MARCH 2000

General

LOS ALAMOS NATIONAL LABORATORY

GROUNDWATER INTEGRATION TEAM ANNUAL MEETING

MARCH 29-31, 2000

VIEWGRAPH PRESENTATIONS

HSWA LANL G/M/HWP/2000

TL

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Annual Meeting for FY99 Activities
Agenda

- Refinements in understanding of the vadose zone from injection test data (Bruce Robinson) 148
- ER Project Approach to Risk Assessment (Diana Hollis) 157

4:00 Agreement on Action Items
4:30 Adjourn

Friday March 31 - LATA 4th Floor Conference Room, Los Alamos

9:00 EAG/Managers Session
11:30 EAG Debrief to GIT
12:00 Lunch
1:00 EAG working session

Water Quality Database

Project Status Report

GIT Annual Meeting
March 29, 2000

Agenda

- **Project Statistics**
- **Review of WQDB System Modules (Phase I)**
- **Software Development Lifecycle**
- **Progress FY 99 - Present**
- **Plans for 2000**
- **System Demonstration**

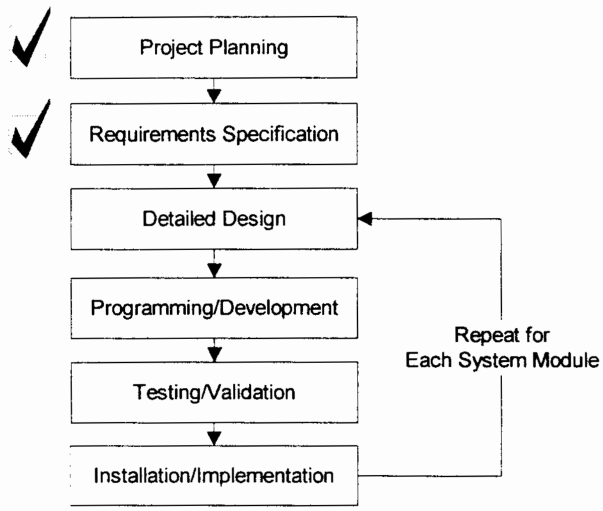
Statistics

Anticipated # of Database Tables	110
Tables Fully Analyzed & Designed	45
Analysis & Design Meetings	40+
Pages of System Documentation	200+
Location Records for Initial Import	800+
Annual Meeting Invitees Named John	6

Review of WQDB System Modules Phase I

- Sampling Locations
- Well Construction
- Water Levels
- Samples Taken
- Field Data
- Analytical Chemistry
- Hydrologic Properties
- Geophysical Logs
- Geologic/Lithologic Data

Software Development Lifecycle



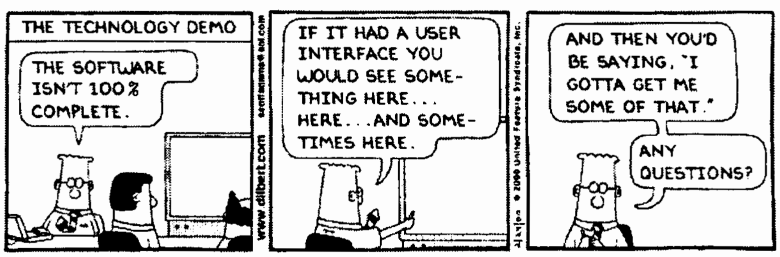
Review of Project Activities FY99 - Present

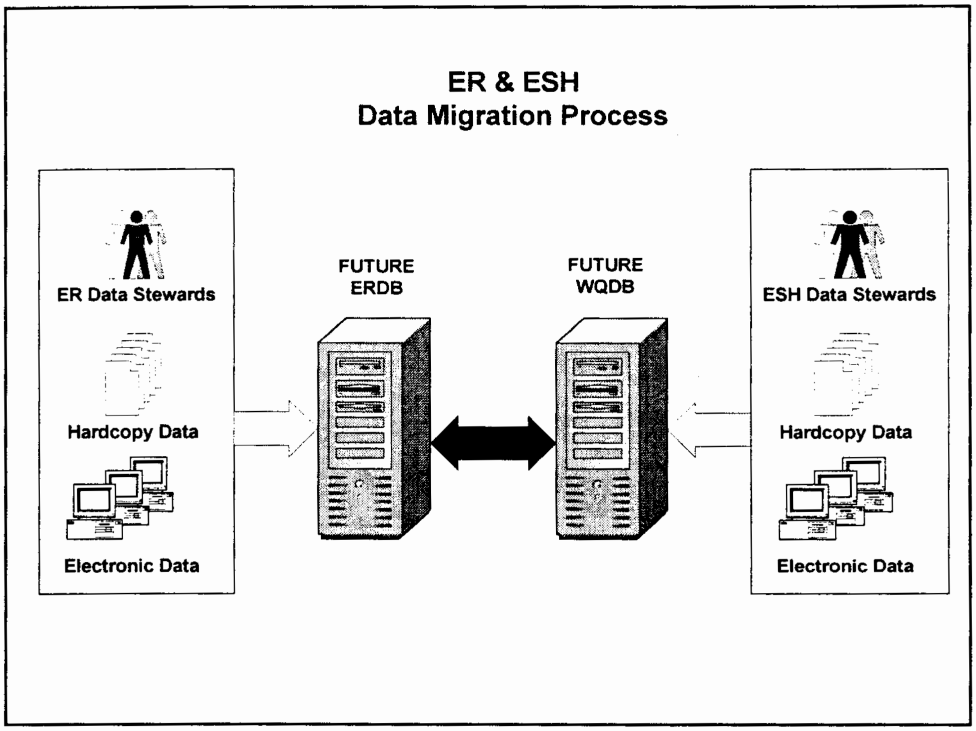
Activity	Status
Project Plan Document	Completed 07/09/1999
System Requirements Document	Completed 11/09/1999
Preliminary Database Design	Completed 11/05/1999
Location Design Specification	Completed 03/09/2000
Well Construction Design Specification	Draft in Review
Location Module Programming	In Progress
Geophysical Log Analysis & Design	In Progress
Water Level Analysis & Design	In Progress
Samples Taken & Chemistry	Start 04/10/2000

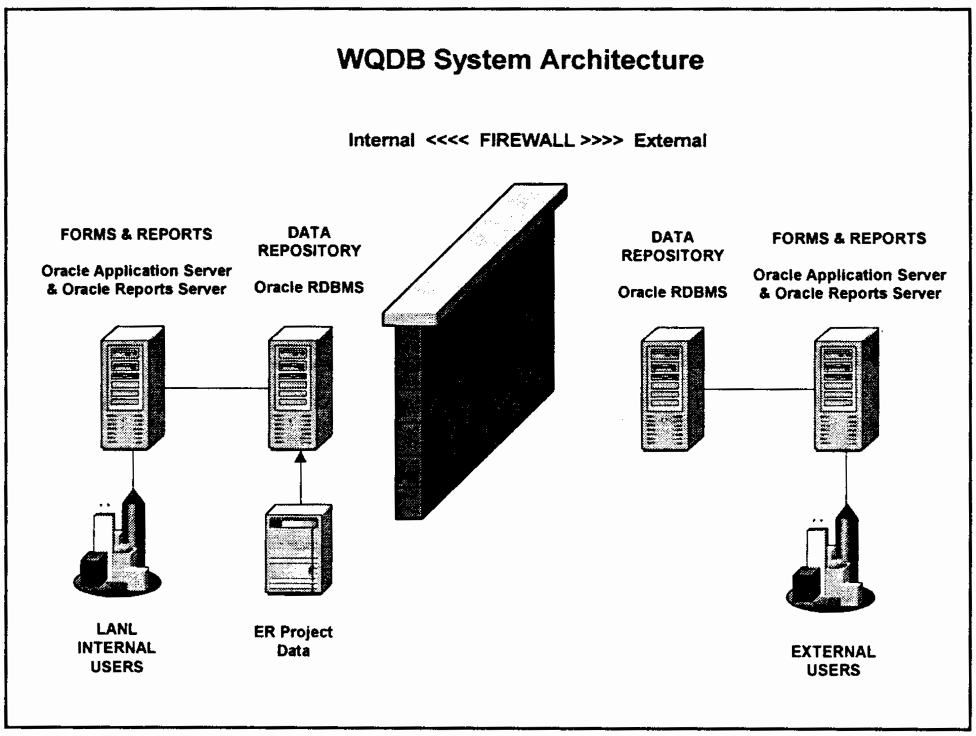
WQDB Schedule for 2000

Module Name	Estimated Implementation (LANL)	Estimated Implementation (External)
Location	April 2000	June 2000
Well Construction	July 2000	July 2000
Water Levels	September 2000	September 2000
Samples Taken & Chemistry	December 2000	December 2000
Geophysical Logs	TBA - 2001	TBA - 2001

WQDB System Demonstration

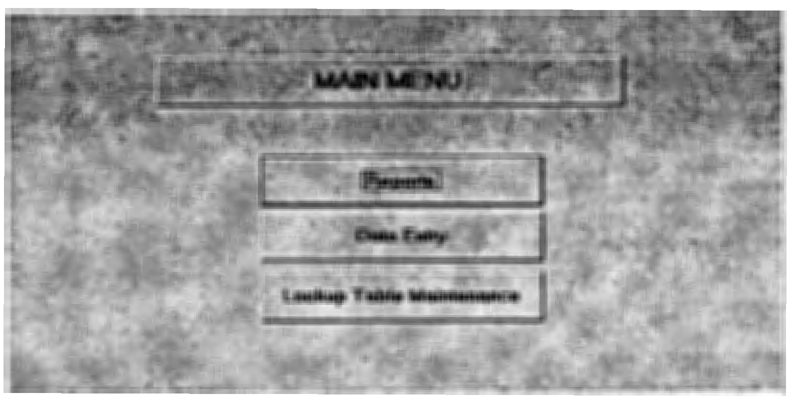


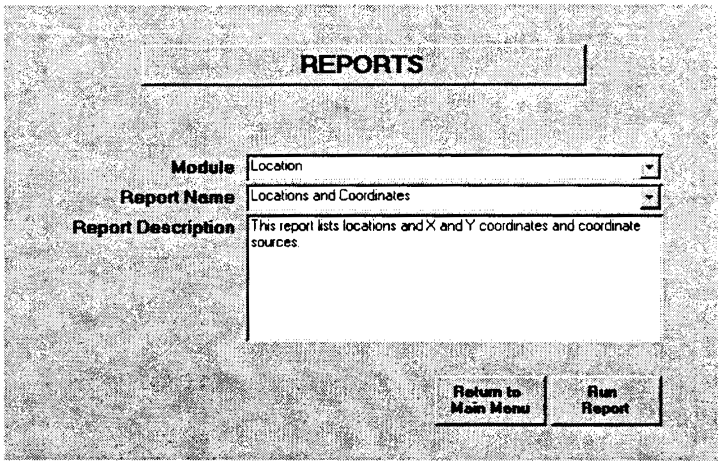

ER & ESH
Data Migration Process
ER Data Stewards
Hardcopy Data
Electronic Data
FUTURE
ERDB
FUTURE
WQDB
ESH Data Stewards
Hardcopy Data
Electronic Data

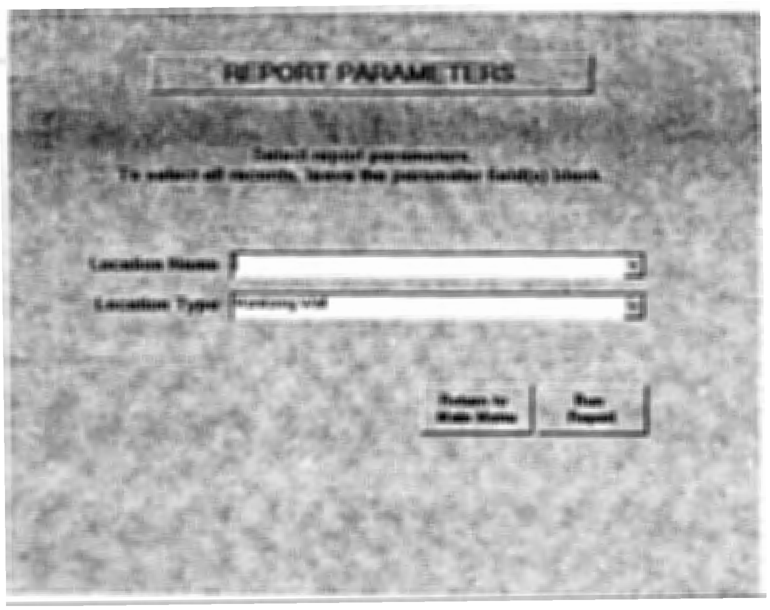

WQDB System Architecture
Internal <<<< FIREWALL >>>> External
FORMS & REPORTS
Oracle Application Server
& Oracle Reports Server
DATA
REPOSITORY
Oracle RDBMS
DATA
REPOSITORY
Oracle RDBMS
FORMS & REPORTS
Oracle Application Server
& Oracle Reports Server
LANL
INTERNAL
USERS
ER Project
Data
EXTERNAL
USERS

Data Migration Across Firewall

- Automated Process
- Migration by QA/QC Release Status
  - Not Released (internal to ESH-18)
  - Released within LANL
  - Released to Public




REPORTS
Module
Location
Report Name
Locations and Coordinates
Report Description
This report lists locations and X and Y coordinates and coordinate sources.
Return to Main Menu
Run Report


REPORT PARAMETERS

WQDB Locations

Report run on: March 21, 2000 4:02 PM

Location Name	X Coord	Y Coord	Coordinate Source
Bernice Garcia Well	1870946	1781752	San I Report
BIA Wellpoint 1	1871683	1774470	
BIA Wellpoint 2	1867407	1777046	
BIA Wellpoint 3	1860038	1772502	
Canada Ancha at Rio Grande	1865538	1758061	
Canada del Buey	1631875	1768728	Arcview
Canada del Buey at SR-4	1651672	1756377	Pratt
Canada Del Buey at WR	1651672	1756377	Pratt
Canada Spring	1672744	1740062	Purtymun
Canon de Valle at SR-501	1609305	1765347	Pratt
CDBO-6	1636200	1764780	Stoker
CDBO-7	1637400	1763301	Stoker
Chaquehui at Rio Grande	1642900	1733217	
Cochiti Lower	1620275	1663790	
Cochiti Middle	1621700	1661186	
Cochiti Upper	1623567	1709600	
Cold Springs: Loc. 31	1401146	1767282	Purtymun
Doe Spring	1642455	1733633	Pratt
Don Juan Playhouse Well	1875000	1774595	
DPS-1	1633308	1774851	Pratt
DPS-2	1634444	1774762	Purtymun
DPS-3	1634744	1774462	Purtymun
DPS-4	1637403	1773263	Pratt
Eastside Artesian Well	1873900	1775705	
El Vado Lower	1498105	2038873	Pratt

Show of Hands:

- How many LANL users will access the WQDB?
- How many DO NOT have a smartcard/cryptocard?

WQDB Question & Answer - Part 1

1. Will stratigraphic contact data (including lithologic data) for each zone for R-wells be available in the WQDB?

Yes. The Geologic Log tables in the Location module of the WQDB store geologic unit and lithologic characteristic data for multiple depth intervals at each location.

2. Will geophysical log data include depth intervals and recorded values?

Yes. The geophysical log module is under detailed analysis and design right now. It is planned to include this data.

3. Will there be a GIS/map interface available to navigate to the available WQDB tabular data? (click on a location & get choices for available tabular data sets)

This is a GIS function that the underlying database design will support, but we do not have the staffing or funding to address this part of the system at this time. It is a very sophisticated functionality, especially when being deployed over the web. This is top priority for Phase II of the project.

4. Will ESH-18 and ER R-well data be accessible in one interface? Will is accommodate the long-term goal to include PRS data?

The ER-ESH joint database design effort is to ensure this will be possible. We fully expect to import ER R-well data into the WQDB alongside ESH-18 data. PRS database design is not part of Phase I of the WQDB, but it could be accomplished with help from ER and a future system enhancement.

