MAY 1998

WATER-ROCK INTERACTIONS IN THE BANDELIER TUFF, LOS ALAMOS CANYON: IMPLICATIONS FOR PATHWAY ANALYSIS

BY

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WATER-ROCK INTERACTIONS IN THE BANDELIER TUFF, LOS ALAMOS CANYON: IMPLICATIONS FOR PATHWAY ANALYSIS

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ABSTRACT

Hydrogeochemical characterization of groundwater and the Bandelier Tuff within upper Los Alamos Canyon is required for risk assessment calculations performed for RCRA-driven investigations. The groundwater pathway is one of the primary mechanisms for contaminant migration occurring within the dynamic hydrologic system. Water-rock interactions, including precipitation/dissolution reactions of silicates-silica glass, control major-ion chemistry for the silica-rich solutions. Alluvial groundwater varies from calcium-sodium-bicarbonate to sodium-chloride-type solutions. Sources of sodium and chloride include dissolution of road salt, ion exchange of sodium and other cations with smectite and other clay minerals, dissolution of volcanic rock, and discharges from facilities located within and adjacent to upper Los Alamos Canyon. Results of geochemical modeling using the computer code, MINTEQA2 suggest that major-ion solutes occur mainly as free or non-complexing species. Hydrolysis of volcanic glass, enriched in silica, aluminum, and sodium, may result in the formation of $Al(OH)_3$ and smectite over long periods of time. Formation of these geochemically-reactive phases probably control migration of cesium-137 and strontium-90. Alluvial groundwater is predicted to be undersaturated with respect to $SrCO_3$ and $SrSO_4$, suggesting that precipitation of these phases is thermodynamically not favored. Sorption and coprecipitation processes probably control minor and trace element distributions in alluvial groundwater. Tritium in the form of tritiated water (^3HHO) behaves as a conservative species.

OBJECTIVE OF PRESENTATION

Provide an overview of water-rock interactions, which control hydrochemical processes important for pathway analysis used in risk assessment calculations for Los Alamos Canyon.

TOPICS OF INTEREST

HYDROGEOLOGICAL SETTING

SPECIATION CALCULATIONS

STABILITY OF SOLID PHASES

ADSORPTION REACTIONS

ANALYTICAL METHODS

ATOMIC ABSORPTION

ION CHROMATOGRAPHY

COLORIMETRY

ICPMS

ICPES

LIQUID SCINTILLATION

ALPHA SPECTROMETRY

GAMMA SPECTROMETRY

HYDROGEOLOGICAL SETTING

HYDROGEOLOGIC MEDIA OF INTEREST INCLUDE

ALLUVIUM,

OTOWI MEMBER OF BANDELIER TUFF,

GUAJE PUMICE BED

PUYE FORMATION, AND

SANTA FE GROUP SEDIMENTS.

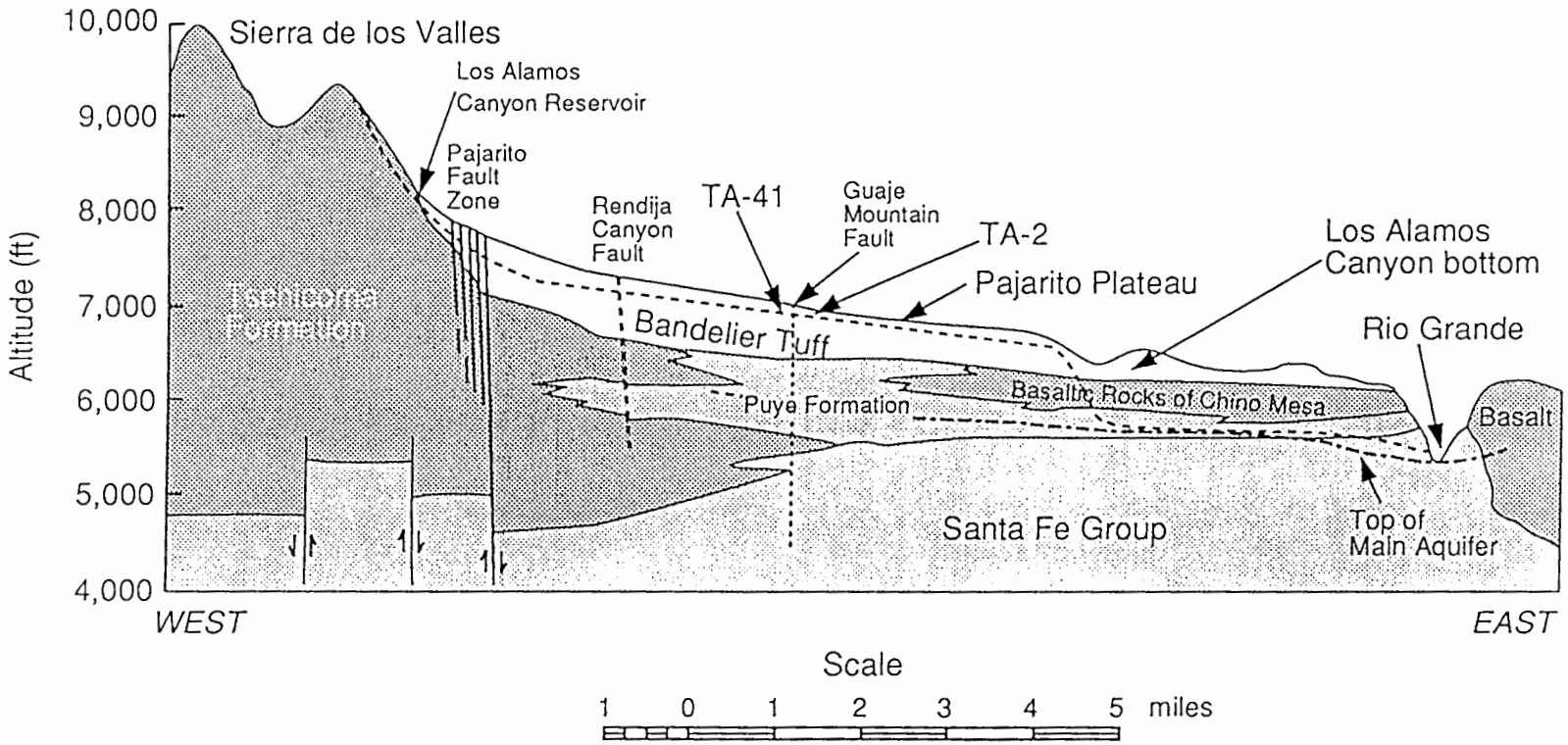
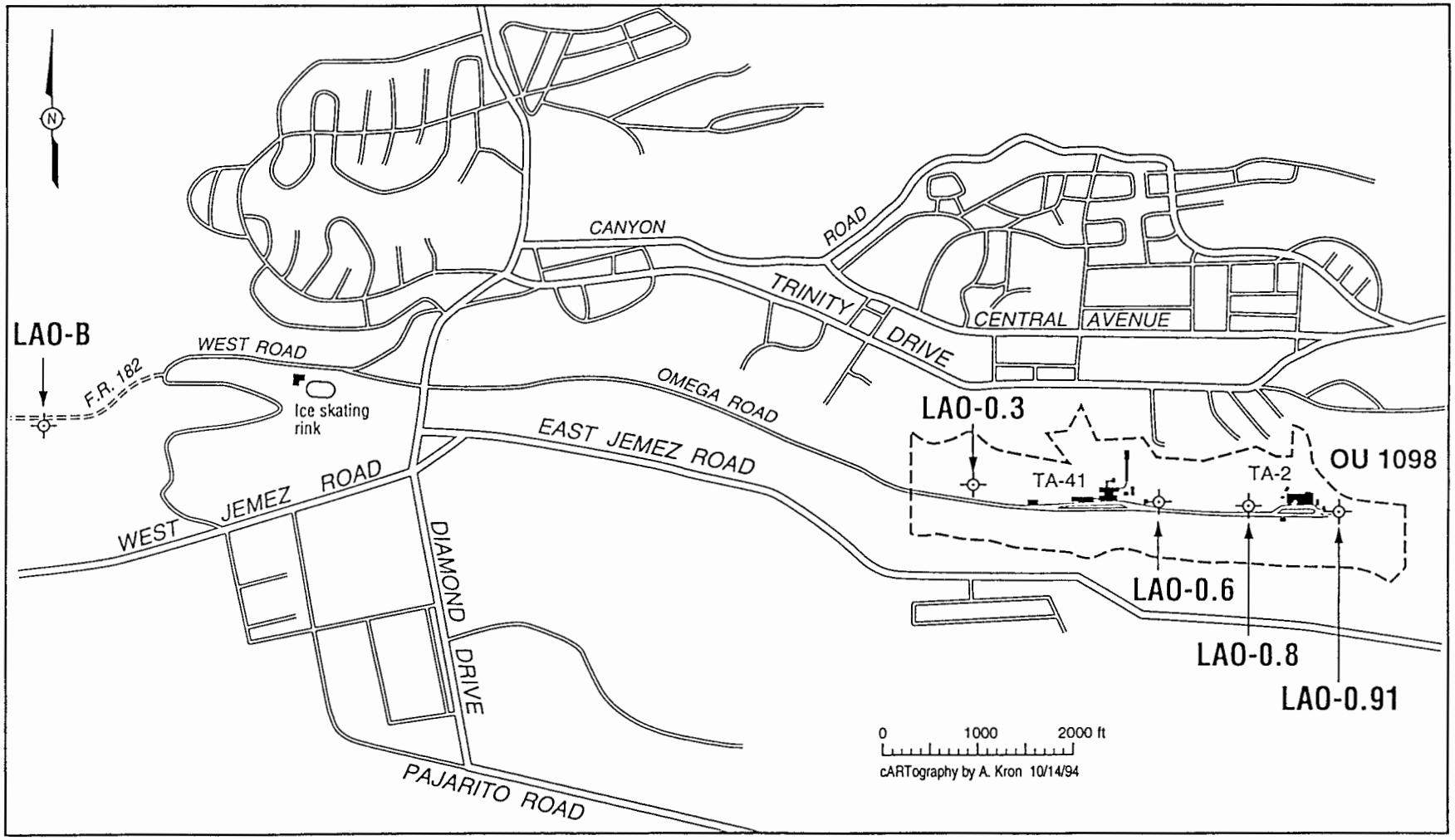
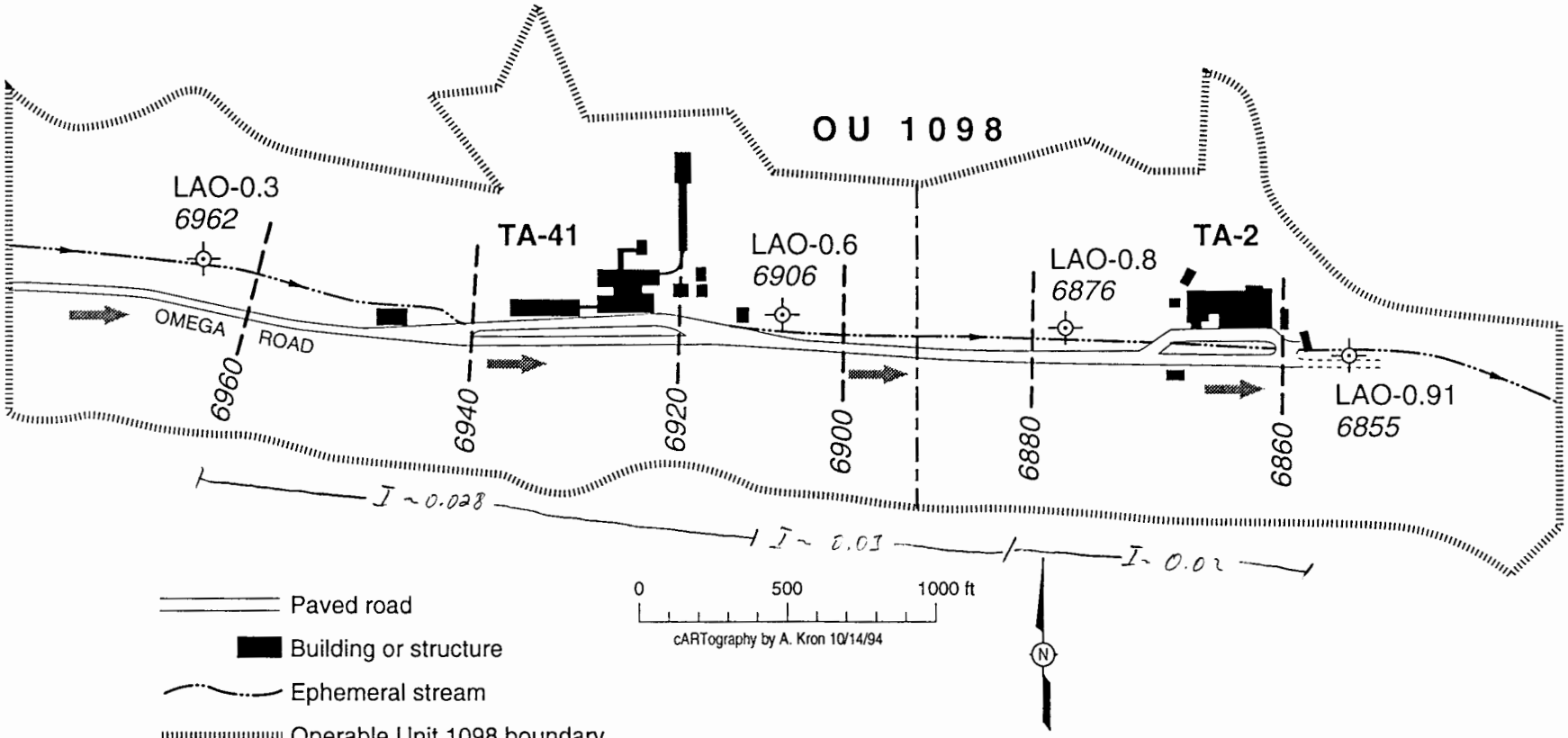


