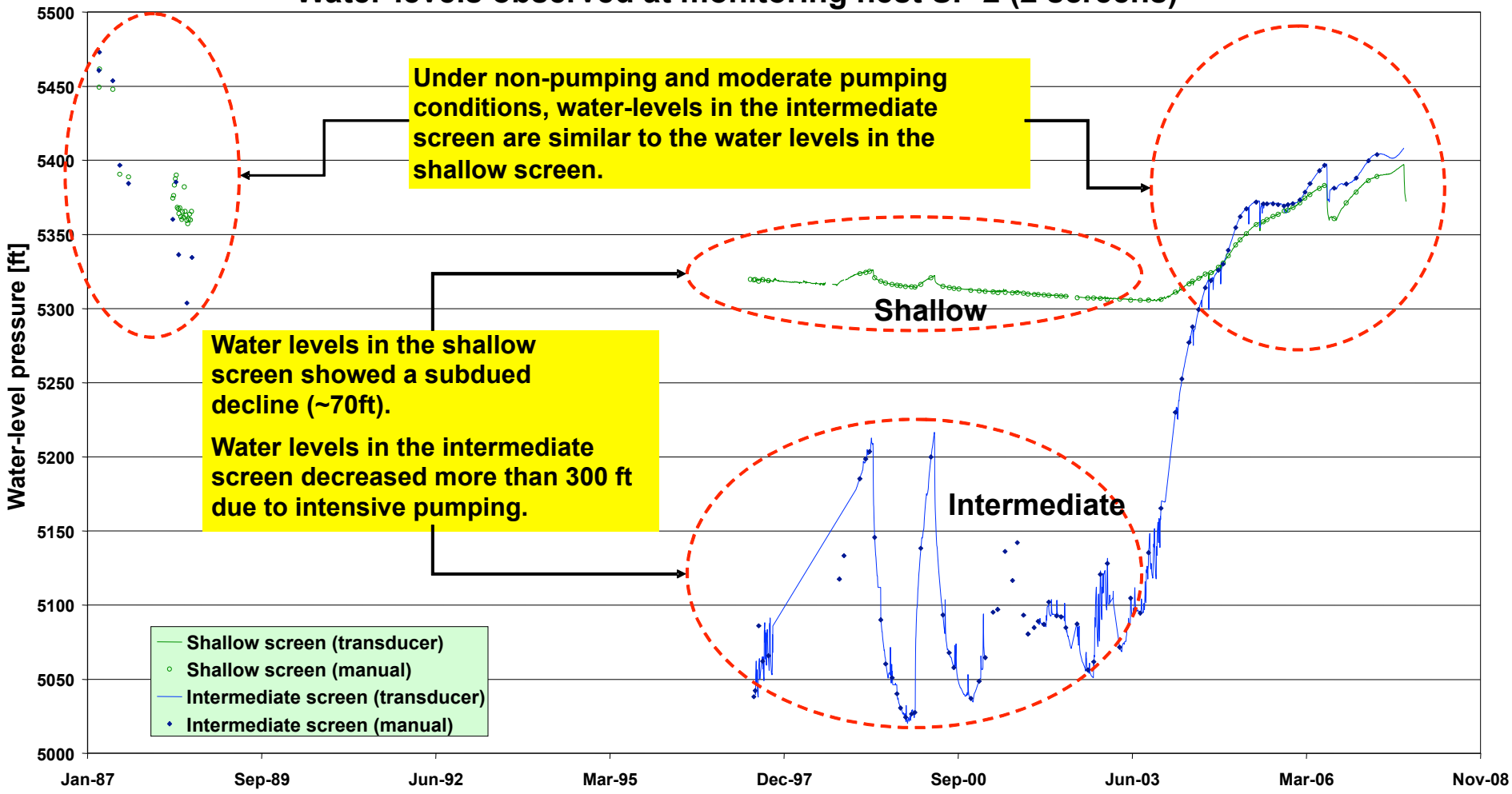
- Ttce — Cejita Member
- Pojoaque Member
- Ttcu — Cuarteles Member east of Rio Grande
- Ttcuf — fine-grained, distal Cuarteles Member east of Rio Grande