5. Could water data from the state be loaded into the WQDB?

If the data can be delivered in a WQDB format that we provide, then yes. We have designed in features that allow us to identify the source of all data in the WQDB and we can accept data from multiple sources. That said, we prefer to hold off on importing LANL-external data into the WQDB until we get ESH and ER R-well data fully imported.

WQDB Question & Answer - Part 2

6. Will core data be included in the WQDB?

The initial design for the Samples module does include core sample & result data. The detailed analysis & design for this module will begin late in April. We will be sure to consider this request in detail at that time.

7. Will the WQDB include flow data and analytical data for springs?

Yes, the Water Level module of the database is being designed to store this data. Flow data is planned to include gage height data and computed unit discharge data. Analytical data from springs can also be stored in this database. In fact, data from a variety of location types (wells, springs, air monitoring stations, etc.) can be stored in this database.

8. Will the WQDB include water level data?

Yes. Both transducer and sounder measurements taken during drilling and after completion in surveillance wells. We plan to provide a web-based user interface for tabular and graphical display of this data. Detailed analysis and design of this system module is underway right now.

9. Will the WQDB contain all historic analytical data?

No. We will migrate the most recent data into the database right away (1996-present). As we have time to QA older data sets, we will load those. If we have special requests for specific data sets, we'll concentrate on those. Focus for data loading will be on Hydrology Team data, but long term, the WQDB is planned as a repository for data from all ESH-18 team data.

10. Will the WQDB include all historical ESH-18 data - chemistry, stratigraphy, hydrologic properties, etc.?

Long term, that is the plan. See above plus this additional caveat - a fair amount of historical data is in hardcopy only. Naturally this will take much longer to migrate than data that is in electronic format.

WQDB Question & Answer - Part 3

11. Will the WQDB include R-well analytical data?

Yes. We have made plans to receive this data from the ER Project and import it into the WQDB as a top priority. All R-well data (not just analytical) has top priority for import into the WQDB.

12. Please be sure to clearly differentiate between data collected during well completion vs. after well completion.

All wells can be assigned a completion date. All data related to a well is assigned a collection date. Some data related to a well can be assigned a "well completion status" flag as well as a collected data. The combination of flags and the comparison of dates will clearly distinguish between data collected pre and post well completion. All user interfaces will be designed to display this status.

13. Please include external entities in beta testing of WQDB user interfaces.

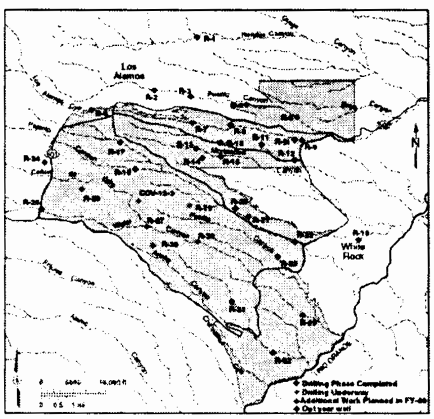
We definitely plan to do this. Providing web-based access to data for users external to LANL will take a bit longer than for those internal to LANL, but this is part of the software test plan. Michael Dale is our NMED representative. Who else do we need to include on the list of external software testers?

Well Construction Subcommittee Report

Deba Daymon

Hydrogeologic Workplan Annual Meeting
March 22, 2000
Ghost Ranch, NM

Drilling status for regional aquifer wells being installed as part of the Hydrogeologic Workplan.



Well R-9

Total Depth:	771 ft
Drilling Completed:	9/29/99
Well Installed:	10/18/99
Well Developed:	2/13/00
Number of Screens:	1
Westbay Installed:	in progress
Quarterly Sampling:	2/28/00
Rig Used:	T-4/DR-24#1
Geophysics:	2/11/00 (S)

Well R-12

Total Depth:	886 ft
Drilling Completed:	1/10/00
Well Installed:	1/24/00
Well Developed:	2/6/00
Number of Screens:	3
Westbay Installed:	3/21/00
Quarterly Sampling:	TBD
Rig Used:	T-4/DR-24#1
Geophysics:	2/8/00 (S)

Well R-15

Total Depth:	1107 ft
Drilling Completed:	9/7/99
Well Installed:	9/20/99
Well Developed:	2/21/00
Number of Screens:	1
Westbay Installed:	n/a
Quarterly Sampling:	2/24/00
Rig Used:	DR-24#1
Geophysics:	2/11/00 (S)

Well R-25

Total Depth:	1942 ft
Drilling Completed:	2/24/99
Well Installed:	5/25/99
Well Developed:	2/1/00
Number of Screens:	9
Westbay Installed:	in progress
Quarterly Sampling:	TBD
Rig Used:	DR-24#1
Geophysics:	2/10/00 (S) 4/21/99 (S) 9/16/98 (L) 10/14/98 (L)

Well R-31

Total Depth:	1103 ft
Drilling Completed:	2/6/00
Well Installed:	3/4/00
Well Developed:	3/25/00
Number of Screens:	5
Westbay Installed:	in progress
Quarterly Sampling:	TBD
Rig Used:	DR-24#2
Geophysics:	3/17/00 (S) 2/9/00 (L)

Well R-9i

Total Depth:	323 ft
Drilling Completed:	3/9/00
Well Installed:	3/11/00
Well Developed:	in progress
Number of Screens:	2
Westbay Installed:	in progress
Quarterly Sampling:	TBD
Rig Used:	DR-24#2
Geophysics:	3/18/00 (S)

Well R-19

Total Depth:	1902 ft
Drilling Completed:	3/12/00
Well Installed:	in progress
Well Developed:	
Number of Screens:	7
Westbay Installed:	
Quarterly Sampling:	
Rig Used:	DR-24#1
Geophysics:	3/16/00 (S) 3/14/00 (L)

Planned Drilling for Rest of Fiscal Year

- Complete well installation at R-19 (~April 21).
- Drill R-7 in Los Alamos Canyon (Start May 15).
- Begin Drilling of R-27 (~September 1)

Evolving Drilling Methods

A variety of drilling methods have been used during installation of the R-Wells. Some examples include:

- Air-rotary drilling using using an under-reaming hammer to advance telescoped casings. Air is the only circulation fluid (e.g. R-9).
- Air-rotary drilling using using an under-reaming hammer to advance telescoped casings and using water to aid circulation in clay-rich units (e.g. R-12).
- Air-rotary drilling using using an under-reaming hammer to advance telescoped casings and using mud or torque eaze behind the casing to reduce the occurrences of rock-locked casing (e.g. R-25).
- A combination of 1) air-rotary drilling using using an under-reamer hammer to advance telescoped casings using mud or torque eaze behind the casing and 2) open-hole drilling using a down-hole hammer with air circulation to explore ahead of the casing advance system (e.g. R-15 and R-31).
- Air-rotary drilling in an open bore hole using water and minimal drilling additives (ez mud and foam) to aid circulation and stabilize the bore hole wall (e.g. R-19 and CDV-15-3).

Drilling Improvements

The pace of drilling has improved significantly. Efficiencies have been gained through:

- Using multiple rigs to accomplish the planned work (currently using Tonto's DR-24, a leased DR-24, Tonto's UDR, Steward Brother's hollow stem auger; LANL's Smeal).
- Drilling 24 hours a day, 7 days a week reduces down time between shifts and results in fewer borehole circulation and stability problems.
- Drilling open bore hole where possible results in much greater drilling rates than is possible by casing advance methods.
- Coring is greatly reduced or eliminated altogether through use of down-hole video logs and geophysical measurements.
- Use of water and minimal drilling additives has improved both open-hole drilling and casing-advancement rates.
- Relaxation in the need to isolate each groundwater zone penetrated results in more open-hole drilling opportunities. However, casing is still used to isolated groundwater zones when contaminants are detected by screening samples.

GIT Hydrology Subcommittee Report for FY 99

Annual Meeting for FY 99 Activities
March 29, 2000

David B. Rogers
Water Quality & Hydrology Group
Los Alamos National Laboratory

1

Presentation Outline

- PM-4 well test
- Moisture profiles
- Modeling & Hydrology subcommittees interpretive task ranking

2

Title
LA6 Prod
Creator
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Preview
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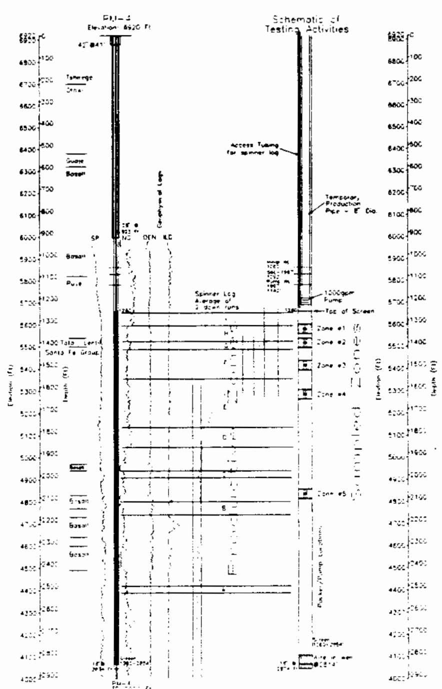
PostScript printer, but not to
other types of printers

PM-4 Test

Background-

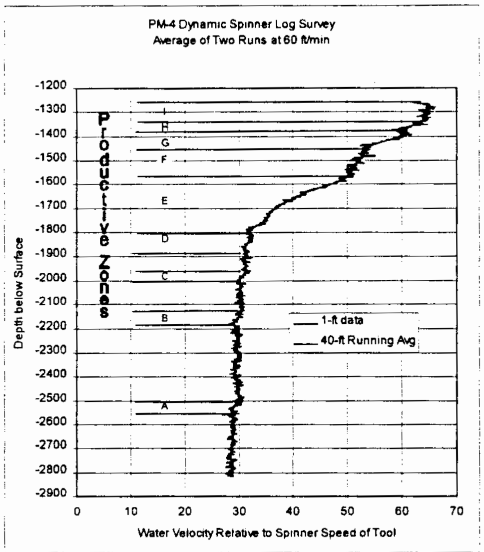
Test of LA-6 in 1975:

- High arsenic led to study
- 400 ft of slotted casing from 420 to 1778 ft
- Water production distributed over entire well depth
- 28% of production from bottom 250 ft of screen



PM-4 Test

- Well depth 2920 ft
- 1592 ft of screen from 1260 to 2854 ft
- Chemistry determined for 5 zones
- All samples similar
- Conclusion: mixing of water in aquifer or during testing



PM-4 Test

- Dynamic spinner log
- Log shows most water production from upper 550 ft
- This 550 ft zone meets pumping demand
- Remainder of well may be as permeable

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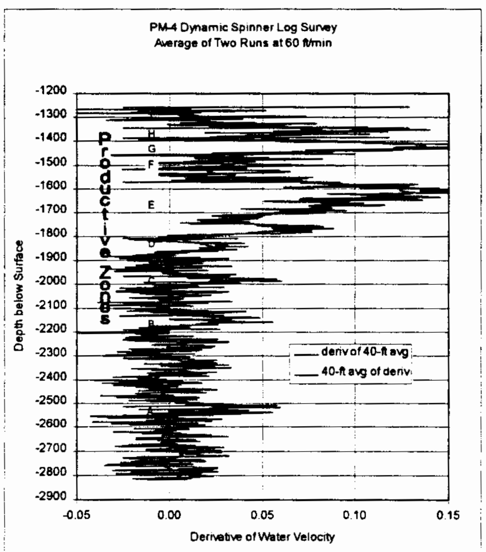


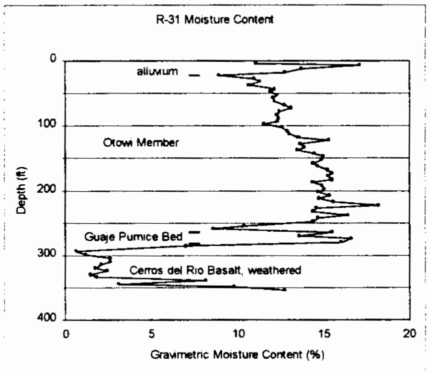
PM-4 Test

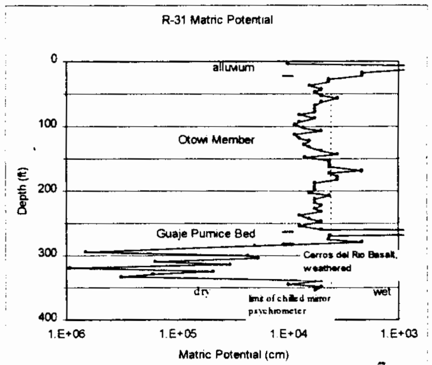
- Derivative of log
- Shows productive zones in more detail
- Production correlates to stratigraphy
- Zones I, H are Puye
- Zone G is Totavi
- F and below are Los Alamos aquifer unit

6

Moisture Profile in R-31

- •Moisture increases with depth in Otowi
- •Basalt is largely unsaturated





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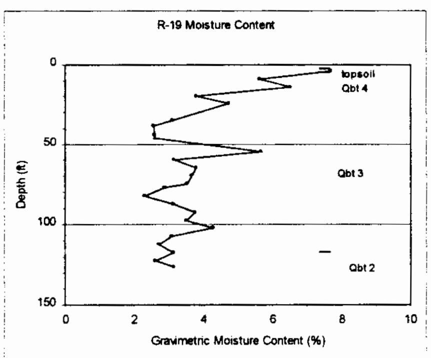
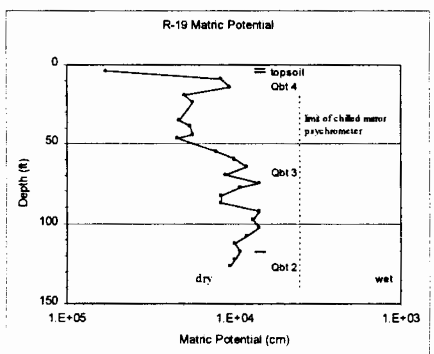
Moisture Profile in R-19

- •Moisture decreases with depth in Tshirege





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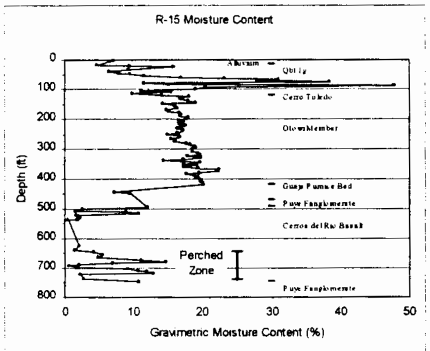
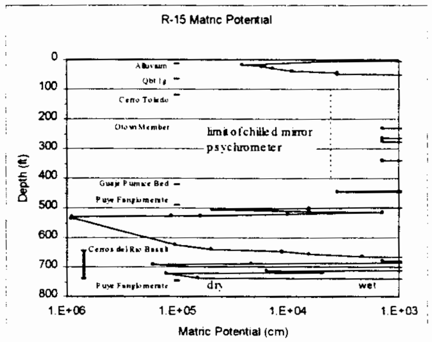
Moisture Profile in R-15

- Moisture increases with depth in Otowi
- Basalt is unsaturated except for part of the perched zone





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Hydrology & Modeling Subcommittee Interpretive Tasks

1) Determination of hydrostratigraphic units and assessment of hydrologic properties data needs. D. Rogers

(tie) 2) Estimation of recharge. E. Kwicklis

(tie) 2) Transmissivity from water level data. S. McLin

4) Evaluation of historical pump test data. S. McLin

10

Hydrology & Modeling Subcommittee Interpretive Tasks

(tie) 5) Permeability model for flow and transport in the Puye Formation and the basalt units. B. Robinson

(tie) 5) Conceptual model for perched water in the vadose zone. B. Robinson

7) Report on Guaje replacement wells. S. McLin

Interpretive Tasks in Progress

1) Hydrogeologic Atlas. W. Stone

2) Consolidation of water level data. S. McLin

3) Hydrologic property measurement during and after drilling. W. Stone

4) Consolidation of Unsaturated Hydrologic Properties Data. D. Rogers

Subsurface Flow and Transport Modeling Activities

Bruce Robinson
Earth and Environmental Sciences Division
Los Alamos National Laboratory
(505) 667-1910, robinson@lanl.gov