Figure 4.1-1 Geologic section showing the location of TA-2 and TA-41 with respect to stratigraphy and structure from the Sierra de los Valles across the Pajarito Plateau to the Rio Grande.

Location of new OU 1098 alluvial aquifer groundwater monitoring wells



Estimated potentiometric surface of the alluvial aquifer in Los Alamos Canyon June 6, 1994



Paved road

Building or structure

Ephemeral stream

Operable Unit 1098 boundary

Technical Area boundary

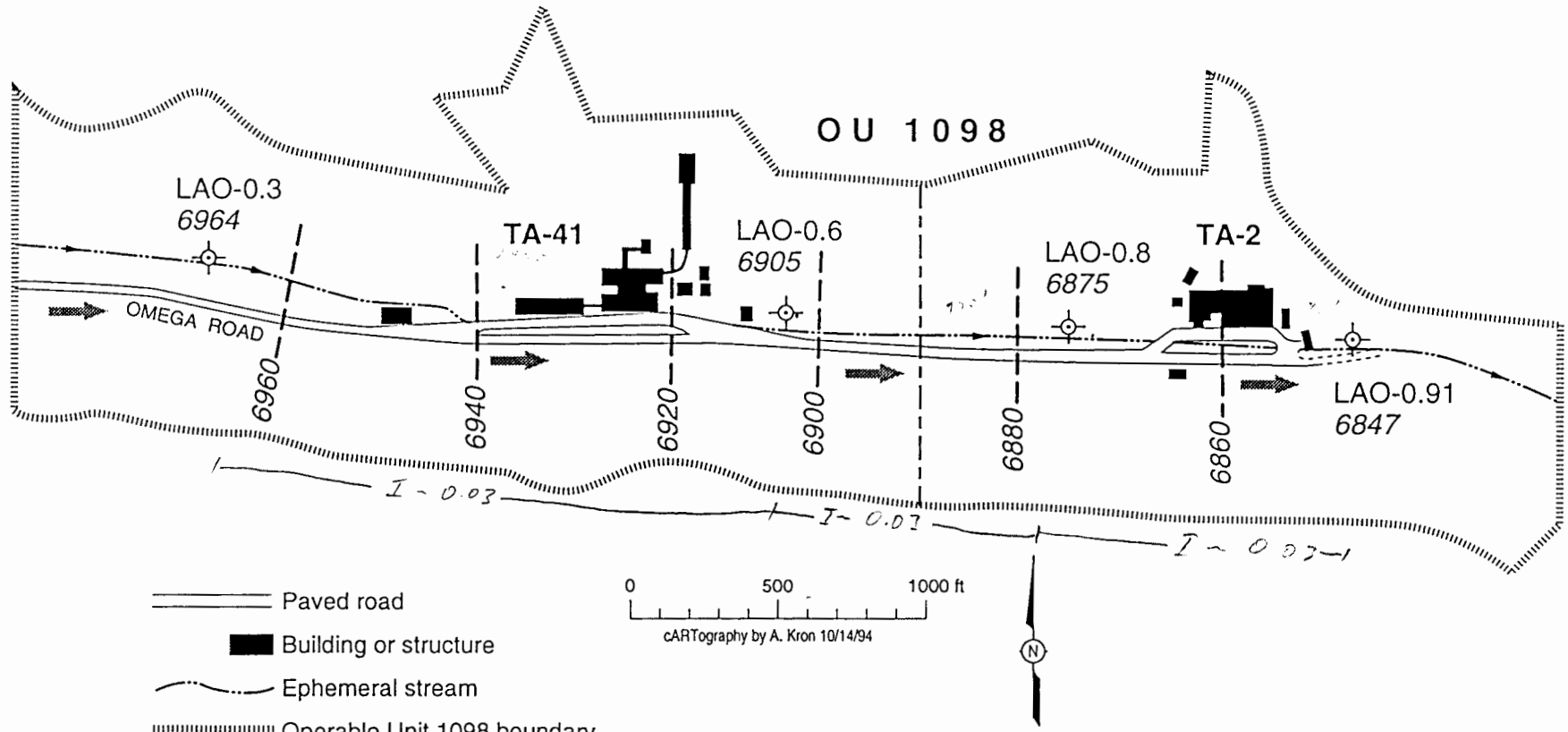
LAO-0.3 6962 — Alluvial aquifer groundwater monitoring well location with measured groundwater elevation (ft NAD83)

6960 — Estimated potentiometric surface elevation contour (contour inveral = 20 ft)

Groundwater flow direction

$\frac{6964 - 6905}{1975} \sim 0.03$

Estimated potentiometric surface of the alluvial aquifer in Los Alamos Canyon October 11, 1994



Paved road

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6960 — Estimated potentiometric surface elevation contour (contour inveral = 20 ft)

Groundwater flow direction

xxxx.??