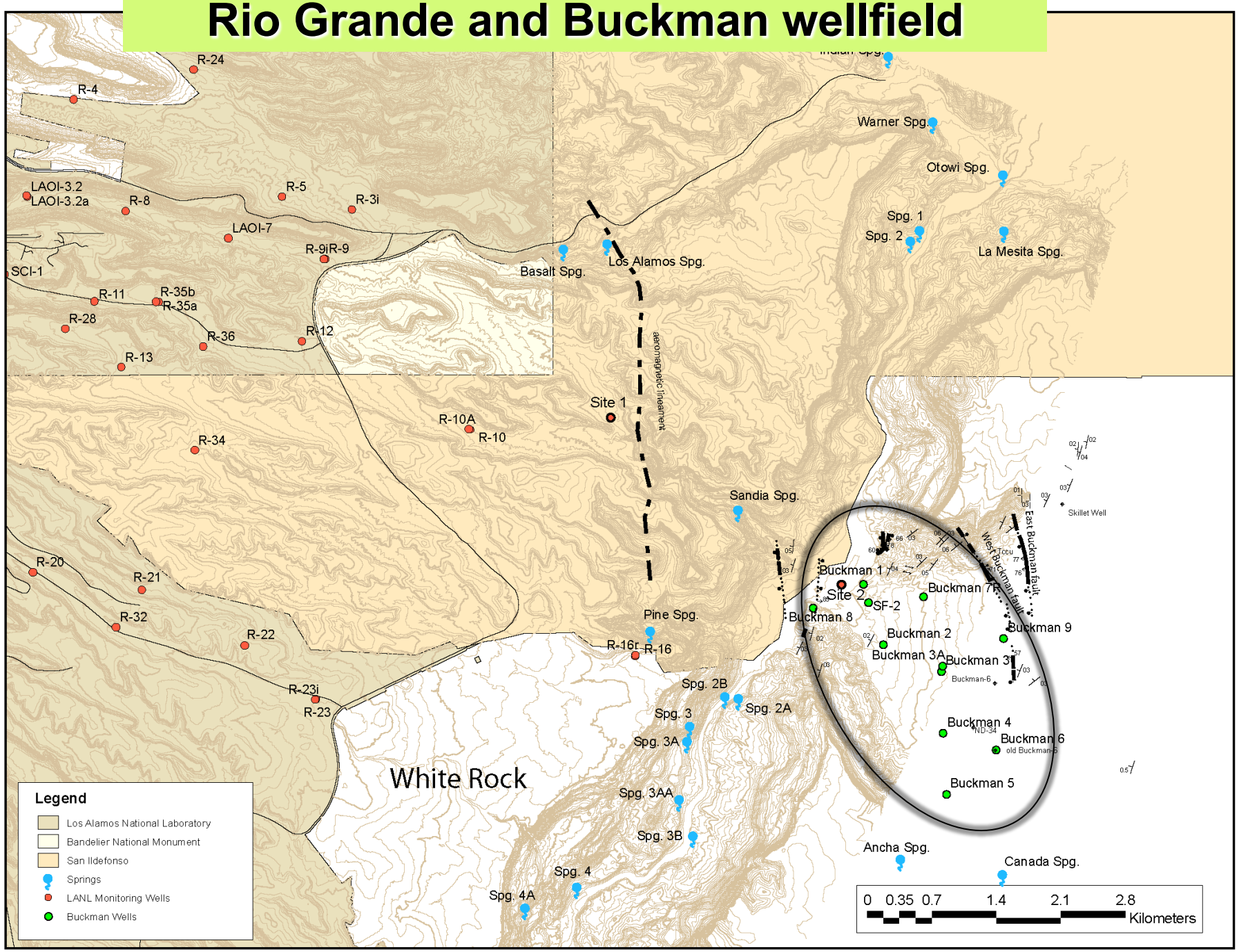
Local Hydrostratigraphy near Buckman 1 and 8