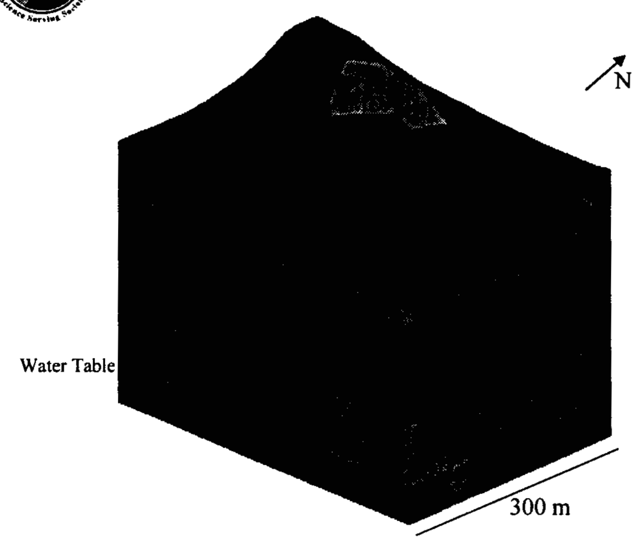
Topics of Discussion

- Current Modeling Activities
  - TA-49 flow and radionuclide transport
  - Area L organic vapor plume
  - Area G risk assessment model development
  - Vadose zone water injection test model
  - Los Alamos canyon flow and transport
  - Regional aquifer flow and transport
- GIT Modeling Subcommittee Activities
- Implications of Modeling to Hydrologic Conceptual Model

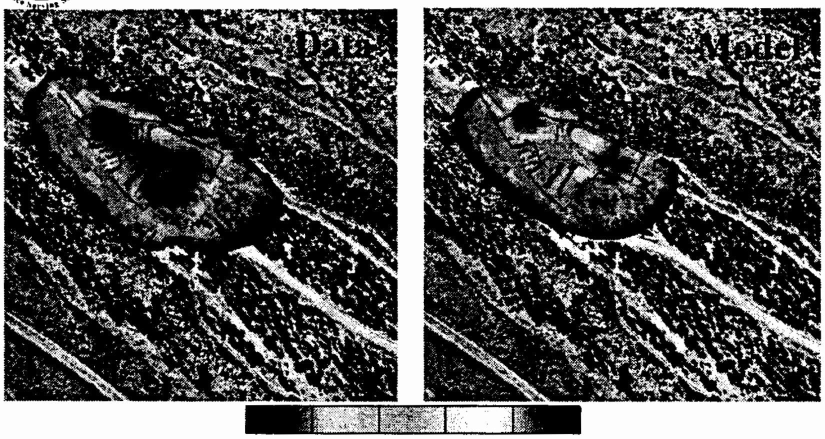
Modeling of Organic Vapor Migration at Area L

- Simulations to assist in the assessment of risk associated with VOCs
- Model results also contribute to understanding vapor-phase transport in the vadose zone

Model Geometry and Computational Grid



Concentration of TCA - Comparison of Data and Model



Concentration map for a horizontal slice at an elevation of 2054 m (6740 ft)

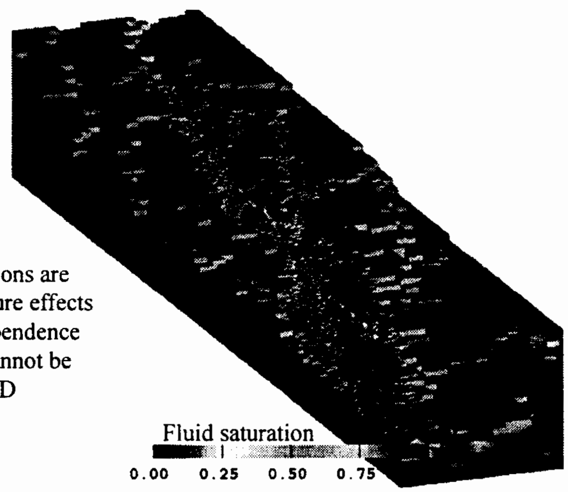
Interface of Risk Assessment and Groundwater Modeling

- Software Package *GoldSim*
    - A commercially available, graphical, object-oriented computer program for carrying out probabilistic simulations
    - We are using GoldSim to carry out probabilistic groundwater transport calculations to evaluate potential contaminant migration impacts to groundwater

Vadose Zone Water Injection Test

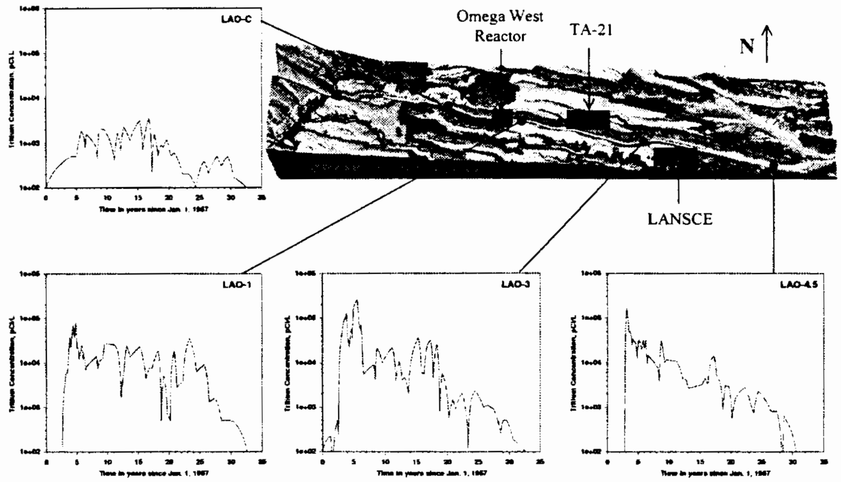
- Water injection and moisture monitoring at a site at TA-50 in 1965
- Three-dimensional calculations of moisture movement have been performed
- Model results compared to published observations are being used to assess the validity of our numerical models of flow in the unsaturated Bandelier tuff

Los Alamos Canyon 3D Fluid Flow Simulation



3D model simulations are performed to capture effects such as spatial dependence of recharge that cannot be fully captured in 2D

Tritium Concentrations in Alluvial Groundwater



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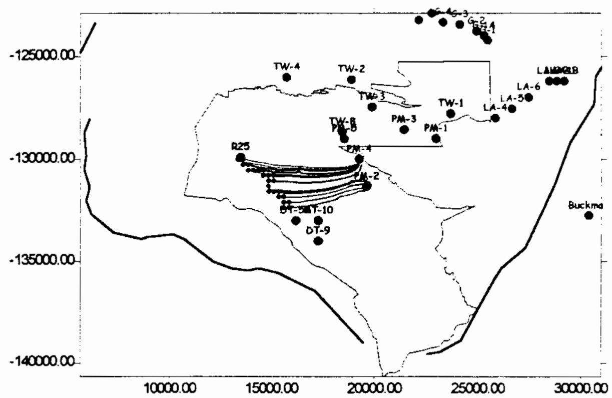
Tritium Transport Model Results

- Travel times of 40 years or less through the vadose zone are explained by the model.
- Vadose zone concentrations will naturally decline over the next 50 to 100 years due to dilution by clean fluid, radioactive decay, and mass arrival at the regional aquifer.
- Tritium concentrations in the perched water zones are predicted reasonably well by the model. Values are considerably lower than the measured alluvial groundwater concentrations.
- Long-term monitoring of intermediate groundwater concentrations is predicted to be a slow process, implying that relatively infrequent samples are required.

10

Predicted Pathways from Various Locations Beneath Canon de Valle



Travel Times to Pumping Wells

	Porosity		Travel time (years) for 50% of particles to breakthrough at PM 2 or PM 4	
	Sedimentary rocks	Crystalline rocks	Source at TA-16	Source beneath Canon de Valle
Case 1	0.1	0.1	1428	PM2: 899 PM4: 719
Case 2	0.1	1.E-3	759	PM2: 899 PM4: 709
Case 3	0.1	1.E-5	749	PM2: 899 PM4: 709
Case 4	0.01	1.E-5	90	PM2: 100 PM4: 80

Confirmation of these travel times must be obtained by:
- passive monitoring of plumes
- tracer testing
- modeling of heterogeneities of aquifer materials

FY 2000 Modeling Deliverables

- Area L organic vapor plume
  - Report on VOC modeling and comparison to data
- Area G risk assessment model development
  - Report on comparison of GoldSim and FEHM process-level models, demonstration of GoldSim application to MDA G
- Vadose zone water injection test model
  - Report on model results and comparison to field observations

13

FY 2000 Modeling Deliverables (cont.)

- Los Alamos canyon flow and transport
  - Report on updated flow and transport model and new transport simulations of Sr and U
- Regional aquifer flow and transport
  - Report on updated flow model incorporating new geology, geochemical data, new hydrologic data from drilling program, refined representation of sedimentary units
  - Model applications: transport simulations of HE migration, pump test design simulations

14

GIT Modeling Subcommittee Activities

- Participation in the development of interpretive tasks (with the Hydrology subcommittee)
- Held discussion sessions on the Following Topics
  - Conceptual model for the basalts and Puye formation
  - Conceptual model for perched water
  - Geologic description of the Los Alamos Aquifer
- Performed an exercise correlating modeling results to the hydrogeologic conceptual model

15

Modeling Results relevant to the Conceptual Model

- Wet canyons/Dry Mesas
  - Los Alamos canyon model
  - TA-49 transport model
- Disturbed conditions on mesas can lead to increasing infiltration and focused flow
  - TA-49 flow model
- Contaminants in wet canyons can migrate significant distances, including to the regional aquifer
- Bandelier Tuff behavior is consistent with flow through the rock matrix (influence of fractures is minor)
  - Vadose zone water injection test model

16

Modeling Results relevant to the Conceptual Model (cont.)

- Regional aquifer transport transport pathways are as expected based on potentiometric surface, but the influence of water supply well pumping on hydraulic gradients must be considered
- Travel times in the regional aquifer will be long unless significant fast pathways exist

STATUS REPORT FOR THE GEOCHEMISTRY SUBCOMMITTEE, GROUNDWATER INITGRATION TEAM, FISCAL YEAR 1999

BY

PATRICK LONGMIRE[1], DALE COUNCE[1], BRENT NEWMAN[2], BART VANDEN PLAS[3], AND FRASER GOFF[1]

MARCH 29-31, 2000

1. EES-1, 2. EES-15, 3. ER-EM, LOS ALAMOS NATIONAL LABORATORY

1

OBJECTIVE OF PRESENTATION

Present a status report for the geochemistry subcommittee and geochemical investigations conducted at the Laboratory and surrounding areas.

Topics of interest include:

- R-15,
- R-25,
- TA-16,
- LANL background groundwater investigation, and
- Geochemical conceptual model.

2

Tritium Activity in Groundwater Zones at R-15

Depth (ft)	Sample Date	Activity (pCi/L)	Analytical Laboratory	Geologic Formation
Perched Zones				
482 (drilling mud)	06/25/99	57.5 ± 9.6	Univ. Miami[a]	Puye Fm.
646	07/22/99	3,770 ± 850	CST-9	basalt
646	07/22/99	4,151	Univ. Miami[b]	basalt
Regional Aquifer				
1,007	08/23/99	220 ± 620	CST-9	Puye Fm.
1,007	08/23/99	<3.192 ± 9.576	Univ. Miami[b]	Puye Fm.
1,100	08/28/99	1.21 ± 0.70	Univ. Miami[a]	Puye Fm.

Analytical error is ±1 standard deviation. LANL and University of Miami perform LSC and direct counting methods, respectively, for measuring tritium activity in these groundwater samples.
[a] Data provided by LANL.
[b] Data provided by DOE Oversight Bureau.

TRITIUM ACTIVITIES AND MOISTURE CONTENTS IN R-15 CORE SAMPLES, MORTANDAD CANYON.

Depth (ft)	Tritium Activity		Moisture Content (wt. %)	Hydrogeologic Unit
	(pCi/g)	(pCi/L)		
22.3	0.665	69.2	9.42	Tshirege Member
39.8	0.077	5.3	6.49	Tshirege Member
59.8	11.64	2,374	16.94	Tshirege Member
69.8	7.78	3,021	27.97	Cerro Toledo interval
84.8	6.39	1,132	15.05	Cerro Toledo interval
104.8	3.99	502	11.18	Cerro Toledo interval
114.8	5.7	621	9.82	Cerro Toledo interval
144.8	12.11	2,852	19.06	Otowi Member
169.8	18.3	3,199	14.88	Otowi Member
229.8	2.88	567	14.46	Otowi Member
269.8	4.97	952	16.08	Otowi Member
319.8	21.8	5,338	19.67	Otowi Member
379.8	22.2	5,405	19.58	Otowi Member
414.8	0.216	54.3	20.08	Otowi Member

HIGH EXPLOSIVE CHEMISTRY OF R-25 SCREENING GROUNDWATER SAMPLES.

Sample Depth (ft)	Sampling Zone	RDX[1] (ug/L)	HMX (ug/L)	4-A-2,4-DNT (ug/L)	2-A-4,6-DNT (ug/L)	TNB (ug/L)	TNT (ug/L)
Otowi Mem.							
747	Upper	**12**	<1	0.38	0.51	<0.26	<0.25
Puye Fm							
867	Upper	**63**	8.3	3.7	5.2	2.2	**19**
1,047	Upper	**84**	12	4.6	5.7	<2.5	**5.3**
1,137	Wet/Dry	**50**	9.2	4.3	2.9	<1.3	<1.3
1,181	Wet/Dry	**4.2**	<1	<0.25	0.43	<0.26	<0.25
1,287	Reg. Aq.	<0.84	<1.0	<0.25	<0.25	<0.26	<0.25
1,407	Reg. Aq.	**62**	9.7	<1.3	2	<1.3	**7.1**
1,507	Reg. Aq.	**4.4**	<1	<0.25	<0.26	<0.26	<0.25
1,607	Reg. Aq.	**15**	2.6	5	0.46	<0.26	0.84
1,747	Reg. Aq.	<0.84	<1	<0.25	<0.25	<0.25	<0.25
1,867	Reg. Aq.	0.97	<1	<0.25	<0.25	<0.26	<0.25
1,939	Reg. Aq.	<0.84	<1	<0.25	<0.25	<0.26	<0.25
1,940 (air lifted)	Reg. Aq.	**8.8**	1.5	1.7	0.69	<0.26	0.77
1,940 (bailer)	Reg. Aq.	**9.6**	1.6	1.8	0.79	<0.26	1.1
1,942	Reg. Aq.	**5.9**	<1	1.1	<0.25	<0.26	0.64
EPA HA[2] (μg/L)		*2*	*400*				*2*

➢ RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), 4-A-DNT (4-amino-2,6-dinitrotoluene), 2-A-DNT (2-amino-4,6-dinitrotoluene), TNB (1,3,5-trinitrobenzene), and TNT (2,4,6-trinitrotoluene) analyzed by high pressure liquid chromatography (HPLC) (EPA Method 8330) at Paragon Analytics, Inc., Fort Collins, Colorado.

2. USEPA (Region 6) lifetime health advisory level. Reg. Aq. means Regional Aquifer.

5

RESULTS OF TA-16 INVESTIGATIONS

Temporal and spatial variability in contaminant concentrations and other geochemical parameters/species are observed.

Barium concentrations in groundwater and surface water are controlled by mineral solubility with $BaSO_4$ (oversaturation) and $BaCO_3$ (saturation).

Precipitation and dissolution could be controlled by evapotranspiration.

Variation of high explosive concentrations in the subsurface are controlled by fractures and high permeable units such as surge beds

Variation in nitrogen isotope ratios within Canon de Valle suggest there are multiple sources of nitrogen species.