ALLUVIAL GROUND WATER FLOW VELOCITY

HYDRAULIC CONDUCTIVITY (K)

AVERAGE: 4.73×10^{-4} FT/SEC

RANGE: 4.78×10^{-5} TO 1.31×10^{-3} FT/SEC
(NINE SLUG TESTS)

HYDRAULIC GRADIENT (dh/dl)

0.027 FT/FT (SLOPE OF CREEK CHANNEL)

ASSUMED EFFECTIVE POROSITY (N_e) - 0.35

$$V = \frac{Kdh}{N_e dl}$$

$$V = 3.65 \times 10^{-5} \text{ ft/sec or } 1150 \text{ ft/yr}$$

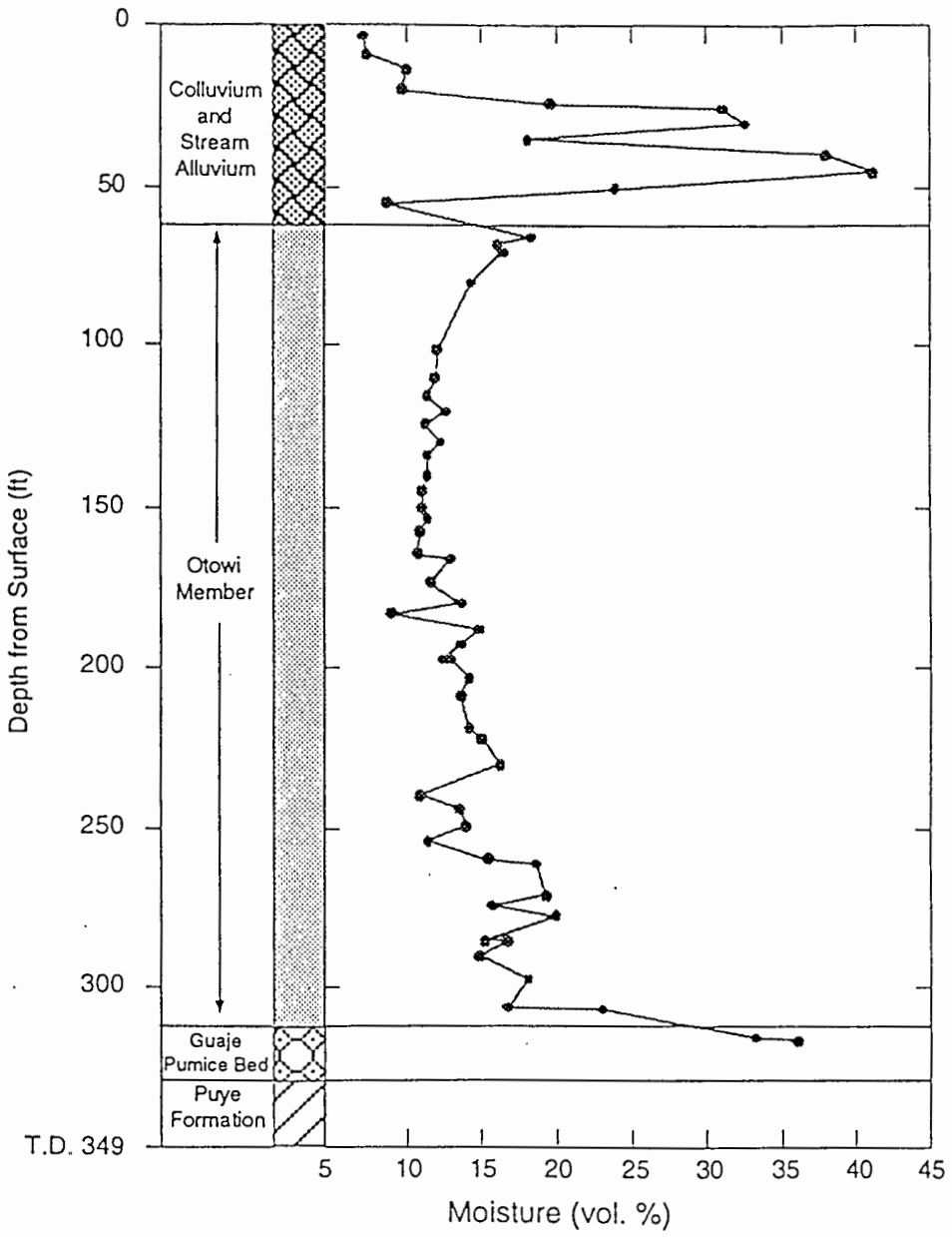
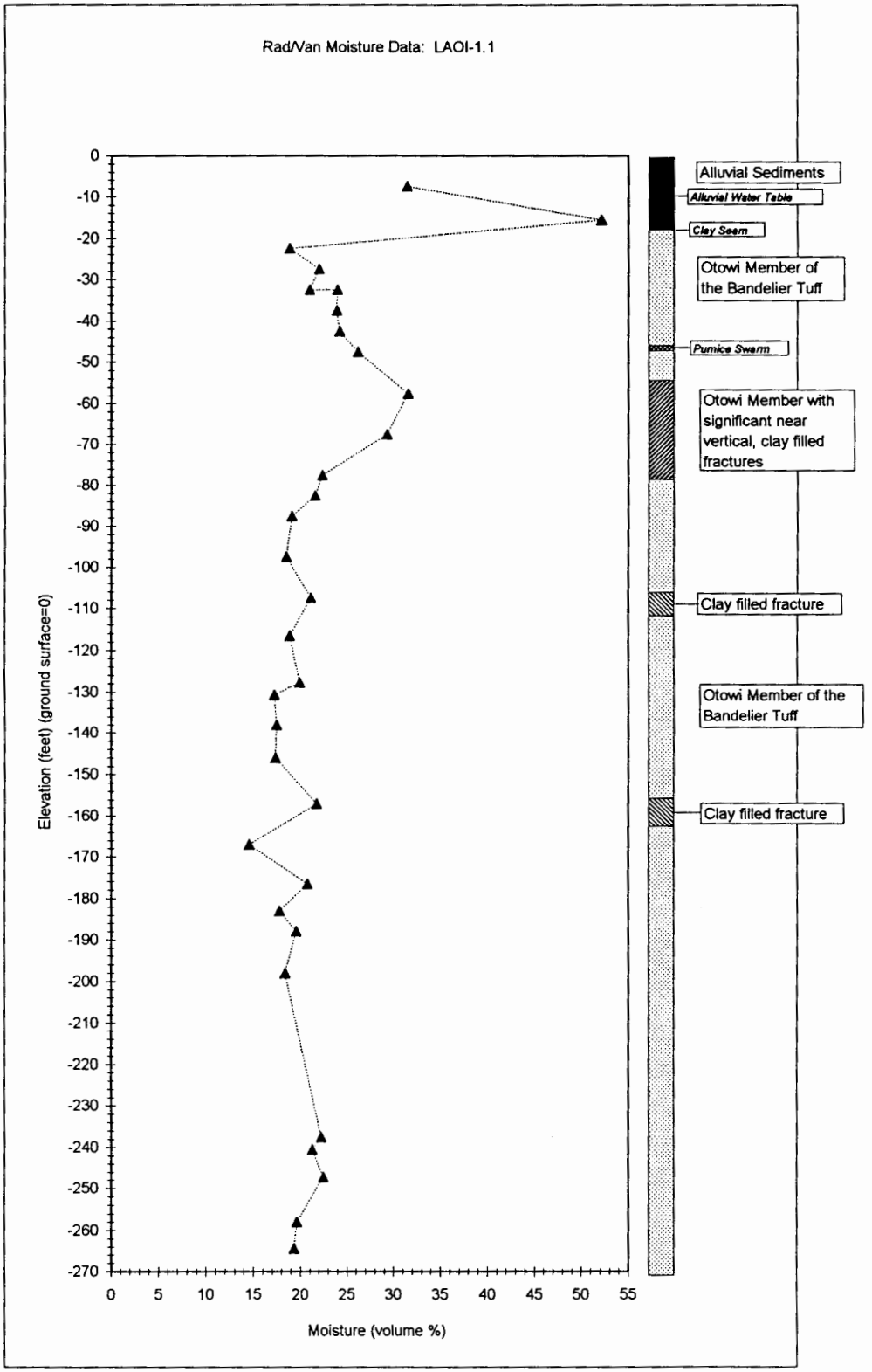
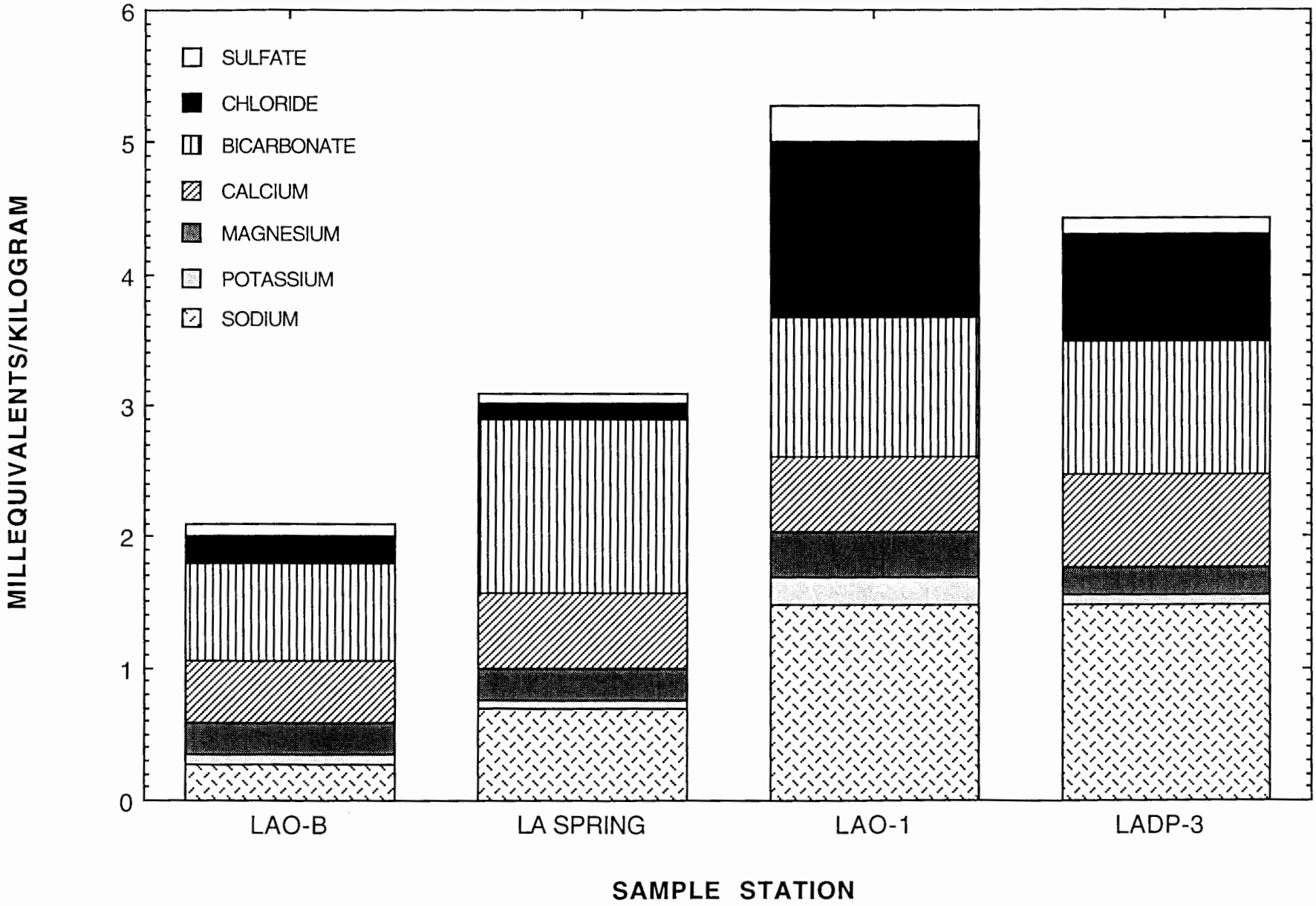