Water-levels observed at the Buckman Monitoring Nest (3 screens)
Water-level pressures [ft]
5920
5900
5880
5860
5840
5820
5800
5780
5760
5740
Oct-03
Mar-04
Sep-04
Mar-05
Sep-05
Apr-06
Sep-06
Apr-07
Oct-07
Mar-08
Deep
Intermediate
Shallow
Higher water levels deep in the aquifer compared to the water levels at shallower elevations demonstrate the confinement of the regional aquifer near Buckman wellfield
Deep screen
Intermediate screen
Shallow screen

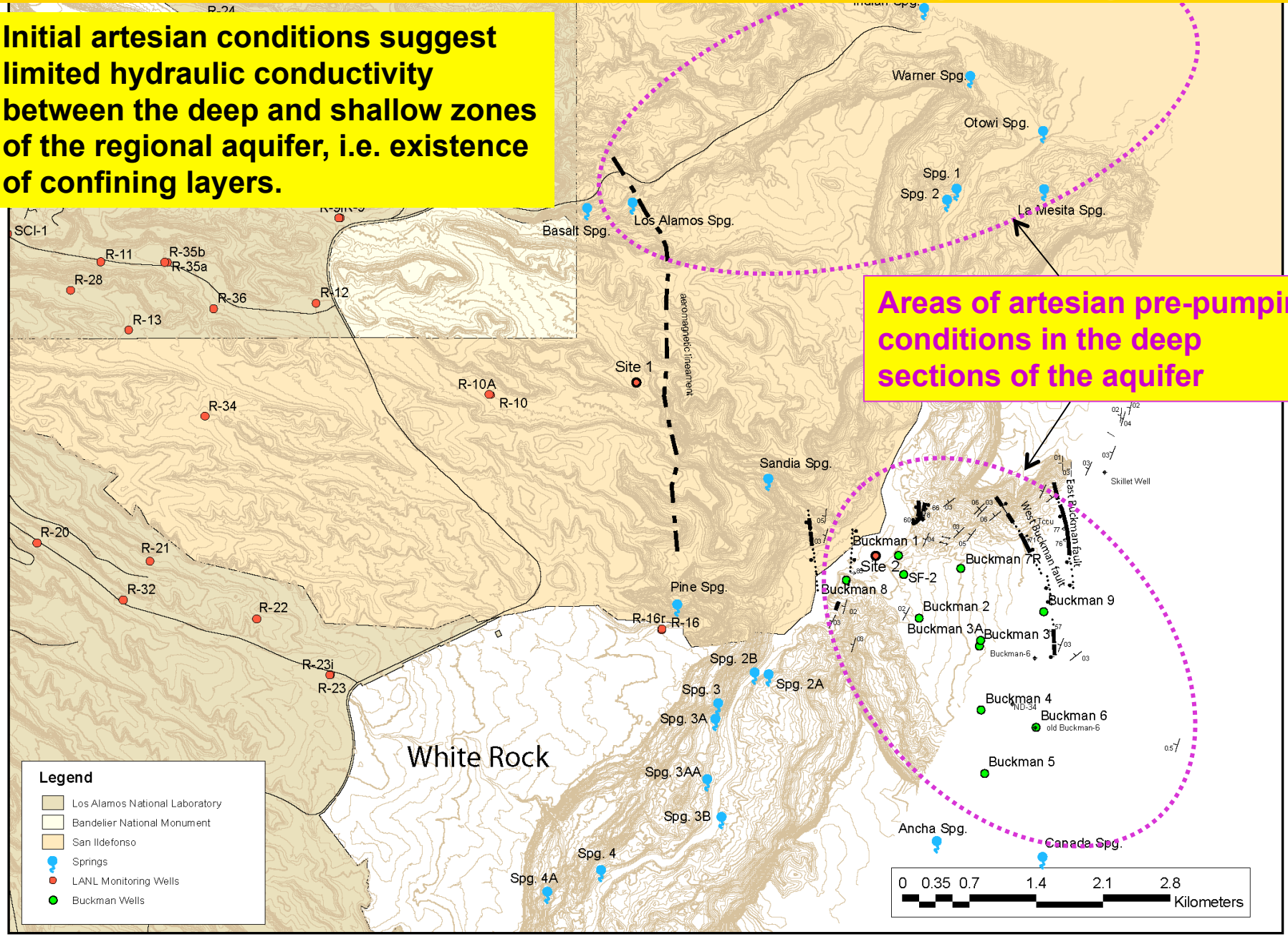

Water-levels observed at monitoring nest SF-2 (2 screens)
Water-level pressure [ft]
5500
5450
5400
5350
5300
5250
5200
5150
5100
5050