6

LANL BACKGROUND GROUNDWATER INVESTIGATION

TOPICS OF INTEREST

I. DATA QUALITY OBJECTIVES

II. QUALITY ASSURANCE AND DATA VALIDATION

II. URANIUM DISTRIBUTIONS

IV. STATISTICAL ANALYSES

V. FY2000 WORK SCOPE

Type of Data	Existing Data	New Data Required
Water quality data	Analyses of groundwater samples are available from Laboratory surveillance program, ER Project, NMED-OB studies, National Uranium Resource Evaluation (NURE) Project, consultant reports, and the US Geological Survey.	Analyses of additional groundwater samples representing each mode of groundwater occurrence.
Sample handling (filtered/ nonfiltered)	Existing data from filtered samples are adequate for use. However, nonfiltered samples that have been collected by other programs have cation-anion charge balance greater errors than ± 10%; therefore not of adequate quality.	Analyses of filtered and nonfiltered samples (low turbidity), except for total suspended solids, which requires a nonfiltered sample.
Analytes	Assessment of the existing data set (of 55 filtered samples) showed good agreement between cation sum and anion sum. Ten samples had laboratory duplicates and the laboratory variation is less than 20% relative standard deviation. Therefore this data can be used in the establishing background. However, most of the major cations and anions are frequently detected, but many of the trace elements have low detection rates.	Major cations (Ca, Mg, Na, K); major anions (HCO_3, Cl, SO_4); trace elements (Ag, Al, As, B, Ba, Be, Br, Cd, ClO_3, Co, Cr, Cs, Cu, F, Fe, Hg, I, Li, Mn, Mo, NH_4, Ni, NO_2, Pb, PO_4, Rb, Sb, Se, S_2O_3, Sn, Sr, Ti, Tl, U, V, Zn); SiO2; total dissolved solids, fallout radionuclides (^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{90}Sr, ^{3}H, ^{234}U, ^{236}U, and ^{238}U); dissolved organic carbon, and stable isotopes ($^{18}O/^{16}O$, $^{15}N/^{14}N$, and D/H).
Analytical methods	Samples analyzed by SW 846 methods are acceptable for use in determining background	SW 846 methods by ICPES, ICPMS, CVAA, ETVAA, AA, SIE, IC, colorimetry, and MS. Analysis of fall-out radionuclides by alpha spectrometry, gamma spectrometry, liquid scintillation, gases proportional counting, electrolytic enrichment/gas proportional counting. Field parameters include temperature, pH, specific conductance, turbidity, carbonate alkalinity.

Alluvial	Perched Intermediate	Regional Aquifer
Well LAO-B, upper Los Alamos Canyon	Apache Spring, west of Lab	Spring 1, White Rock Canyon, San Ildefonso
	Seven Springs, Jemez Mountains	Sacred Spring, north of lower Los Alamos Canyon, San Ildefonso
	Water Canyon Gallery, west of Lab	La Mesita Spring, White Rock Canyon, San Ildefonso
	Upper Canon de Valle Spring, west of Lab	Water Supply Well O-4, Los Alamos Canyon
	Pine Spring, north of Lab	Water Supply Well G-5, Guaje Canyon north of Lab
	Well LAOI-1.1, Los Alamos Canyon	
	Doe Spring, White Rock Canyon	
	Spring 9B, White Rock Canyon	
	Spring 4A (Pajarito Spring), White Rock Canyon	

9

FY99 AND FY00 WORK ACTIVITIES-LANL BACKGROUND GROUNDWATER INVESTIGATION

Validate groundwater data for major ions, trace elements; trace metals, radionuclides, and DOC fractionation.

Identify additional data needs (ICPMS) for selected trace elements and trace metals.

Present an ER Project peer review focusing on the LANL background groundwater investigation (technical approach, analytical results, and statistical analyses of data).

Perform additional groundwater sampling in early FY00, if required.

Prepare LANL background groundwater report in FY00.

10

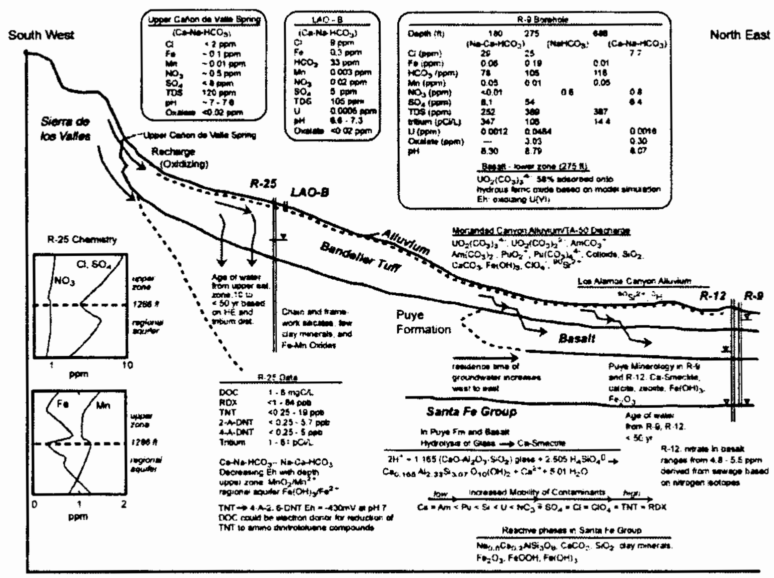
CONCLUSIONS

Geochemistry subcommittee members analyzed and interpreted data and information collected from TA-16, R-15, R-25, and background groundwater stations.

Background geochemical groundwater data and information are collected for regulatory purposes and applied scientific investigations.

A preliminary geochemical conceptual model was developed, based on data and information collected from R wells, ER Project wells, LANL surveillance wells. This conceptual model shall be updated and revised as new geochemical data and information are collected and analyzed.

11



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SUPPLEMENTAL MATERIAL FOR GEOCHEMISTRY SUBCOMMITTEE STATUS REPORT, FY1999

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES FOR R-25, SURFACE WATER, AND SELECTED LOS ALAMOS NATIONAL LABORATORY BACKGROUND SPRINGS[a,b]

Location	NO_3-N	NH_4-N	$\delta^{15/14}N$-NO_3	Water Type
R-25 (747 ft)	0.95	0.03	+3.1	upper zone
R-25 (867 ft)	0.90	0.03	+2.8	upper zone
R-25 (1,286 ft)	0.32	0.02	+2.6	regional aquifer
R-25 (1,407)	0.51	<0.02	+4.3	regional aquifer
R-25 (1,607 ft)	0.42	<0.02	+2.5	regional aquifer
R-25 (1,747 ft)	0.31	<0.02	-0.6	regional aquifer
R-25 (1,867 ft)	0.20	<0.02	1.1	regional aquifer
R-25 (1,942 ft)	0.25	<0.02	+0.3	regional aquifer
Los Alamos Canyon reservoir	0.04	-	-2.4	surface water
Upper Pajarito Canyon	0.01	-	-2.4 (2)	Surface water
Water Canyon Gallery	0.10	-	0	spring
Apache Spring	0.35	-	-0.5 (2)	spring
HNO_3 Std.[c]	5.7	<0.02	1.0 (4)	dilute acid

a. Concentrations of nitrate and ammonium in units of ppm; isotopes in units permil or parts per thousand.
b. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas. The number of isotopic analyses for each sample is given in parentheses.
c. Laboratory HNO_3 standard prepared at EES-1.

ANALYTES OF INTEREST FOR LANL BACKGROUND GROUNDWATER INVESTIGATION

Major ions, trace elements, and trace metals.

Dissolved organic carbon fractionation.

Radionuclides
(^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, ^{90}Sr, ^{137}Cs, and ^{3}H).

Stable isotopes (H, O, and N).

Groundwater Data Distribution Policy

Steven Rae
Water Quality and Hydrology
(ESH-18)

1

Hydrogeologic Data Collected

- Groundwater and geologic samples are collected while drilling wells.
- Samples are collected and analyzed following a formal process to ensure the integrity of the data derived from the samples
- Testing and analytical data received are validated and verified

2

Validation and Verification

- Validation and verification is a process by which data are accepted, qualified, or rejected for use.
- Typically includes evaluating chain of custody, transmittal errors, field and laboratory quality control, detection limits, calibration, contract compliance, identification of outliers, special sampling requirements

3

Mechanisms of Data Release

- Notices of Intent to Discharge (NOIs) to NMED
- Validated and verified data in data reports (e.g. well completion reports, Annual Status Report)
- Presented to NMED and other stakeholders at Quarterly and Annual meetings
- Special presentations to NMED and other stakeholders (Pueblos, CAB, County)
- Press releases

4

Terminology - Groundwater Data

- Screening data: data that has been collected prior to the completion of a well, that may not be representative if ambient groundwater
- Preliminary data: any data that has been received from an analytical laboratory that has not been subject to validation and verification process

5

Terminology - Groundwater Data (cont.)

- Validated and verified data: any data that has been received from an analytical laboratory that has been validated and verified.
- Confirmed data: any data that has been confirmed by the analysis of one or more additional samples, collected from the same source and analyzed for the same analytes.

6

Policy for Release of Groundwater Data

- Validated data will be available from the WQDB through the internet (CY2000)
- Validated data available at the time of a quarterly or annual meeting will be available for discussion
- Preliminary data or unvalidated screening data will only be released when required to make decisions on well completion or produced water disposal

7

News Releases

- Press releases now sent to DOE, Pueblos, and NMED 24 hours prior to release (example: perchlorate news release)
- Plan to expand 24-hour pre-notification to an e-mail distribution of stakeholders as requested.

8

Recent Groundwater Findings at Los Alamos National Laboratory

Annual Meeting for FY 99 Activities
March 29, 2000

David B. Rogers
Water Quality & Hydrology Group
Los Alamos National Laboratory

1

Presentation Outline

- Perched zones in basalt
- Tritium and Sr-90 in Los Alamos wells
- Perchlorate at Los Alamos

2

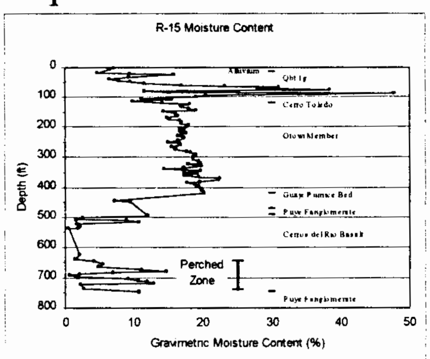
Perched Zones in Basalt

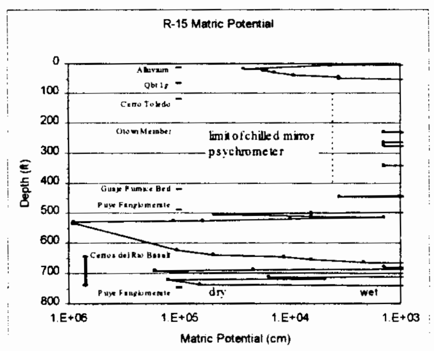
- Perched zones occur in the Cerros del Rio Basalt at R-9, R-12, R-15
- At R-9 and R-9i water was encountered at 186 ft and water level rose to 137 ft- is the perched zone confined?
- At R-15 unsaturated basalt samples are found within the perched zone

Moisture Profile in R-15

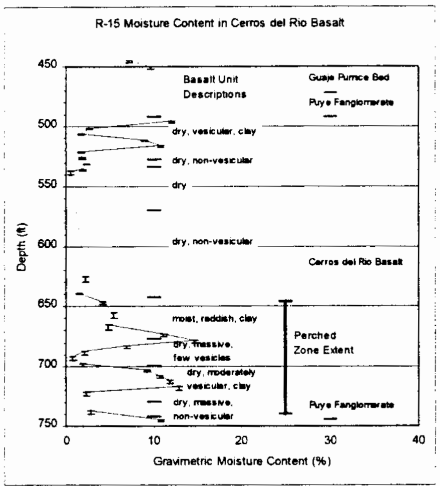
•Moisture increases with depth in Otowi

•Basalt is unsaturated except for part of the perched zone



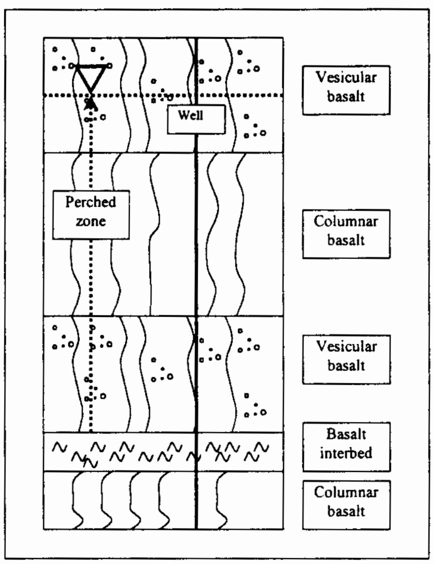


Perched Zones in Basalt: R-15



- Within perched zone some basalt is unsaturated
- Saturation occurs where vesicles or clay are present
- Water levels show perched zone is continuous

Perched Zones - Caused by Permeability?



- Basalt interbed perches water
- Joints provide water communication
- Dry columnar basalt
- Vesicular basalt is more permeable

Tritium in the Aquifer

- Tritium is highly mobile in water
- Drinking water MCL is 20,000 pCi/L based on 4 mrem/yr dose
- Levels in most water supply wells are 1 pCi/L- a background value
- NMED reported 40 pCi/L in Otowi 1- or 1/500 of MCL
- Nearby test well has 360 pCi/L tritium

7

Strontium-90 in the Aquifer

- Strontium-90 is somewhat mobile in water
- Drinking water MCL is 8 pCi/L based on 4 mrem/yr dose
- LANL water supply data show 2 detects out of 117 measurements for 18 water supply wells
- NMED reported 1 pCi/L in Pajarito 1
- Strontium-90 analysis method is imprecise

8

What is Perchlorate?

- Perchlorate has numerous industrial uses including analytical chemistry, rocket fuel, explosives, and manufacturing
- Perchlorate is mobile and persistent in groundwater and surface water

9

Perchlorate in Drinking Water

- EPA added perchlorate to its Safe Drinking Water Act Contaminant Candidate List in 1998
- EPA is reviewing perchlorate toxicology
- California has a water supply action level of 18 ppb and EPA indicates a provisional cleanup level of 4-18 ppb

10

No Perchlorate in Los Alamos Drinking Water

- Testing of Los Alamos water supply entry points in 1997-98 found no perchlorate at a 4 ppb detection limit
- Testing of wells PM-1, PM-2, and PM-5 nearest Mortandad Canyon shows no perchlorate at a 2 ppb detection limit in February 2000

11

Perchlorate at LANL

- Used in nuclear chemistry and high explosives
- TA-50 RLWTF feed water contains about 500 ppb perchlorate, dropping to 24-66 ppb in the discharge after reverse osmosis

12

Perchlorate in LANL Waters

- Recent Laboratory data show that shallow groundwater in Mortandad Canyon contains 80-220 ppb perchlorate
- Well R-15 in Mortandad Canyon found perchlorate at 12 ppb in a perched groundwater zone at 646 ft
- The regional aquifer in R-15 had no perchlorate at a 2 ppb detection limit

13

Perchlorate in LANL Waters

- Well R-31 at TA-39 and R-25 at TA-16 show no perchlorate in the regional aquifer at a 2 ppb detection limit
- More testing of waters at the Laboratory is planned

14

Conclusions- LANL Actions

- Continue Surveillance Program and special quarterly monitoring for HE, strontium-90, and perchlorate
- Continue Hydrogeologic Workplan and new monitoring well project
- ER Project Cleanups
- Watershed Management Plan
- Continue treatment plant upgrades

15

Well Prioritization and FY01Activities

Charlie Nylander

Hydrogeologic Workplan Purpose

"Workplan describes activities proposed to be performed by Los Alamos National Laboratory to characterize the hydrogeologic setting beneath the Laboratory and to enhance the Laboratory's groundwater monitoring program."