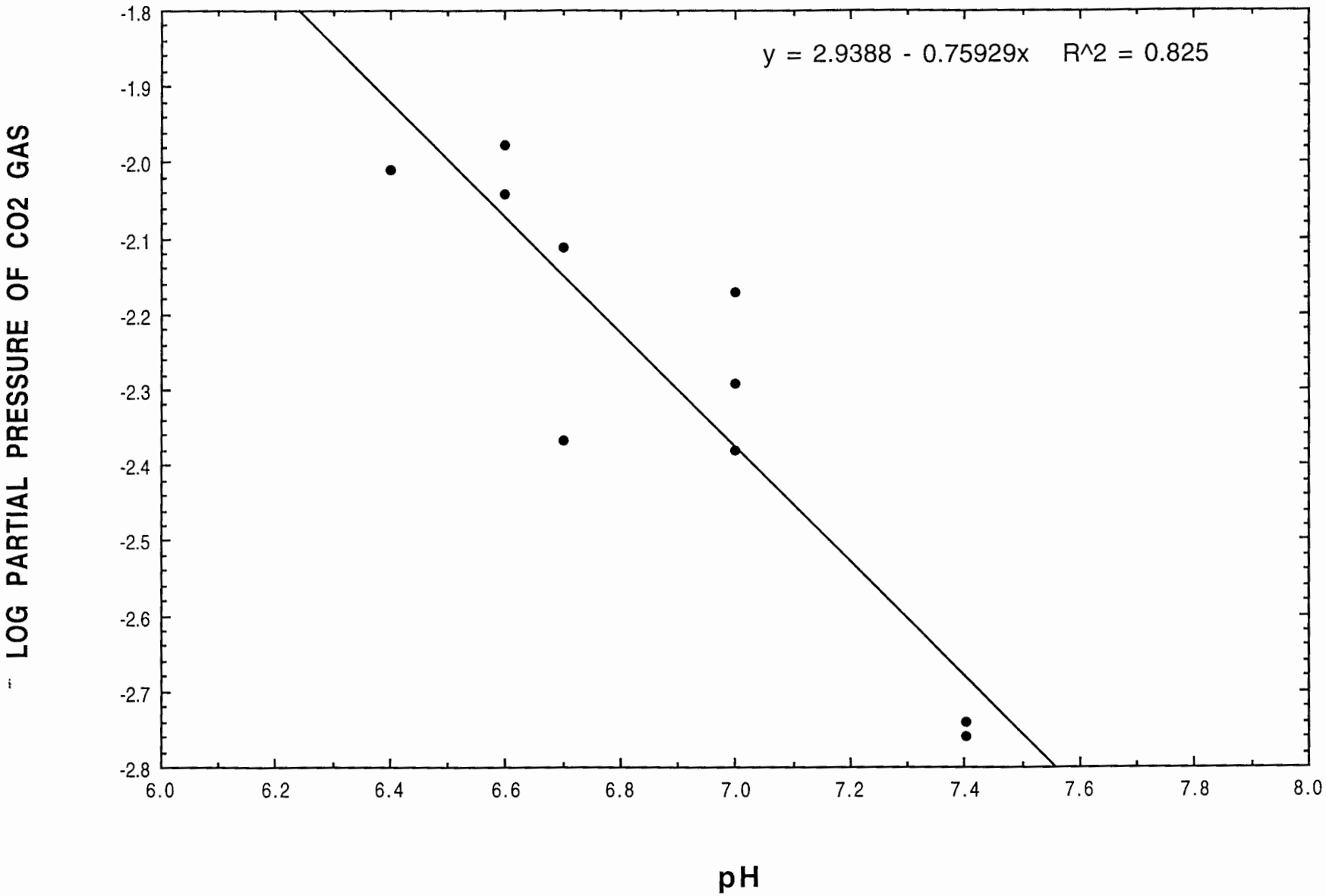
Fig. 5. Preliminary geologic information and variation in moisture content as a function of depth in bore hole LADP-3, Los Alamos Canyon.


Rad/Van Moisture Data: LAOI-1.1
Elevation (feet) (ground surface=0)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
-230
-240
-250
-260
-270
0
5
10
15
20
25
30
35
40
45
50
55
Moisture (volume %)
Alluvial Sediments
Alluvial Water Table
Clay Seam
Otowi Member of the Bandelier Tuff
Pumice Swarm
Otowi Member with significant near vertical, clay filled fractures
Clay filled fracture
Otowi Member of the Bandelier Tuff
Clay filled fracture