5000
Jan-87
Sep-89
Jun-92
Mar-95
Dec-97
Sep-00
Jun-03
Mar-06
Nov-08
Under non-pumping and moderate pumping conditions, water-levels in the intermediate screen are similar to the water levels in the shallow screen.
Water levels in the shallow screen showed a subdued decline (~70ft).
Water levels in the intermediate screen decreased more than 300 ft due to intensive pumping.
Shallow
Intermediate
Shallow screen (transducer)
Shallow screen (manual)
Intermediate screen (transducer)
Intermediate screen (manual)

Rio Grande and Buckman wellfield



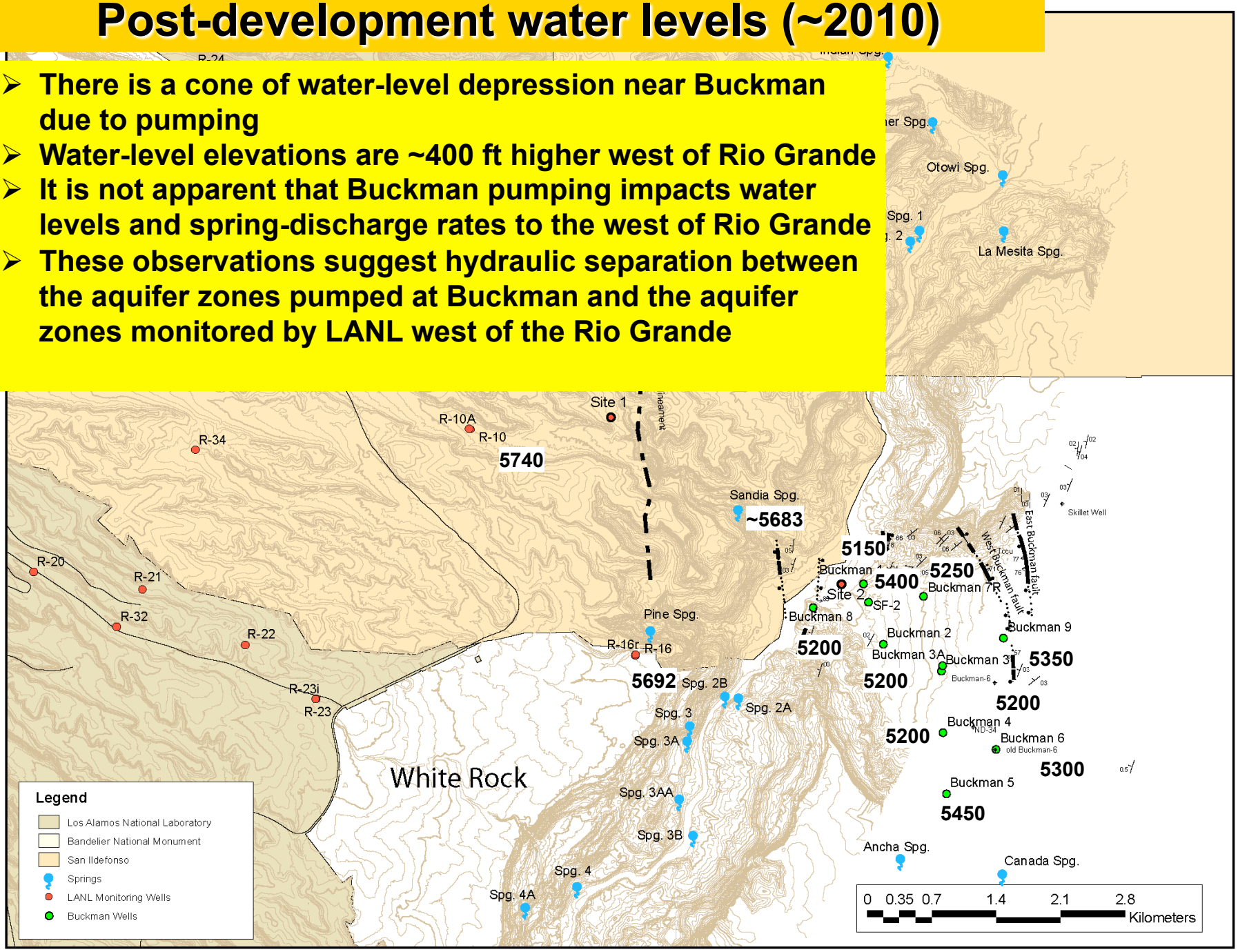
Pre-development water levels (~1950s)