Hydrogeologic Workplan Objectives

Objectives of the activities described in the Workplan are to address the four specific issues raised by NMED in the letter dated August 17, 1995:

- **Individual zones of saturation beneath LANL**
- **The recharge areas for the regional and perched aquifer**
- **The ground water flow directions**
- **Aquifer characteristics**

3

NMED Concerns Incorporated in the Hydrogeologic Workplan

- The four issues were incorporated into the EPA Data Quality Objective process used to plan the Workplan activities.
- The four issues were emphasized in the scoring criteria for the scheduling of well construction by assigning the highest points related to those issues.

4

Hydrogeologic Workplan Prioritization Emphasis

- Reduce the hydrologic setting uncertainty
- Reduce stratigraphic and structural uncertainty
- Detect contamination of the water supply system

Application of this emphasis resulted in the prioritization of the 32 R-wells targeting areas with no data and areas potentially impacted by contamination

Evolution of Well Prioritization

- Hydrogeologic Workplan was designed to re-prioritize wells based on new information
- Prioritized sequence of wells has been changed a number of times based on input from stakeholders:
  - R-9 moved up 2 years for LA/Pueblo Work Plan
  - R-15 moved up 1 year to address impact from discharges
  - R-19 moved 1 year to address HE

NMED Proposed Prioritization

"The drilling project's primary goal is to characterize the hydrogeology beneath the Pajarito Plateau; however, the characterization of the hydrogeology should initially be focused on canyons/watersheds where the greatest potential for contaminant migration is likely to occur."

Consensus on Well Prioritization

Meeting with HRMB to dialog about prioritization approach. Agreements were:

- Maintain focus on site-wide characterization, but
- Increase focus on priority watersheds
- Construct 2 R-wells each year in a priority watershed

Proposed FY01 Activities

- Drill and construct R-5, R-8, R-1, R-22, R-27
- Modeling activities
- GIT subcommittee interpretative tasks
- Information management activities
- GIT bi-weekly meetings
- Quarterly and Annual meetings
- EAG semi-annual meetings

Plugging and Abandonment

Annual Meeting for FY 99 Activities
March 29, 2000

David B. Rogers
Water Quality & Hydrology Group
Los Alamos National Laboratory

1

Existing Test Wells

- Ten existing test wells are used for monitoring the regional aquifer and intermediate perched zones
- These wells have been sampled for decades and continue to be sampled at least annually

2

Existing Test Wells (cont.)

- Analysis by Purtymun and Swanton (1998) of the wells used for monitoring found:
  - Nine wells are sound and should be retained as monitoring wells
  - TW-8 was recommended for plugging and abandonment based on tritium

3

Rehabilitation of Test Wells

- Current test wells do not meet RCRA monitoring well standards
- Well rehabilitation would be more expensive than installing a new well
- Based on experience with the R-wells, injecting backfill material may be impossible

4

Approach to Test Wells

- Test wells will continue to be sampled until a nearby R-well is installed
- Both wells may be sampled for a transitional period

5

Approach to Test Wells (cont.)

- Test wells may be used for hydrologic testing
- After the transition period, test wells may be plugged and abandoned depending on their soundness and usefulness

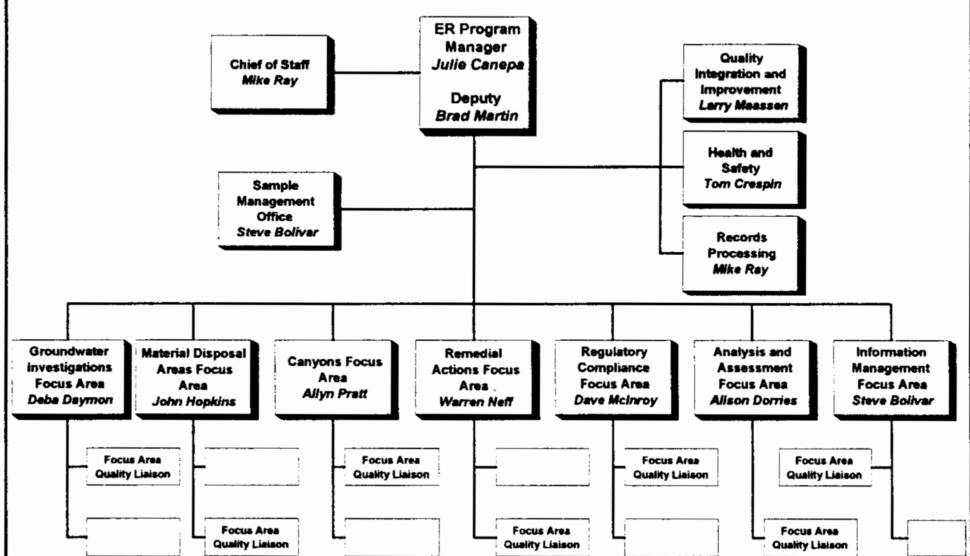
6

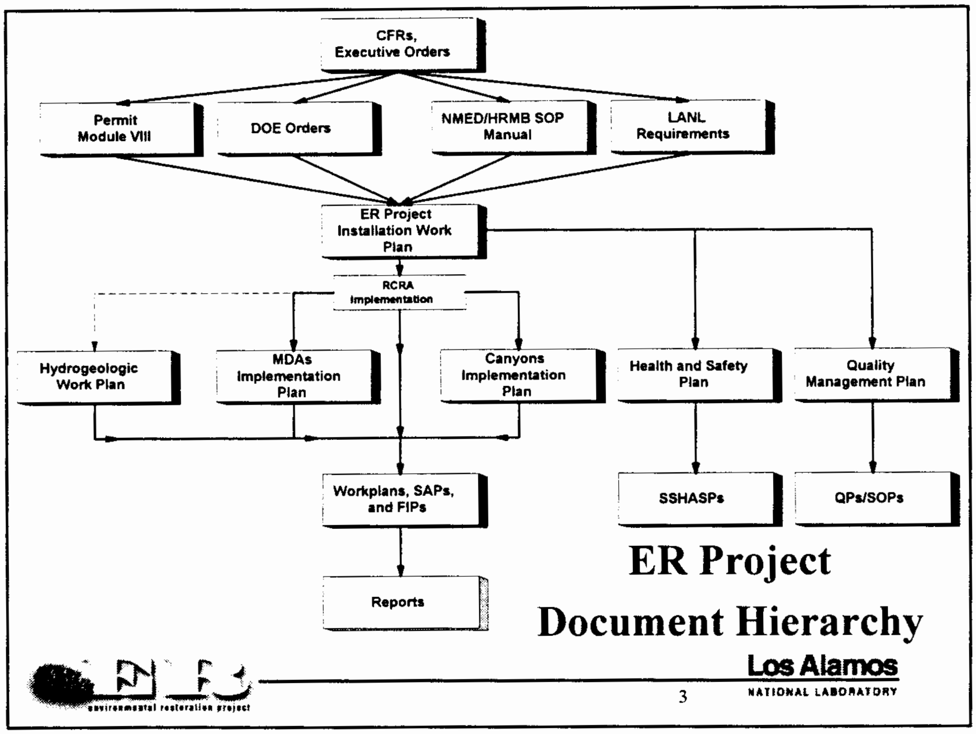
ER Quality Program Overview

Presentation for GIT Annual Meeting
March 30, 2000

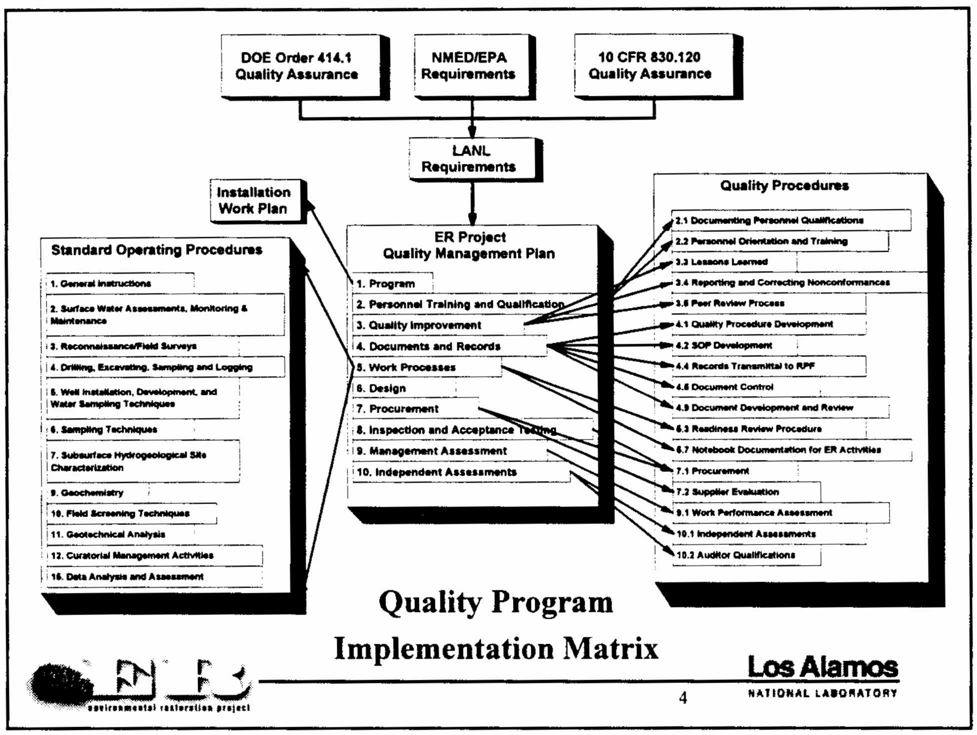
Larry Maassen
Quality Program Project Leader

ER Project Organization





ER Project Document Hierarchy



Quality Program Implementation Matrix

Management Assessment of Groundwater Investigations Focus Area

**ER Project
Quality Management Plan**

1. Program
2. Personnel Training and Qualification
3. Quality Improvement
4. Documents and Records
5. Work Processes
6. Design
7. Procurement
8. Inspection and Acceptance Testing
9. Management Assessment
10. Independent Assessments

Are personnel qualified?
Trained?

Are appropriate records being generated?
Are they complete and accurate?
Are data valid?
Are records captured in Records Processing Facility?

Are procedures in place?
Are they current?
Are they being followed?

What design controls are in place?

Are procurement procedures being followed for items?
Services?

Are sufficient I & AT controls in place?
Are existing controls being followed?

GEOCHEMISTRY AND HYDROLOGY TECHNICAL ISSUES, FISCAL YEAR 1999

BY

PATRICK LONGMIRE[1], DAVID ROGERS[2], BRENT NEWMAN[3], AND ROBERT HULL[4]

MARCH 29-31, 2000

1. EES-1, 2. ESH-18, 3. EES-15, LOS ALAMOS NATIONAL LABORATORY; 4. LATA,

1

OBJECTIVE OF PRESENTATION

Present a technical response to geochemical and hydrological issues provided by GIT External Advisory Group.

Topics of interest include:

- Adsorption,
- Well drilling methods,
- Well completion, and
- Core and groundwater sampling.

2

THE RETARDATION EQUATION

Kd is related to the transport velocity of the adsorbate to that of water by determining the retardation factor, R_f.

The retardation equation is:

$$R_f = 1 + \frac{pKd}{n}$$

Where p = bulk density (g/cm^3) and n = effective porosity (V_{void}/V_{total}).

$$R_f = 1 + \frac{2.5g/cm^3(2.31cm^3/g)}{0.30}$$

R_f = 20. ***Uranium at R-9 is predicted to migrate 1/20 the rate of average groundwater flow in the lower perched zone (275 ft).***

SURFACE COMPLEXATION MODELING OF R-9 GROUND WATER: DIFFUSE LAYER MODEL

The diffuse-layer adsorption model considers solution speciation and aqueous ion activities. The model uses the electric double-layer (EDL) theor EDL theory assumes that the + or – surface charge of a sorbent in contact with solution generates an electrostatic potential that declines rapidly away from the sorbent surface. The potential is the same at the zero (sorbent surface) and d (solution) planes.

The concentration of hydrous ferric oxide (HFO) at 275 ft is 1.46 g/L.

The specific surface area of HFO is 600 m^2/g.

Model uranyl sorption with one surface containing two sites, high energy (s) (8.2×10^{-5} mol active site HFO/L) and low energy (w) (0.003 mol active site HFO/L). The estimated intrinsic constants for uranyl sorption (Langmuir, 1997) include:

$Fe^{s}OH + UO_2^{2+} = Fe^{s}OHUO_2^{2+}$ (log K_1 = 5.2) and

$Fe^{w}OH + UO_2^{2+} - H^{+} = Fe^{w}OUO_2^{+}$ (log K_2 = 2.8).

SURFACE COMPLEXATION MODELING OF R-9 GROUND WATER: DIFFUSE LAYER MODEL

The DLM predicts that 112 ppb total uranium (nitric acid digestion) in the 275 ft perched zone at pH 9 occurs as:

57.5 percent uranyl bound as $SO2UO_2^{+}$ (64 ppb sorbed U),

5.1 percent uranyl bound as $UO_2(CO_3)_2^{2-}$ (7 ppb dissolved U), and

36.6 percent uranyl bound as $UO_2(CO_3)_3^{4-}$ (41 ppb dissolved U) (calculated total dissolved U is 48 ppb, measured dissolved U is 48.4 ppb).

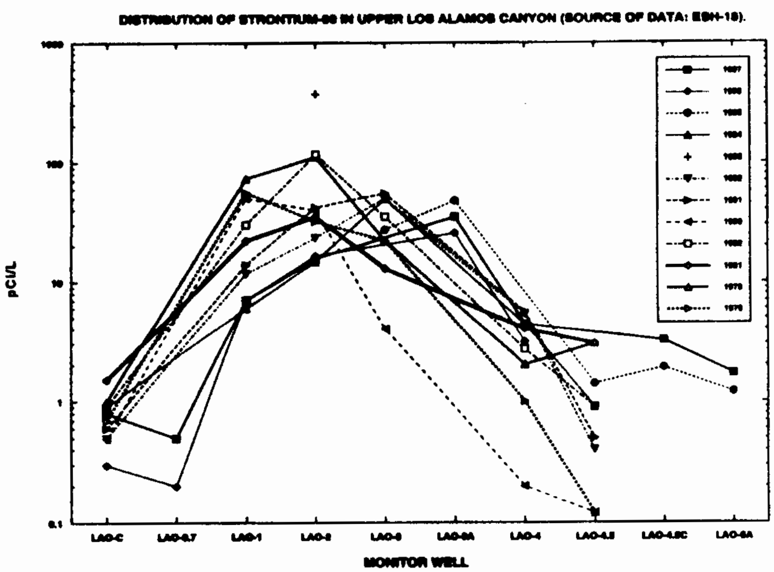
The Kd, based on the DLM, is

(U sorbed M)/(U dissolved M) X (10^3mg/g)/(1.46 mg/ml),

($10^{-6.57}$ M)/($10^{-6.70}$ M) X (10^3mg/g)/(1.46 mg/ml),

$Kd_{(DLM)}$ = 926 ml/g.