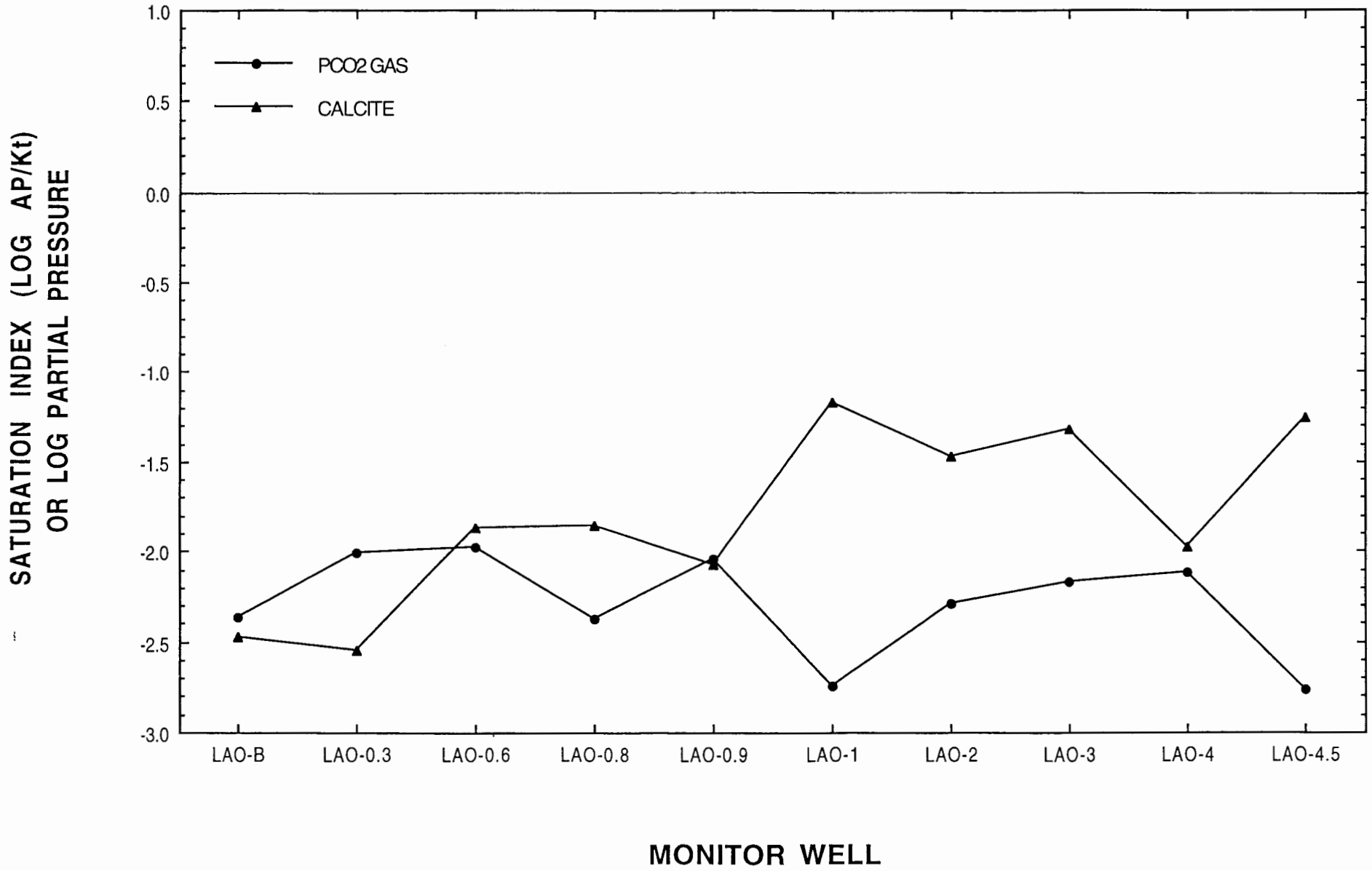
WATER QUALITY, LOS ALAMOS CANYON



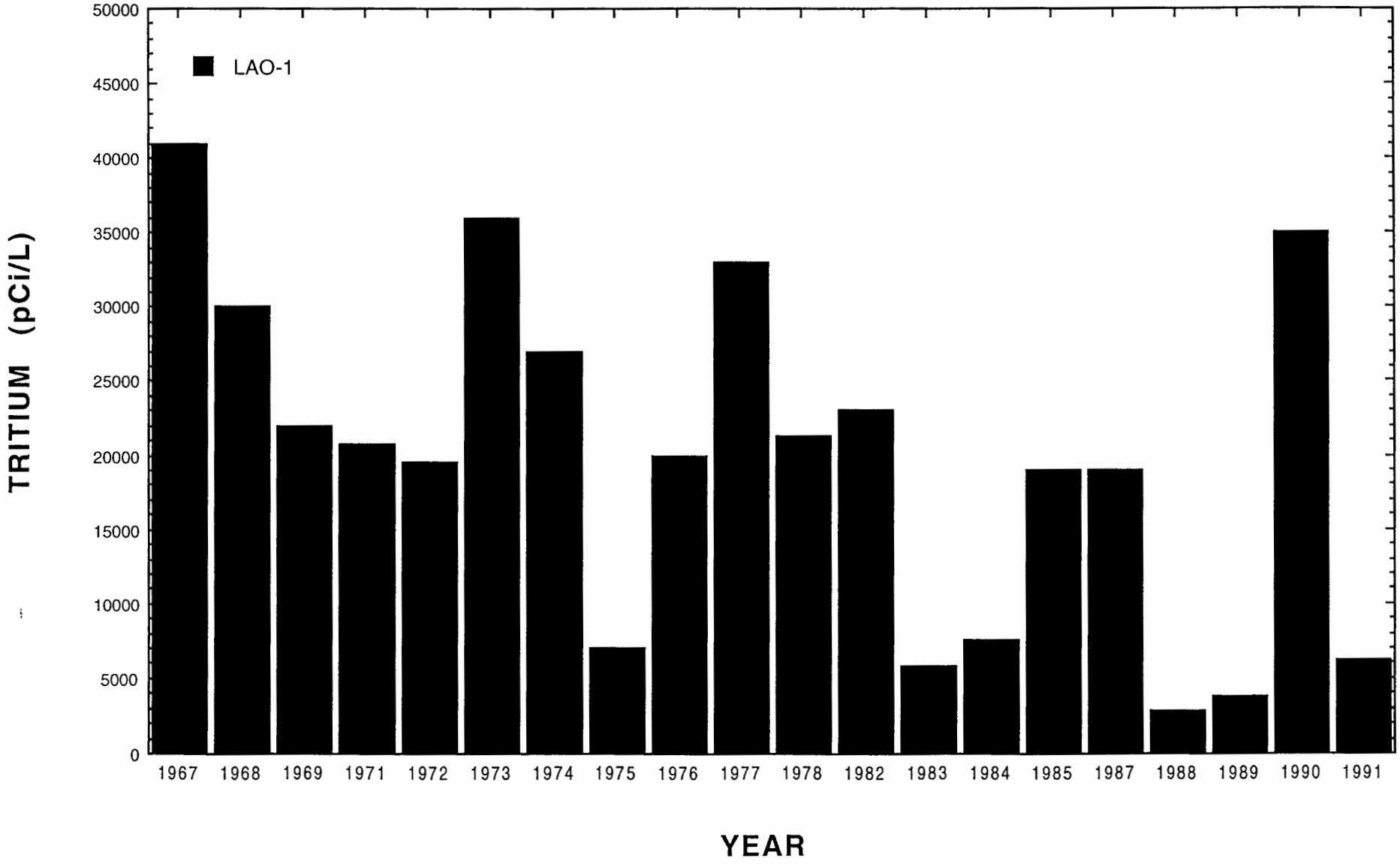
ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



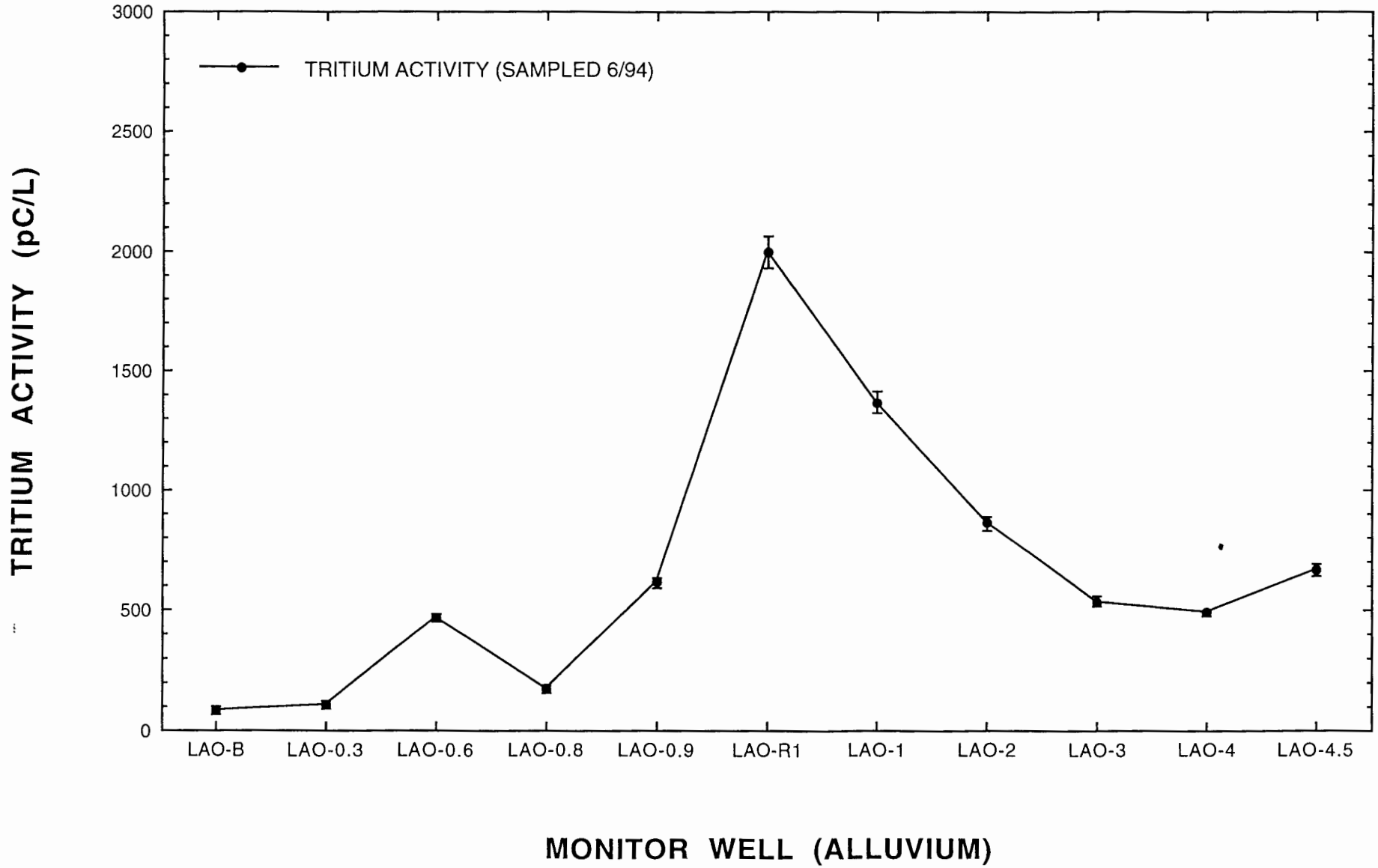
ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