Initial artesian conditions suggest limited hydraulic conductivity between the deep and shallow zones of the regional aquifer, i.e. existence of confining layers.



Post-development water levels (~2010)

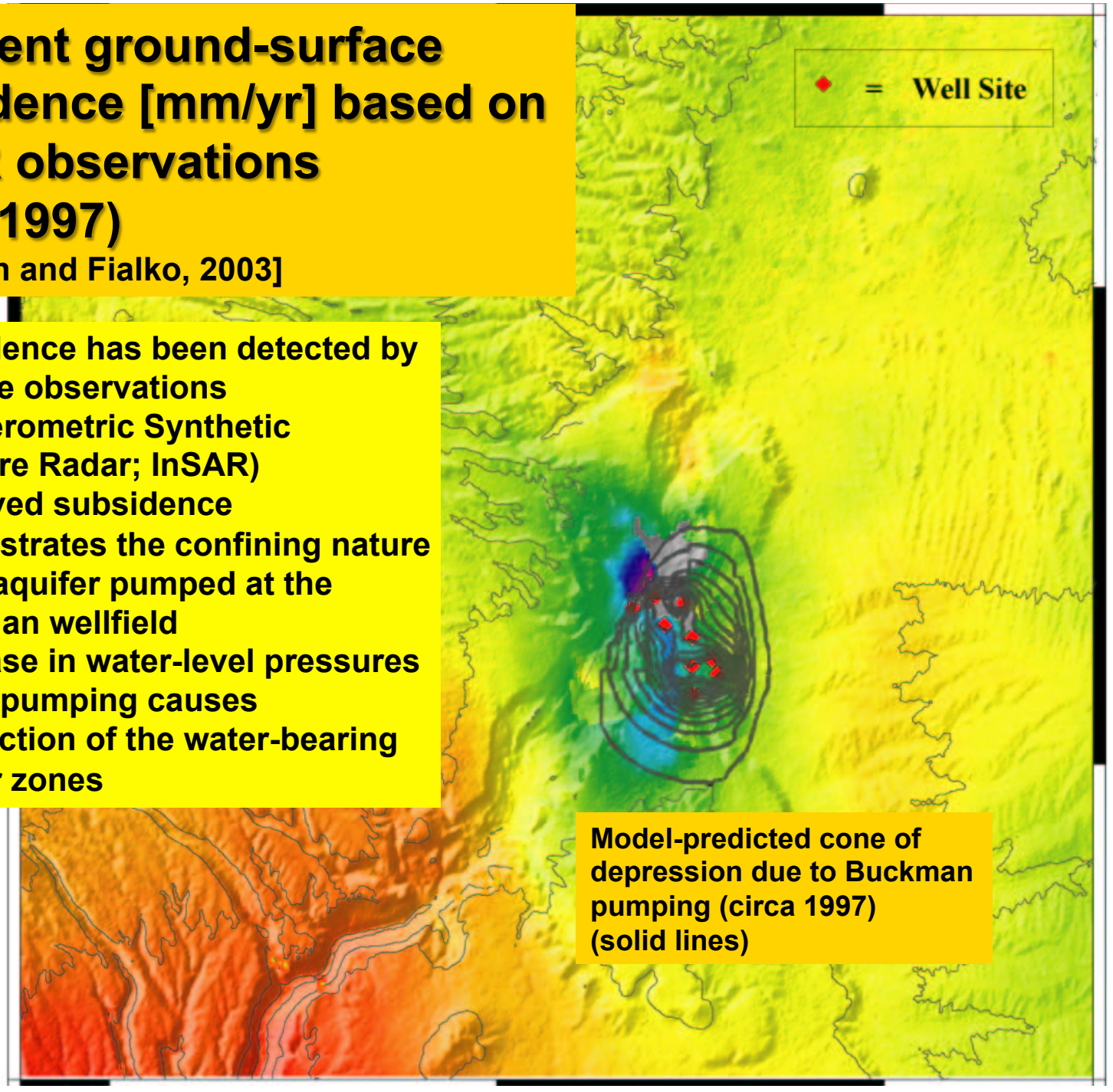
- There is a cone of water-level depression near Buckman due to pumping
- Water-level elevations are ~400 ft higher west of Rio Grande
- It is not apparent that Buckman pumping impacts water levels and spring-discharge rates to the west of Rio Grande
- These observations suggest hydraulic separation between the aquifer zones pumped at Buckman and the aquifer zones monitored by LANL west of the Rio Grande