5



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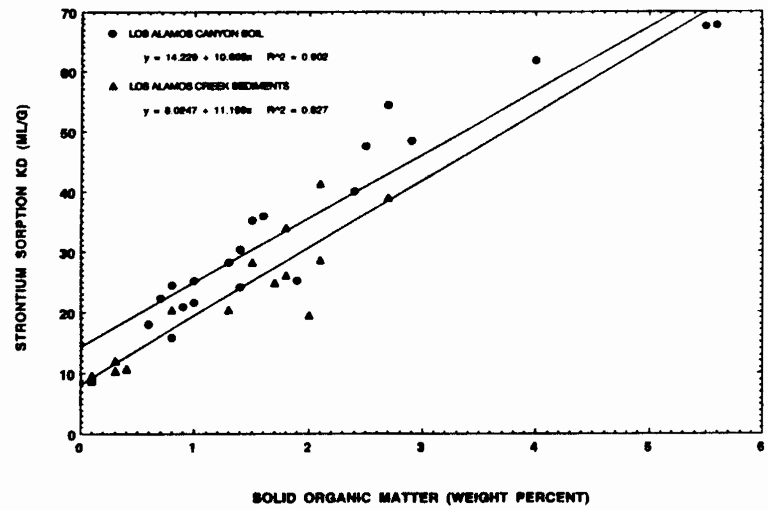
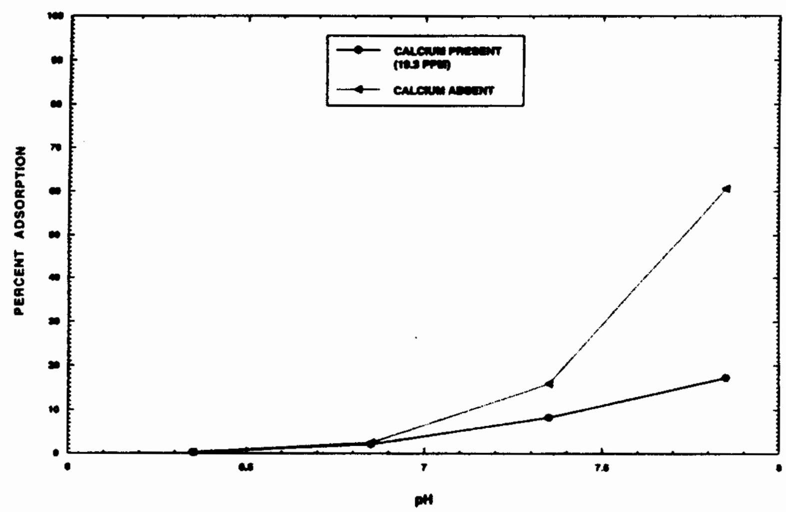


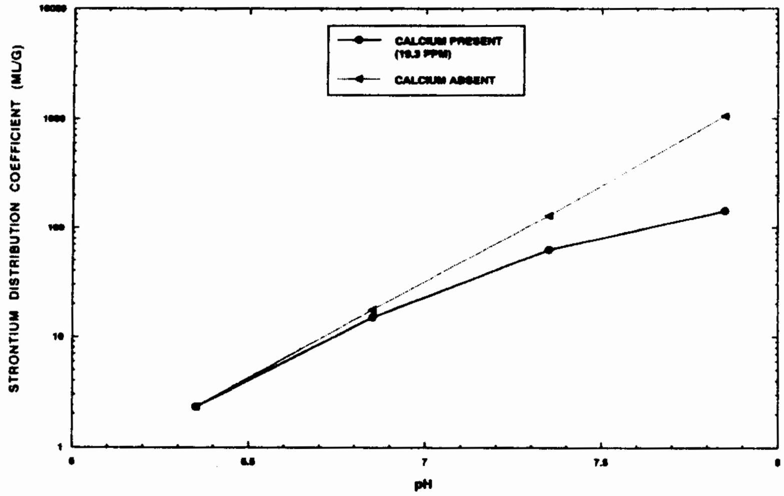
7

PERCENT ADSORPTION OF STRONTIUM ONTO HYDROUS FERRIC OXIDE (1.46 GRAMS PER LITER) IN THE PRESENCE AND ABSENCE OF CALCIUM AT LAO-0.91 (TOTAL DISSOLVED STRONTIUM = 0.14 PPM, 25 C).



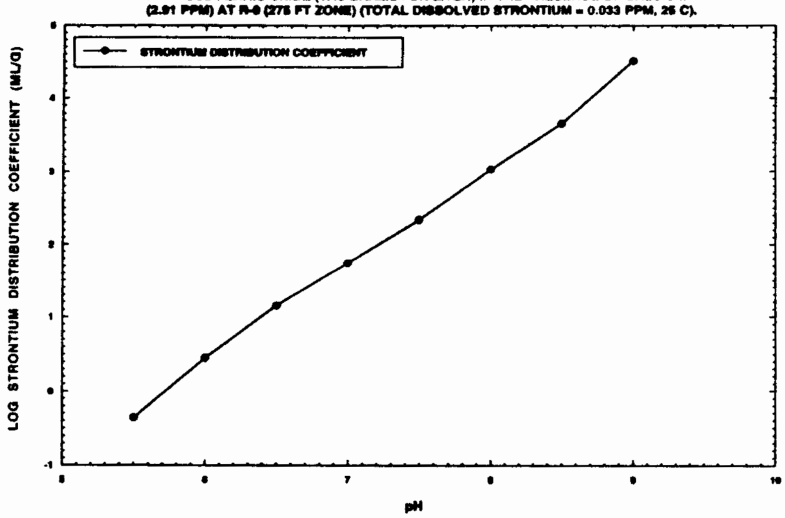
8

CALCULATED DISTRIBUTION COEFFICIENTS FOR STRONTIUM ADSORPTION ONTO HYDROUS FERRIC OXIDE (1.46 GRAMS PER LITER) IN THE PRESENCE AND ABSENCE OF CALCIUM AT LAO-0.91 (TOTAL DISSOLVED STRONTIUM = 0.14 PPM, 25 C).



9

CALCULATED DISTRIBUTION COEFFICIENTS FOR STRONTIUM ADSORPTION ONTO HYDROUS FERRIC OXIDE (1.46 GRAMS PER LITER) IN THE PRESENCE OF CALCIUM (2.91 PPM) AT R-9 (275 FT ZONE) (TOTAL DISSOLVED STRONTIUM = 0.033 PPM, 25 C).



10

GROUNDWATER SAMPLING AND MONITORING

Drilling with mud and failure to collect core and/or cuttings.

Decisions were made by ER Project and ESH-18 staff to drill with mud (behind casing) to expedite drilling advancement and to lower drilling costs.

Use of long screens.

Longevity of wells necessitated use of long screens due to drawdown.

Single completion wells screened above water table.

Language in Laboratory HSWA (EPA) permit dictates use of well screens above the water table based on potential distribution of liquid organic compounds (LNAPLs).

High purging and sampling flow rates in long-screened single completion wells.

Hydrodynamic mixing occurs in long-well screens (< 10 ft) and micropurging (low-flow sampling) would not eliminate mixing. Micropurging shall be used for Westbay-constructed wells.

Stratigraphy at Drill Hole R-31

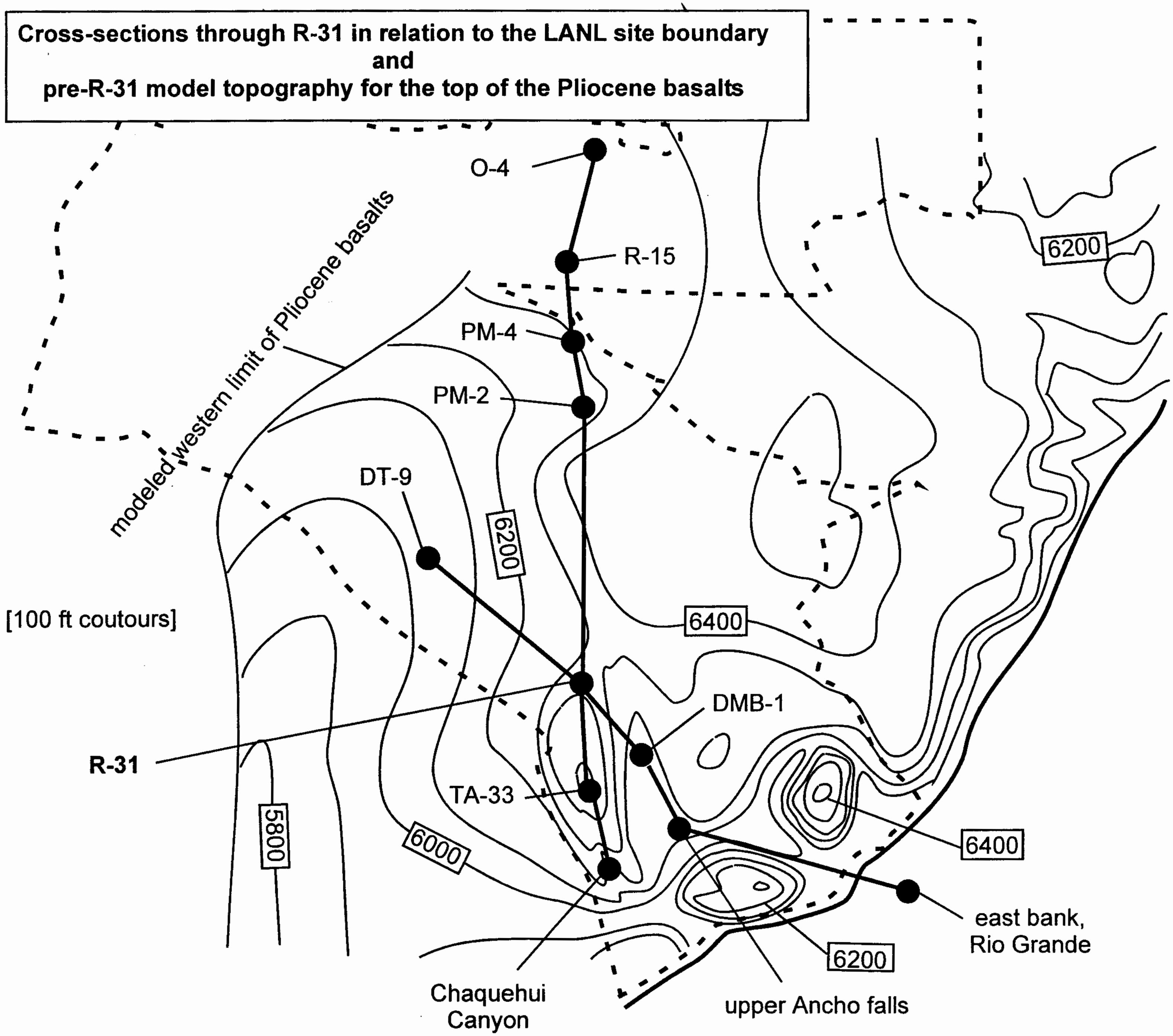
D. Vaniman, J. Marin, R. Koch, D. Broxton

- Predicted versus actual stratigraphy
- Paleotopography on the Puye surface
- Treatment of river gravels ("Totavi")
- In broader context: Interrelations between transmissive units

Drill hole R-31 has provided new information in the southeastern portion of Los Alamos National Laboratory. Two cross sections place R-31 in site context:

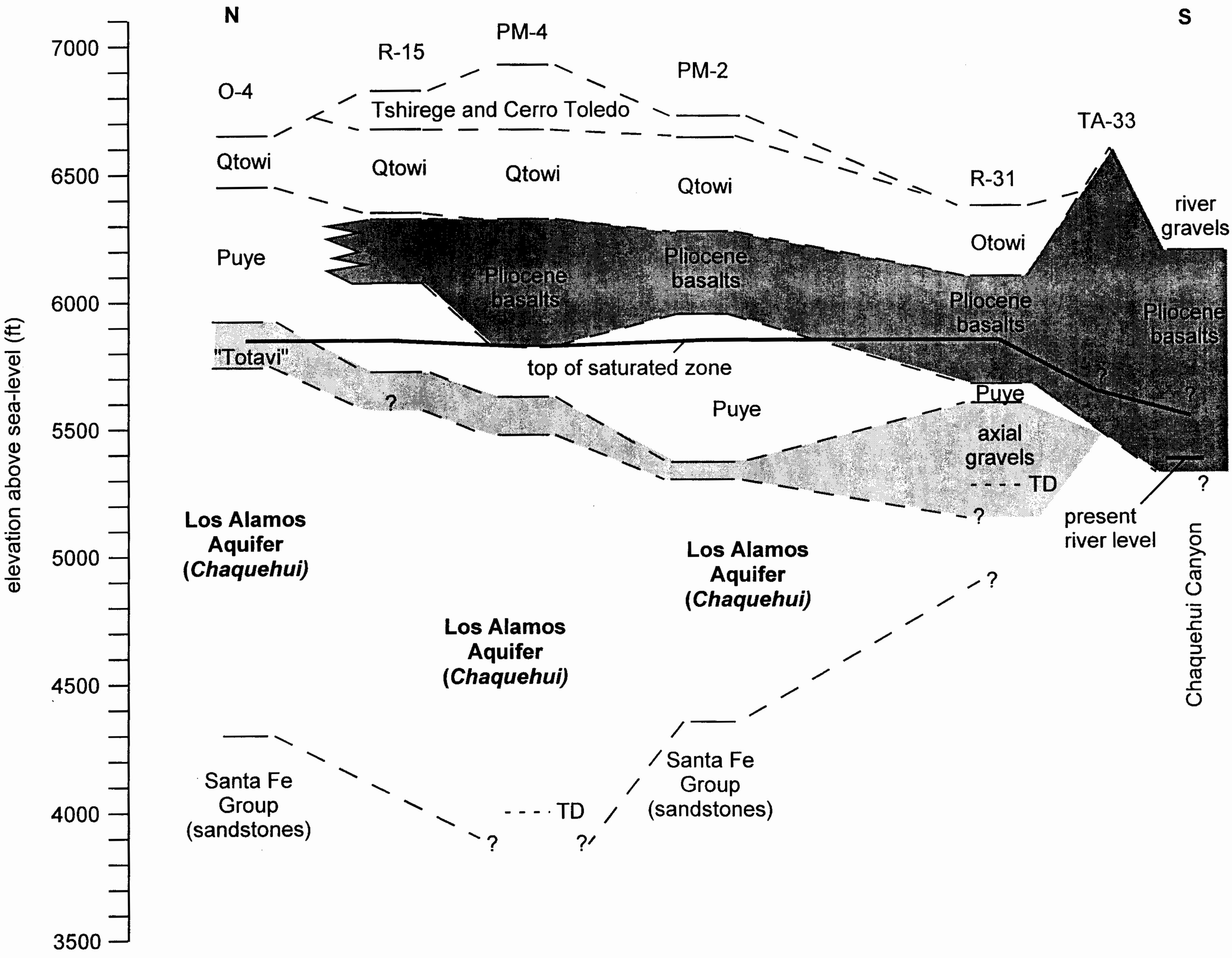
North to south from drill hole O-4 to outcrop in Chaquehui Canyon

Northwest to southeast from drill hole DT-9 through Ancho Canyon and across the Rio Grande



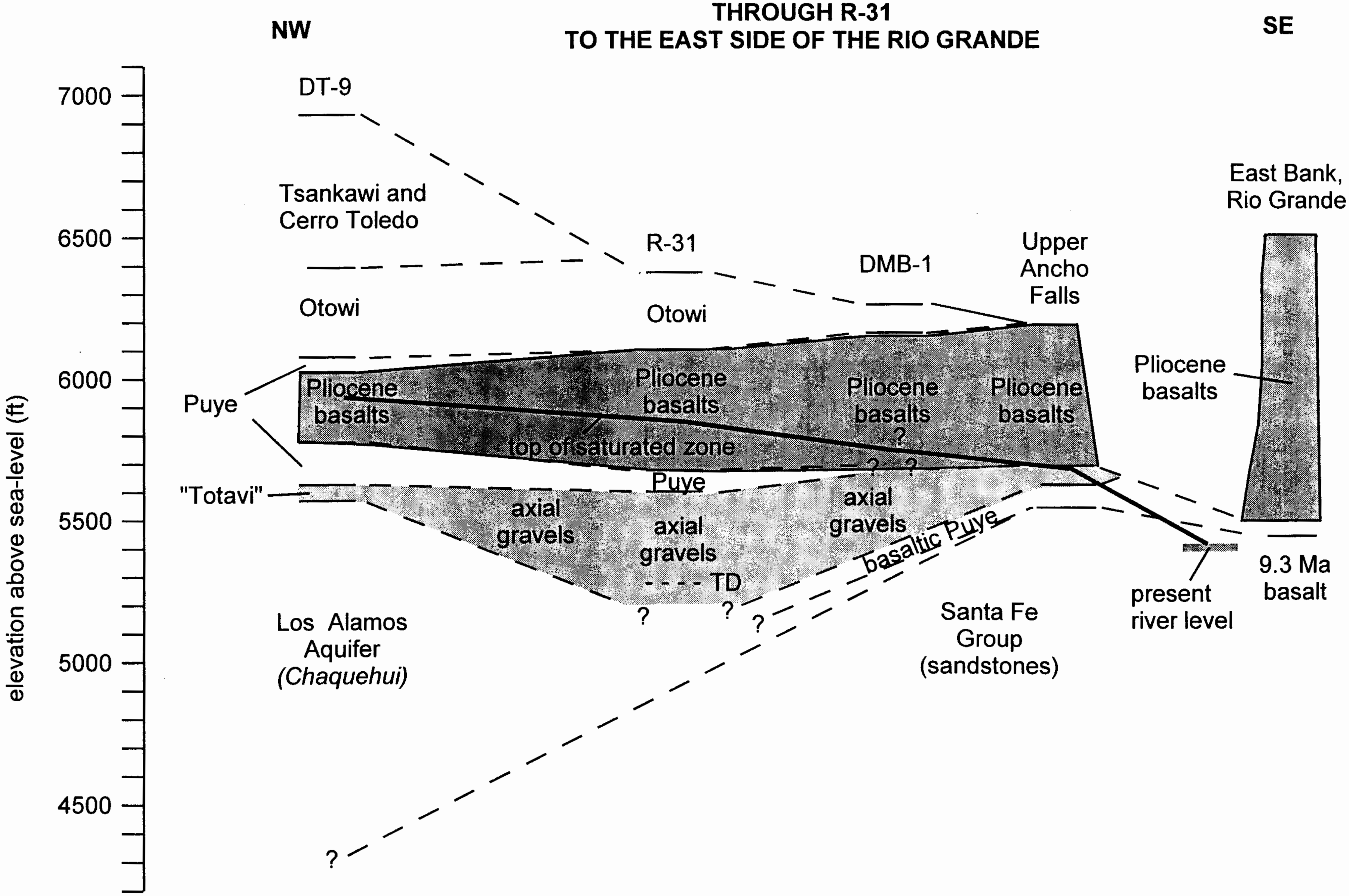
Cross-sections through R-31 in relation to the LANL site boundary and pre-R-31 model topography for the top of the Pliocene basalts