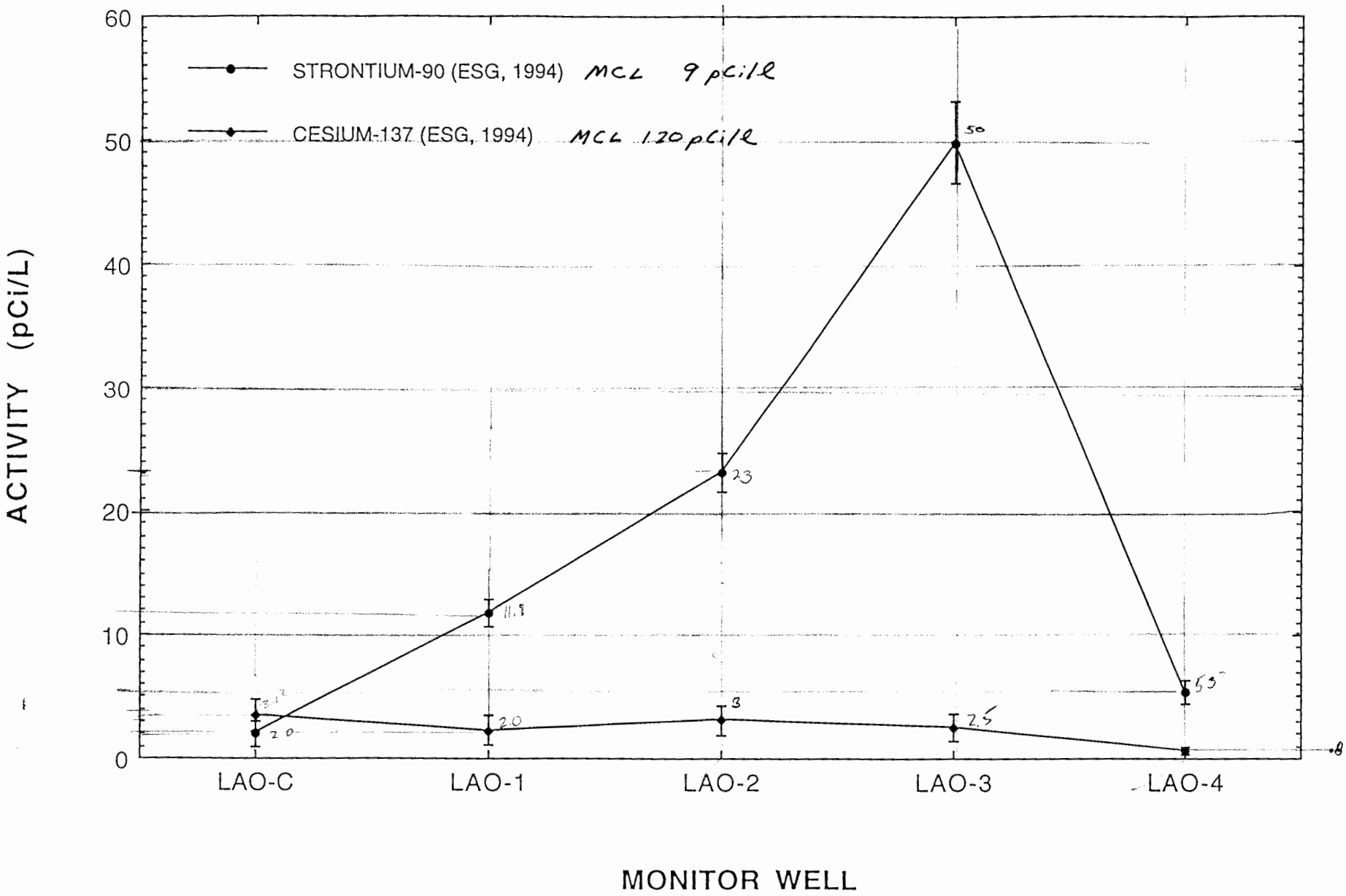
LOS ALAMOS CANYON, ALLUVIAL WELL LAO-1



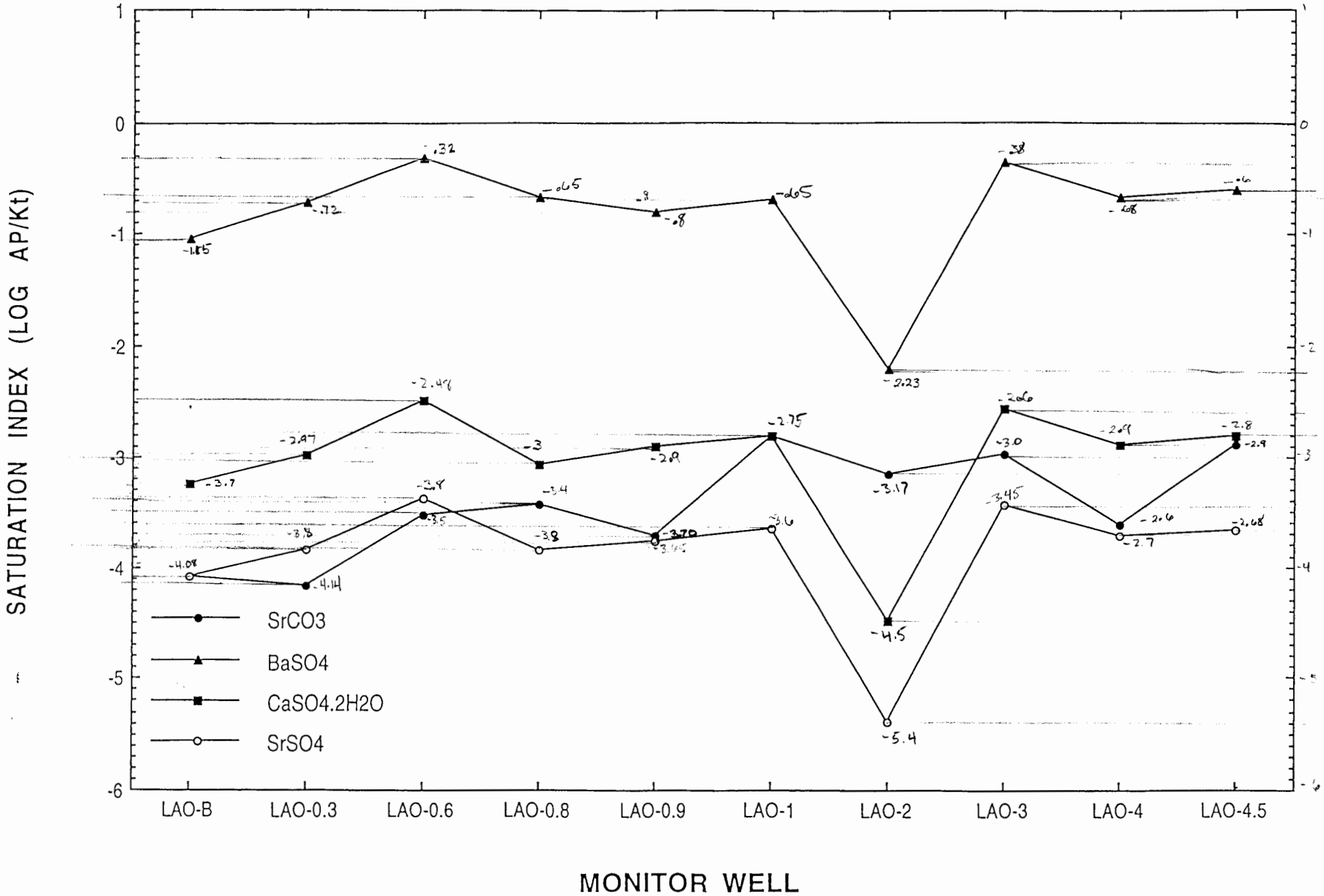
LOS ALAMOS CANYON, ALLUVIAL AQUIFER



ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



SORPTION/DESORPTION VALUES FOR CESIUM, STRONTIUM, AND URANIUM IN TUFFACEOUS ROCKS[1]

RANGES OF SORPTION RATIOS (mL/g)

Element	*Devitrified Tuff*
Cesium	150-870
Strontium	53-190
Uranium	1.6-2.2

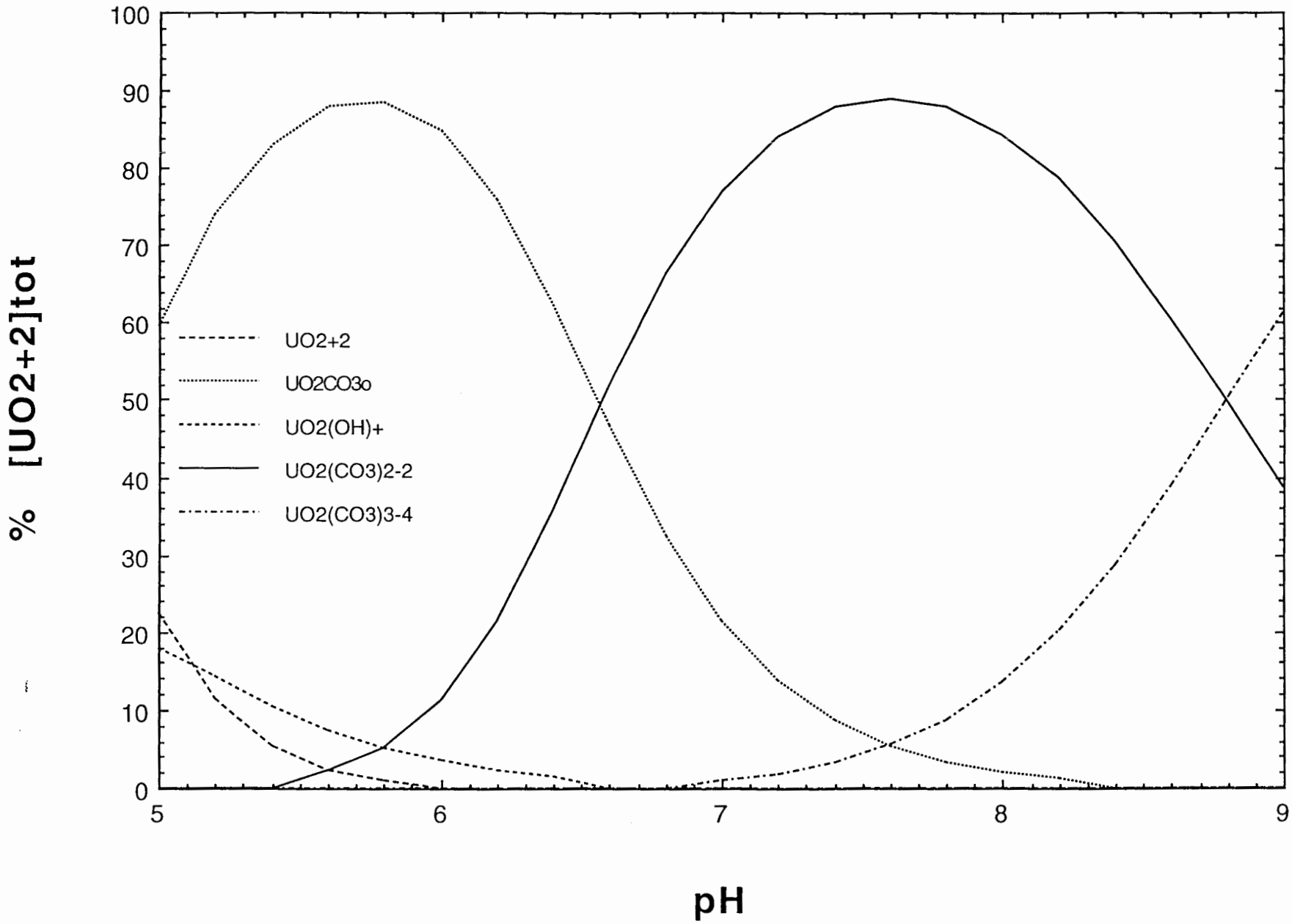
RANGES OF DESORPTION RATIOS (mL/g)

Element	*Devitrified Tuff*
Cesium	310-630
Strontium	56-200
Uranium	6-13

Source: Wolfsberg (1980).