Apparent ground-surface subsidence [mm/yr] based on InSAR observations (1993-1997)

[Thomsen and Fialko, 2003]

- Subsidence has been detected by satellite observations (Interferometric Synthetic Aperture Radar; InSAR)
- Observed subsidence demonstrates the confining nature of the aquifer pumped at the Buckman wellfield
- Decrease in water-level pressures due to pumping causes compaction of the water-bearing aquifer zones

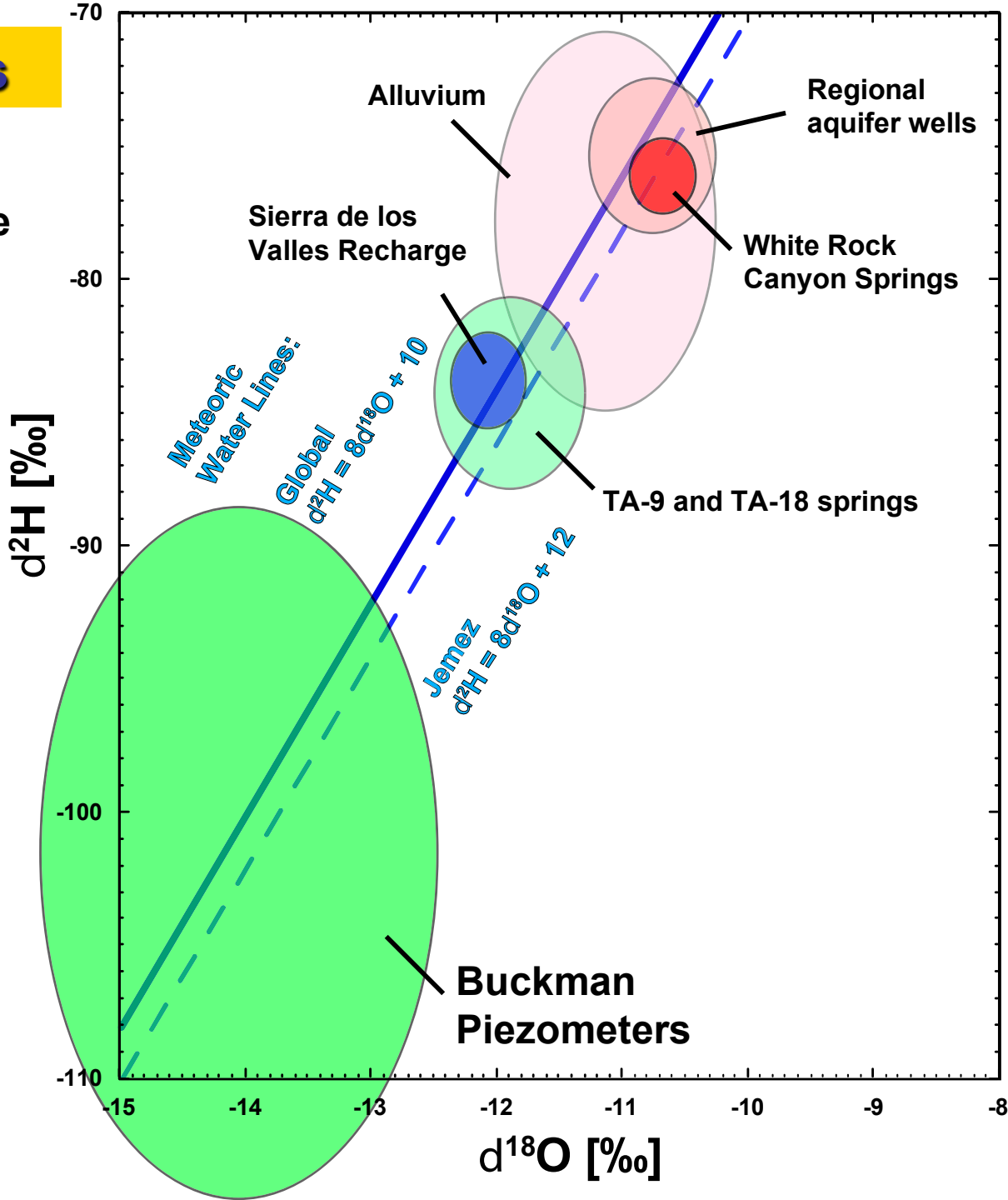


Model-predicted cone of depression due to Buckman pumping (circa 1997) (solid lines)

Isotope $\delta^{18}O/\delta^{2}H$ ratios

Substantially different isotope ratios are observed between Buckman wells and Pajarito Plateau springs and wells (regional, intermediate, and alluvial)

These data suggest different groundwater origins and little or no contribution of Pajarito Plateau groundwater at Buckman



White Rock Canyon springs:

Water origin and discharge rates

- White Rock Canyon springs are predominantly located West of Rio Grande
- The groundwater discharged by the springs West of Rio Grande has infiltrated along the Pajarito Plateau
- Most of the springs are discharging the regional aquifer (the rest are discharging perched horizons fed by local infiltration)
- Annually-averaged recharge occurring along the Pajarito Plateau is about 67 kg/s [*Kwicklis, et al., 2005*]
- Annually-averaged discharge at the springs is about 60 kg/s [*Purtymun, 1995*].
- Intensive water-supply pumping of the deep aquifer zones beneath the Pajarito Plateau and the Buckman wellfield appear to have no impact on the discharge rate of springs located West of Rio Grande.
- It appears that the water-supply wells and the springs discharge different portions of the regional aquifer which are somewhat separated hydraulically.

Rio Grande and Regional Aquifer:

- Rio Grande appears to be a gaining stream near Buckman
- It is unknown what portion of the groundwater gained by the river originates from western (Pajarito Plateau/Sierra de Los Valles), and eastern (Sangre de Cristo) sections of the basin-scale aquifer
- Stream flow data (1926–1969) provide information on how much water the river has potentially gained from the regional aquifer near Buckman
- Keating et al. [2005] estimated the river gain to be about 370 kg/s with uncertainty range from 120 to 620 kg/s (95% confidence range)
- About 60 kg/s are provided by the discharge at the White Rock Canyon springs

Conclusions:

- **Multiple lines of evidence support a conceptual model of limited hydraulic connection between the deep (pumped) and shallow section of the regional aquifer in the area of Buckman wellfield**
- **Vertical upward gradients within the Buckman wellfield under pre-development conditions indicate an inherent protection of the Buckman water resources from local contamination sources**