NORTH-TO-SOUTH CROSS-SECTION FROM O-4 THROUGH R-31 TO CHAQUEHUI CANYON



73

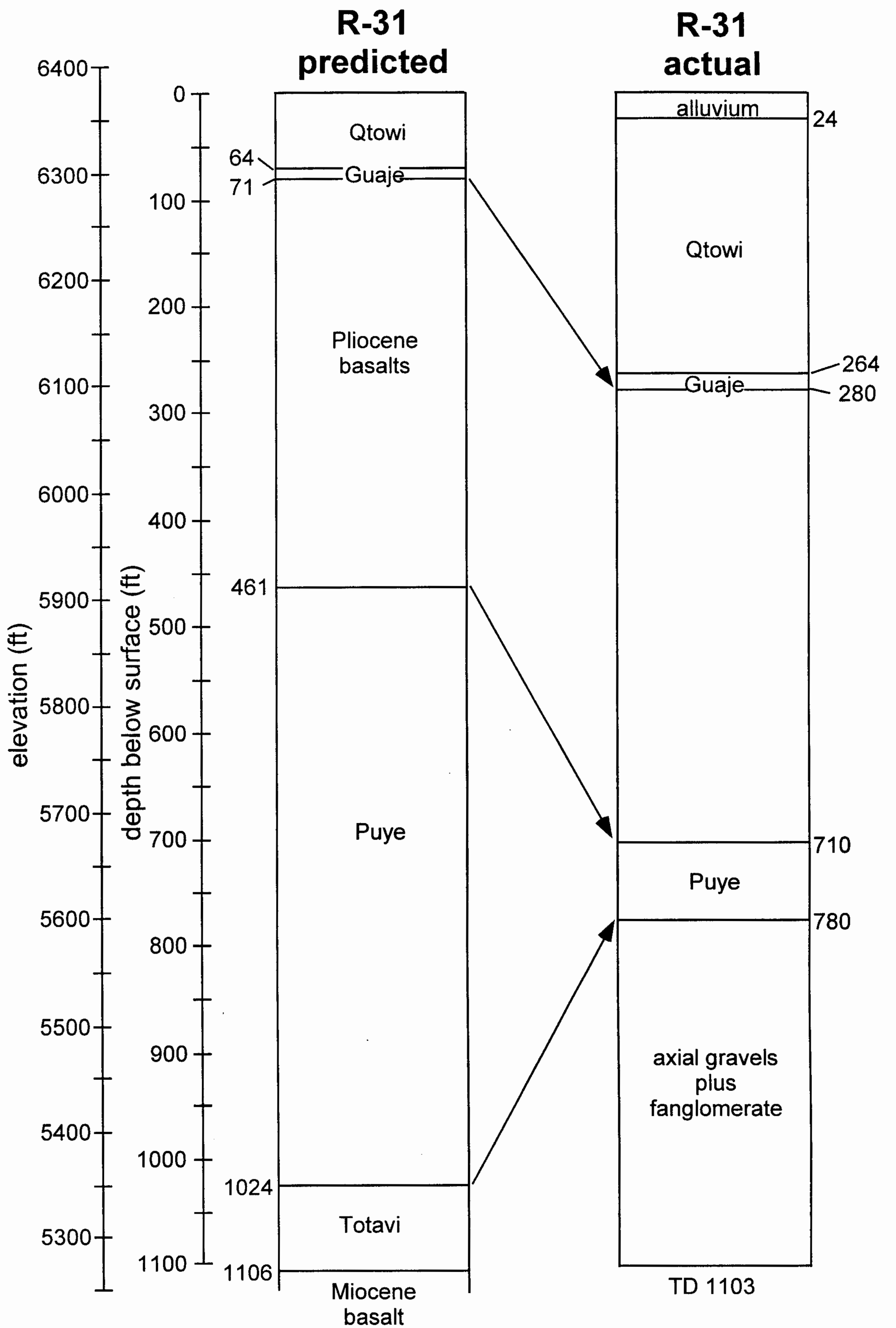
NORTHWEST-TO-S0UTHEAST CROSS-SECTION FROM DT-9
THROUGH R-31
TO THE EAST SIDE OF THE RIO GRANDE



Predicted versus actual stratigraphy at drill hole R-31:

The Otowi ash flows of the lower Bandelier Tuff are much thicker than anticipated, indicating a pre-Bandelier paleocanyon or lowland at this site rather than a “saddle” between paleocanyons.

Contrary to predictions, Puye deposits of volcaniclastic debris from the west (fanglomerates) are thinner than axial river gravels (Totavi-like deposits) from the north.



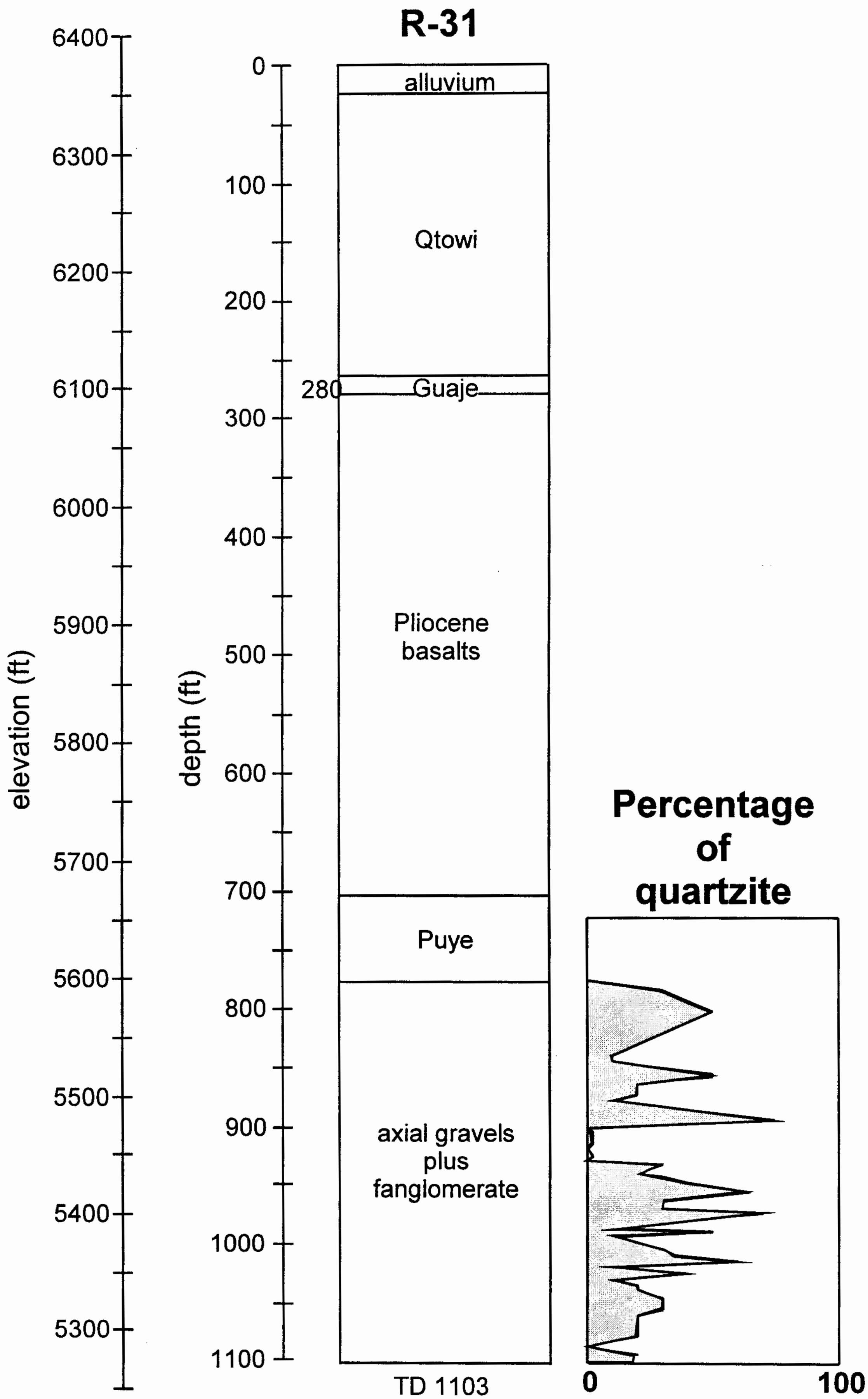
R-31 predicted
R-31 actual
elevation (ft)
6400
6300
6200
6100
6000
5900
5800
5700
5600
5500
5400
5300
depth below surface (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
Qtowi
64
Guaje
71
Pliocene basalts
461
Puye
1024
Totavi
1106
Miocene basalt
alluvium
24
Qtowi
264
Guaje
280
710
Puye
780
axial gravels plus fanglomerate
TD 1103

Paleotopography of internal Puye surfaces:

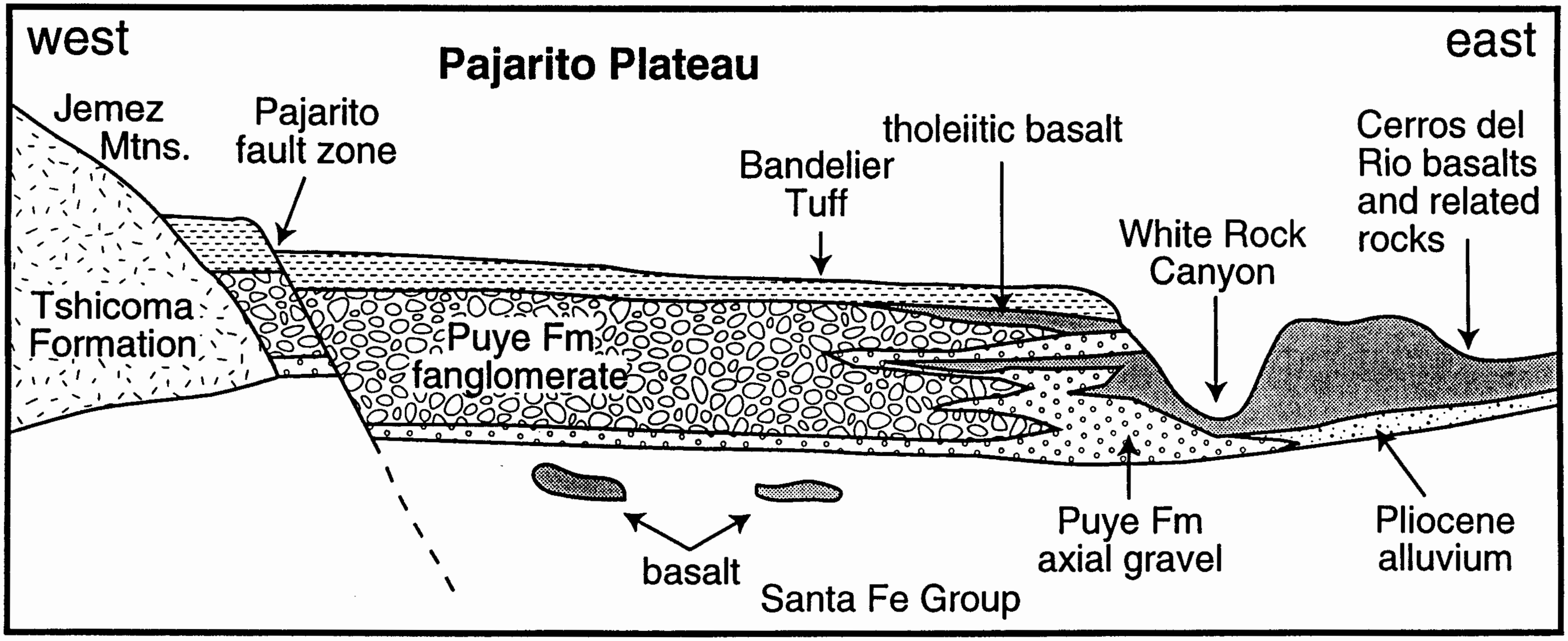
Pliocene basalts were emplaced above Puye deposits that show an irregular surface (cutting across paleocanyons) in the N-S cross-section. The base of the Pliocene basalts is much flatter in the NW-SE cross-section and may be close to the axis of a paleocanyon or within a Puye lowland.

Treatment of river gravels ("Totavi"):

Axial river gravels of the ancestral Rio Grande date from about 5 million years ago and are distinguished by abundant quartzite derived from sources in the north. In R-31 these deposits exceed 300 ft in thickness, contrasted with a predicted thickness of only 82 ft.