1. $R_d = \frac{\text{Activity in solid phase per unit mass of solid}}{\text{Activity in solution per unit volume of solution}}$

URANYL IN LAO-B, LOS ALAMOS CANYON



PROBABLE REACTIVE GEOCHEMICAL SOLID PHASES

ALUMINUM HYDROXIDE

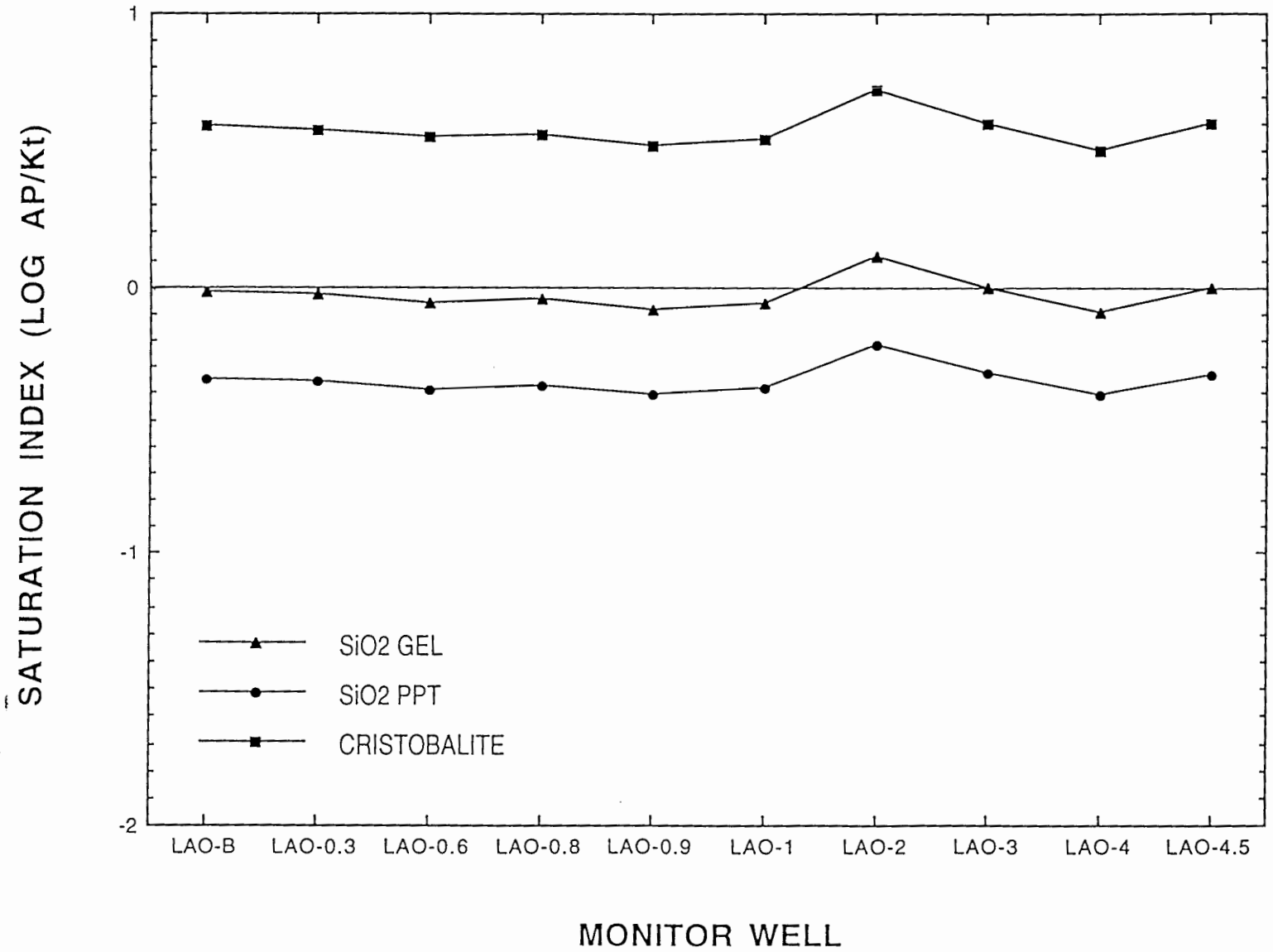
CLAY MINERALS (KAOLINITE, SMECTITE)

FERRIC HYDROXIDE

SILICA

SOLID ORGANIC CARBON (HUMIC AND FULVIC ACIDS)

ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



MAJOR ELEMENT CONCENTRATIONS AND MINERALOGICAL COMPOSITION OF THE OTOWI MEMBER

OXIDE		WEIGHT PERCENT[1]
Al_2O_3	(whole rock)	12.0
	(glass)	11.8
	(feldspar)	19.1
SiO_2	(whole rock)	77.0
	(glass)	76.5
	(feldspar)	66.5
	(silica phases)	100
Na_2O	(whole rock)	3.80
	(glass)	3.49
	(feldspar)	6.80

SOLID PHASE	WEIGHT PERCENT[2]
Glass	68
Feldspar	21
Silica Minerals (quartz, cristobalite, tridymite)	11

1. determined from XRF, 2. determined by XRD

SOURCE: DAVID BROXTON

MAJOR ELEMENT CONCENTRATIONS IN NA-BEIDELLITE AND KAOLINITE

NA-BEIDELLITE

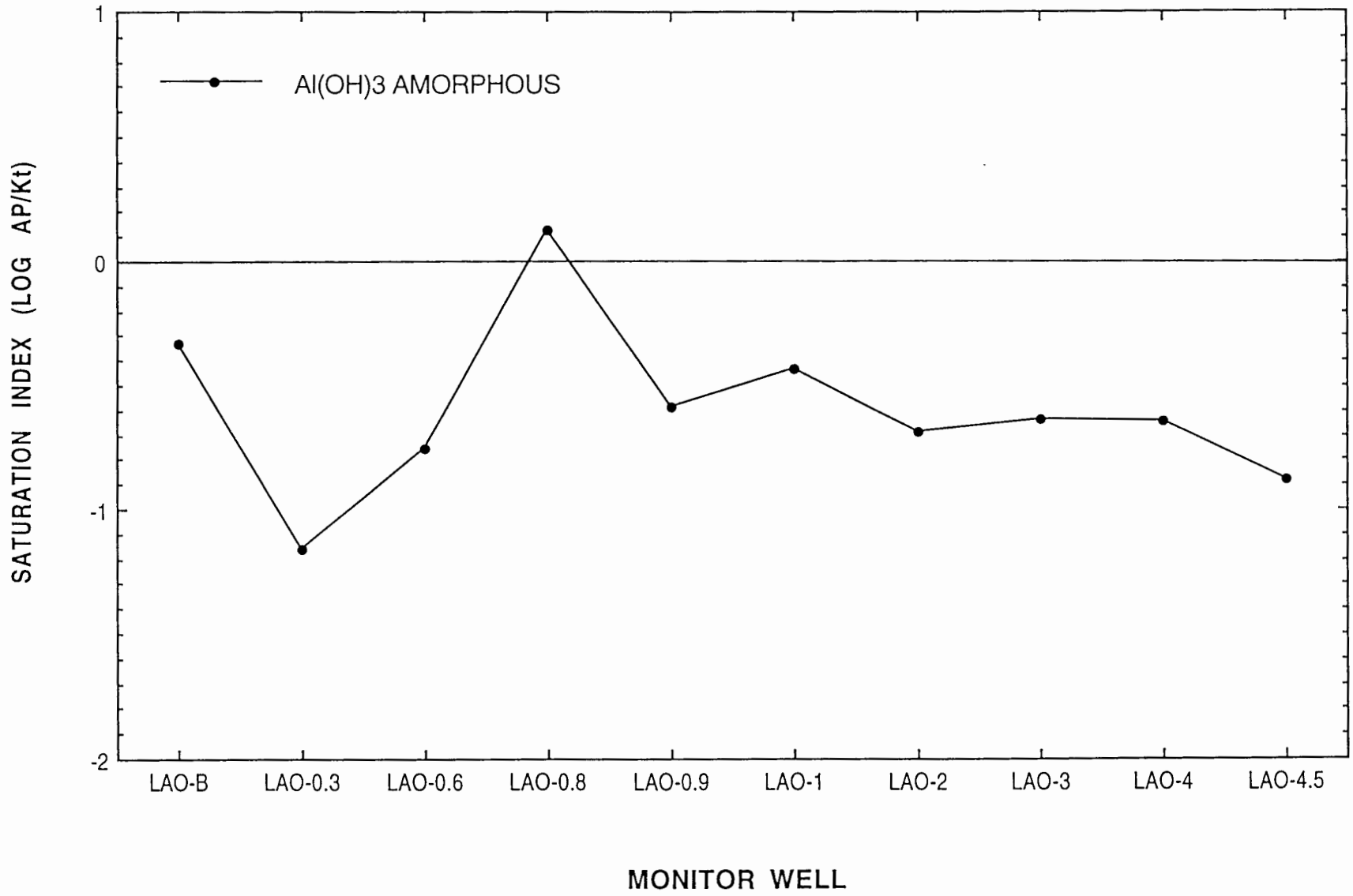
OXIDE	WEIGHT PERCENT[1] MEAN	RANGE (n=101)
SiO_2	59.49	51.20-65.00
Al_2O_3	21.93	15.20-34.00
Na_2O	0.82	0.00-3.74

KAOLINITE

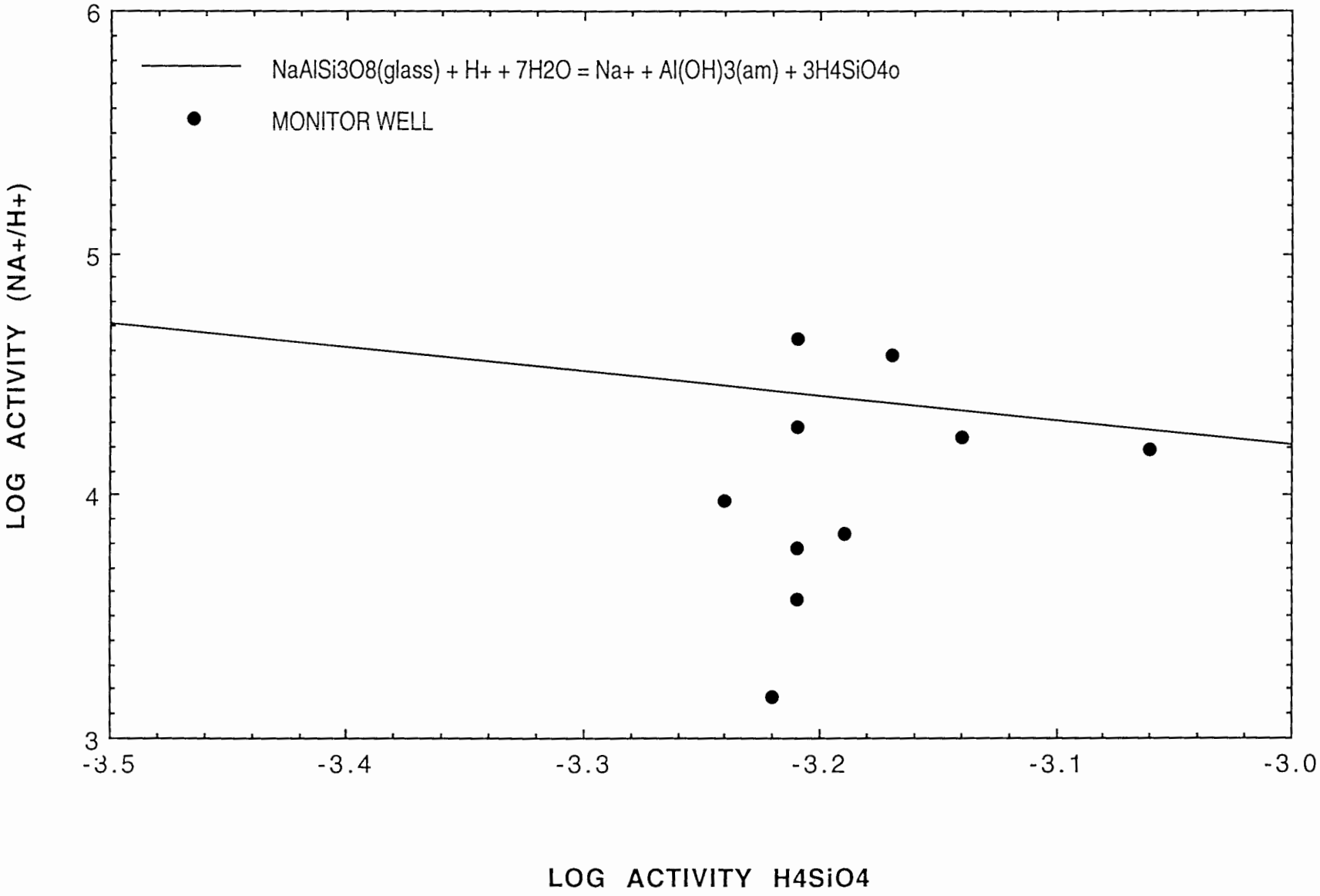
OXIDE	WEIGHT PERCENT[1] MEAN	RANGE (n=17)
SiO_2	43.54	41.03-46.86
Al_2O_3	37.05	32.32-38.99

SOURCE: WEAVER AND POLLARD, 1973

ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



ALLUVIAL GROUNDWATER, LOS ALAMOS CANYON



POSSIBLE GEOCHEMICAL REACTIONS CONTROLLING PRECIPITATION OF CLAY MINERALS IN SATURATED ZONE

HYDROLYSIS OF GLASS FORMING KAOLINITE

$$(Na_2O\text{-}Al_2O_3\text{-}SiO_2)Gel + H_4SiO_4 + 2H^+ =$$

$$Al_2Si_2O_5(OH)_4 + 2Na^+ + H_2O$$

HYDROLYSIS OF GLASS FORMING SMECTITE

$$1.165(Na_2O\text{-}Al_2O_3\text{-}SiO_2)Gel + 2.505H_4SiO_4$$

$$+ 2H^+ = Na_{0.33}Al_{2.33}Si_{3.67}O_{10}(OH)_2$$

$$+ 2Na^+ + 5.01H_2O$$

HYDROLYSIS OF FELDSPARS FORMING KAOLINITE AND SMECTITE IS LIKELY.

CONCLUSIONS

ALLUVIAL GROUND WATER RANGES FROM CALCIUM-SODIUM-BICARBONATE TO SODIUM-CHLORIDE TYPE SOLUTIONS.

^{3}H, ^{90}Sr, AND ^{137}Cs ARE PREDICTED TO BE STABLE AS ^{3}HHO, Sr^{2+}, AND Cs^{+}, RESPECTIVELY.

PRECIPITATION OF KAOLINITE, SMECTITE, OTHER LARGE-SURFACE AREA SOLIDS ENHANCES SORPTION OF ^{90}Sr AND ^{137}Cs.

QUANTIFYING SITE-SPECIFIC HYDRO-CHEMICAL REACTIONS IS ESSENTIAL FOR PERFORMING ACCURATE AND MEANINGFUL PATHWAY ANALYSIS.

SUMMARY OF CARBON-14 AND TRITIUM BASED AGE ESTIMATES for Wells in Los Alamos Area

Locale	Carbon-14 (% modern)	Carbon-14 Age Estimates Minimum[a]	Carbon-14 Age Estimates Maximum[b]	Tritium (T.U.[c])	pCi/l	Tritium Age Estimates Piston Flow[d]	Tritium Age Estimates WellMixed[e]
Los Alamos Supply Wells (Main Aquifer)							
O-4	25.0	3890	11500	0.32	1.04	>50	>5000
PM-1	18.5	5620	14000	0.51	1.65	>45	>3000
PM-2	62.7	50	3860	0.49	1.57	>45	>3000
PM-3	23.9	4950	11800	0.14	0.45	>70	>9000
PM-3 @2000'	23.9	6390	11800	0.01	0.032	>100	>10000
PM-3 @1650'	22.9	7910	12200	0.01	0.032	>100	>10000
PM-3 @1226'	24.5	7700	11600	0.23	0.74	>60	>7000
PM-3 @987'	28.2	6770	10500	0.13	0.42	>70	>9000
PM-5	53.7	1040	5140	0.09	0.29	>70	>10000
G-5	26.8	6110	10900	0.08	0.26	>70	>10000
Los Alamos Test Wells and Springs							
Intermediate Depth Perched Groundwater							
TW-1A	182.2	Contaminated		45.8	148	20-30	<20
TW-2A	--	--	--	699	2265	Contaminated	
LADP-3	--	--	--	1800	5800	Contaminated	
Basalt Spring	--	--	--	50	162	20-30	<20
Main Aquifer							
TW-1	237.2	Contaminated		113	366	Contaminated	
TW-2	57.3	<0[f]	4610	0.85	2.75	~40	>1500
TW-3	40.45	921	7480	0.89	2.9	~40	>1500
TW-4	57.1	<0[f]	4630	3.34	10.8	~35	~500
TW-8	--	--	--	89.4	290	Contaminated	
DT-5A	57.6	1810	4560	0.07	0.23	>80	>10000
DT-9	69.1	163	3060	0.14	0.45	>70	>9000
DT-10	82.0	<0[f]	1640	0.41	1.33	~55	>4500
Perched Water in Volcanics							
Water Canyon Gallery Spring				12.8	41.5	2-40	5-100

Footnotes

[a] Assumes dilution by "dead" carbon from dissolution of carbonates, estimated by del C-13

[b] Assumes radioactive decay only, no dilution by dissolution of carbonates

[c] Tritium Units, One tritium atom in 10^{18} hydrogen atoms; 1 TU = 3.24 pCi/L

[d] Piston Flow model assumes no mixing or dilution with other water

[e] Well Mixed model assumes complete mixing in reservoir, inflow = outflow, no other inputs

[f] Applying dilution factor (footnote [a]) results in meaningless minimum age.

SUMMARY OF CARBON-14 AND TRITIUM BASED AGE ESTIMATES for Wells in Los Alamos Area

Well	Carbon-14 (% modern)	Carbon-14 Age Estimates Minimum[a]	Carbon-14 Age Estimates Maximum[b]	Tritium (T.U.[c])	Tritium Age Estimates Piston Flow[d]	Tritium Age Estimates WellMixed[e]
San Ildefonso Wells						
LA-1B	<0.9	>27000	>39000	0.18 .58	>60	>8000
LA-1A	13.9	6250	16300	19.7 63.8	20-30	10-50
LA-2	27.2	5850	10800	4.04 13.	35-40	~400
E. Artesian	3.8	18200	27000	0.31 1.00	>50	>5000
W. Artesian	0.0	>35000	>45000	0.12 0.39	>70	>10000
Halladay	10.7	13400	18500	0.29 0.94	>50	>5000
Pajarito #2	30.9	1280	9700	0.94 3.0	~40	>1500

Footnotes

[a] Assumes dilution by dead carbon from dissolution of carbonates, estimated by del C-13

[b] Assumes radioactive decay only, no dissolution of carbonates

[c] Tritium Units, One tritium atom in 10^{18} hydrogen atoms; 1 TU = 3.24 pCi/L

[d] Piston Flow model assumes no mixing or dilution with other water

[e] Well Mixed model assumes complete mixing in reservoir, inflow = outflow, no other inputs