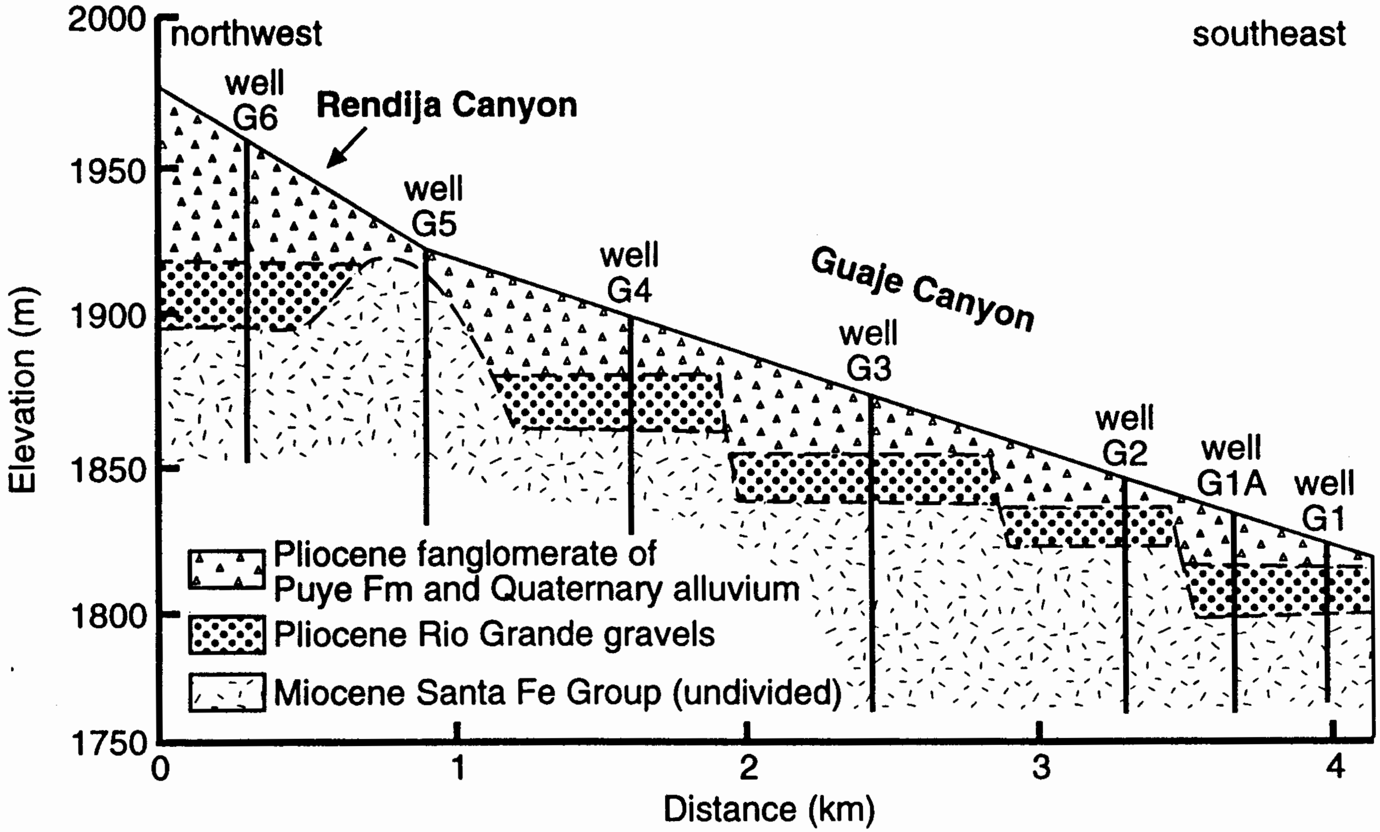

R-31
elevation (ft)
6400
6300
6200
6100
6000
5900
5800
5700
5600
5500
5400
5300
depth (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
alluvium
Qtowi
280
Guaje
Pliocene basalts
Puye
axial gravels plus fanglomerate
TD 1103
Percentage of quartzite
0
100

The quartzite-rich river gravels in R-31 are interbedded with quartzite-poor fanglomerates, indicating that R-31 was drilled in a location that was near the ancestral Rio Grande throughout most of Puye time (see model section from Waresback and Turbeville, 1990).



Schematic geologic cross section showing relationships of the primary geologic units exposed in the vicinity of the Pajarito Plateau. (Modified from Waresback and Turbeville, 1990).

Outside of those zones where the ancestral Rio Grande maintained a presence for the last 5 million years, river gravels may have been deposited in sets of relatively thin and possibly disconnected terraces (see model section of Reneau and McDonald, 1996, based on data from Purtymun and Griggs).

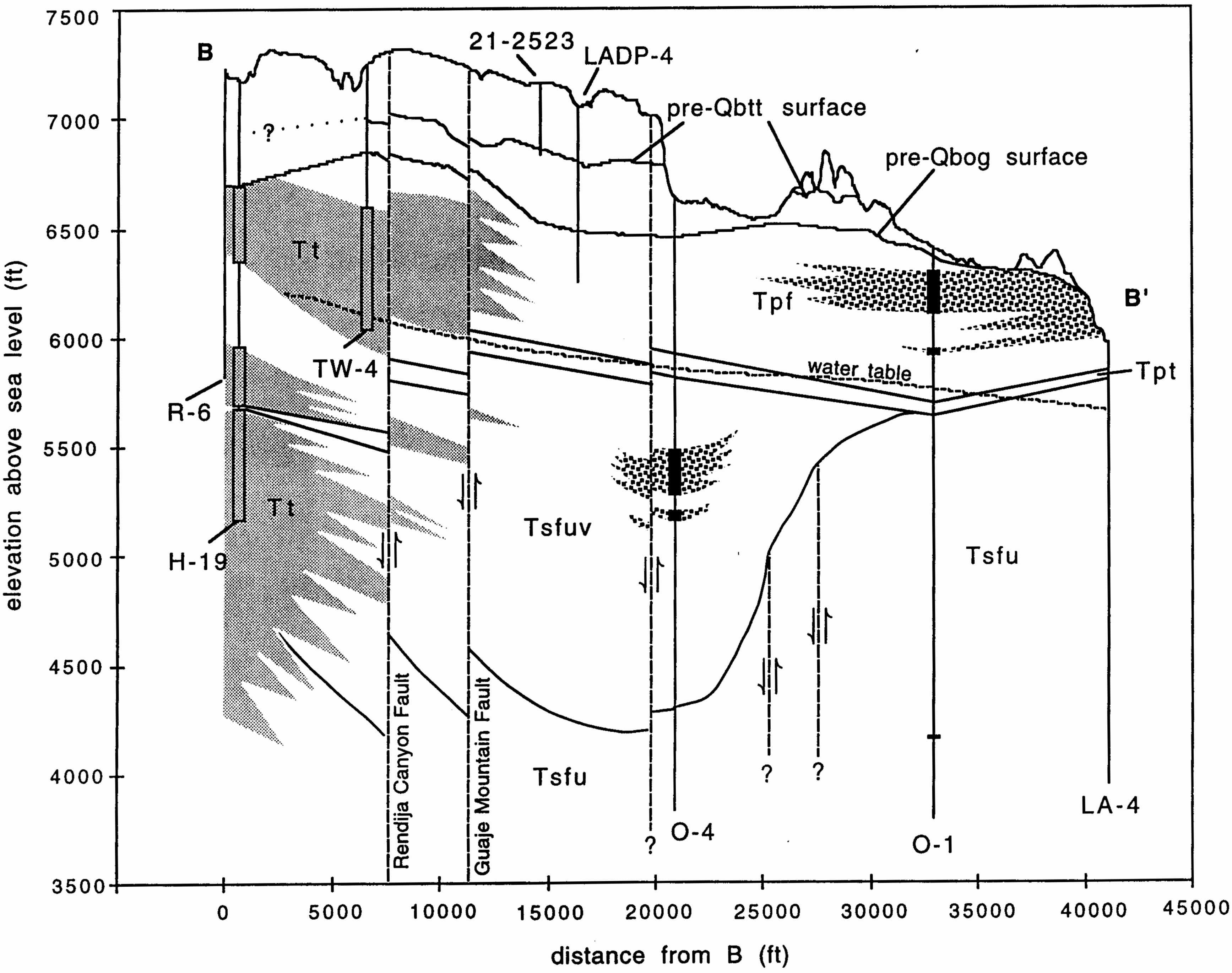


Schematic cross section through the Guaje well field, Guaje and Rendija Canyons, northern Pajarito Plateau, showing possible context of axial Rio Grande gravels ("Totavi Lentil") at base of Puye Formation as buried Pliocene terraces. Well logs from Purtymun (1995; see also Griggs, 1964).

In broader context: Interrelations between transmissive units.

Basalts, river gravels, and the upper Los Alamos Aquifer (Chaquehui) all have hydrologic importance. Earlier models generally placed discontinuities between the Santa Fe Group sandstones (Tsfu), the Los Alamos Aquifer (Tsfuv), and the overlying river gravels (Totavi, Tpt).

Section B-B' (10x Vertical Exaggeration)



Some Conclusions

Drill hole R-31 provides unexpected depths to key contacts that will lead to significant modifications in the LANL Site Geologic Model. However . . .

the unexpected stratigraphy at R-31 points to uncertainties in our understanding of the stratigraphy beneath the southern part of LANL. Future drilling across the site is needed to improve concepts that impact modeling of flow and transport.

Evidence from R-31 for thick deposits of axial river gravels interfingered with volcaniclastic deposits provides new information on where transmissive sediments of the Puye Formation are located beneath LANL.

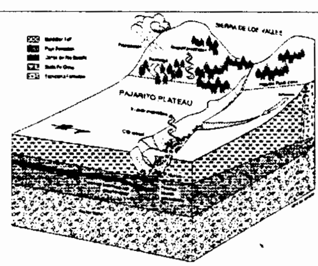
Facies interfingering will be important to consider in studies of transmissive units at LANL.

Geology and Hydrology of the Regional Aquifer:

Uncertainties in our conceptual model

Elizabeth Keating
Bill Carey
Greg Cole

Elements of regional aquifer characterization	Relevant data
Recharge rates, location	streamflow, spring flow, water chemistry, water levels in wells
Groundwater flow directions	water levels in wells, permeability of aquifer units
Groundwater flow velocity	permeability, porosity of aquifer units
Groundwater chemistry	water chemistry data, aquifer mineralogy



89

How much do we need to know about permeability heterogeneity?

1. Reproduce steady-state "pre-development" flow conditions
2. Reproduce observed water level declines due to pumping
3. Predict travel times and pathways

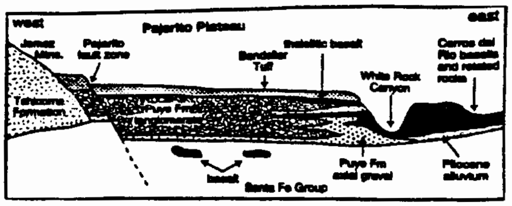
3

First-order control on aquifer properties:
stratigraphy

- **Puye formation**
  - **fanglomerate (???)**
  - **Totavi Lentil (high permeability)**
- **Santa Fe group**
  - **"Los Alamos aquifer" (high permeability)**
  - **Santa Fe group (lower) (low permeability)**
- **Basalts (fracture flow and/or aquitards)**

Second-order control on aquifer properties:
facies within sedimentary units

4



5

<u>Do the established stratigraphic units</u>

Make sense from a geologic perspective?

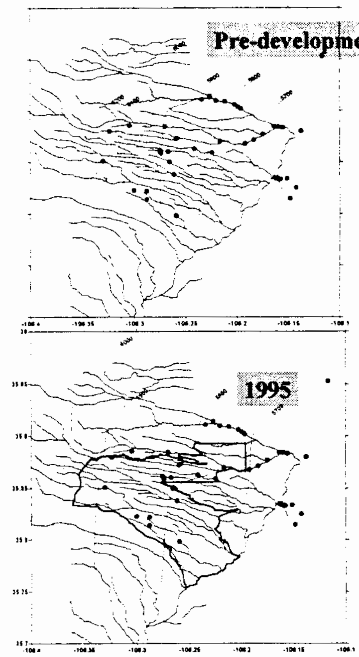
Make sense from a hydrologic perspective?

Geologic issues:

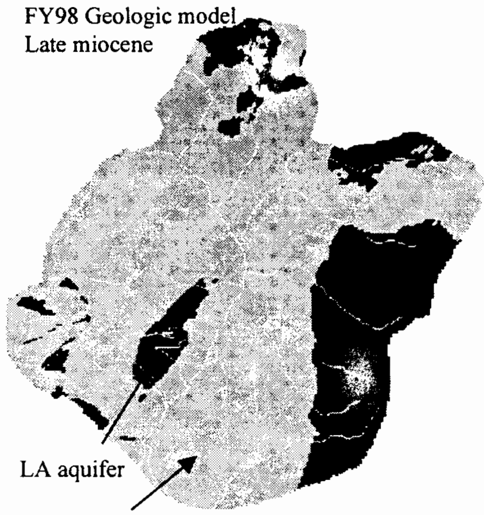
1) What is the "Los Alamos aquifer" ? What is its characteristic lithology? What is the provenance of the sediments? Is it time-stratigraphic or time-transgressive?

2) Is the Totavi Lentil a basal unit within the Puye formation (continuous) or does it interfinger with the fanglomerate member (discontinous)

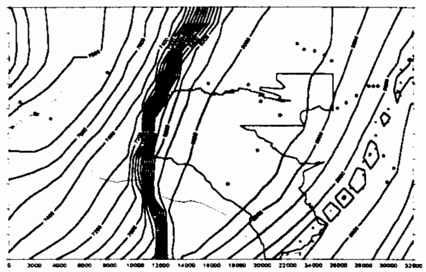
6


Pre-development
1995

7

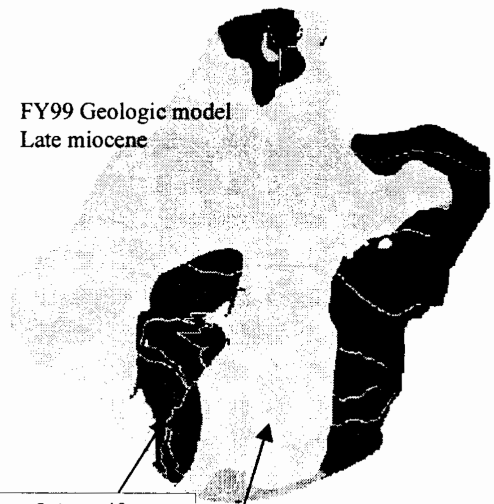

FY98 Geologic model
Late miocene
LA aquifer
Lower Santa Fe group

8

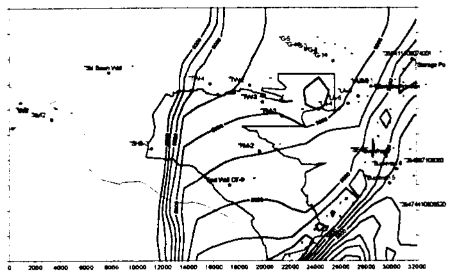


Water level contours predicted using FY98 geologic model to define permeability zones

9

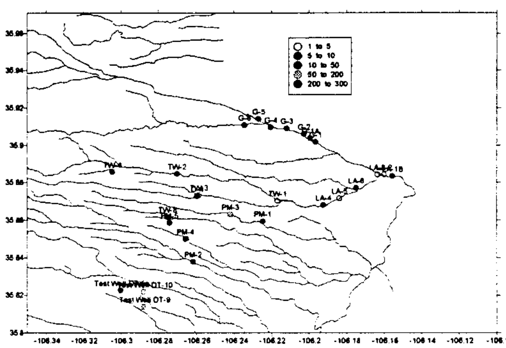


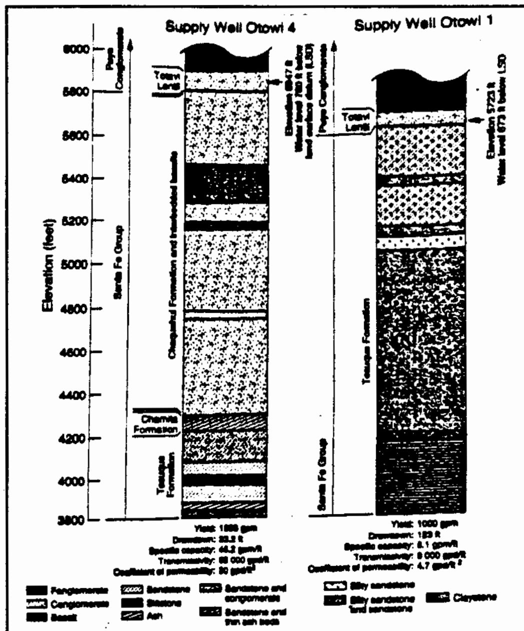
10



Water level contours using FY99 geologic model, assuming that "Los Alamos aquifer" permeability is higher than the lower Santa Fe group rocks

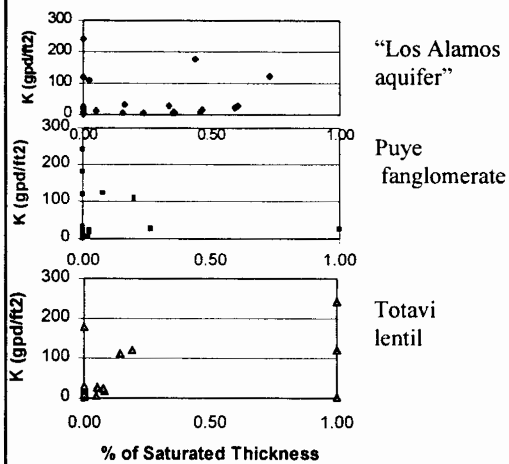
Specific capacity (gpd/ft²)



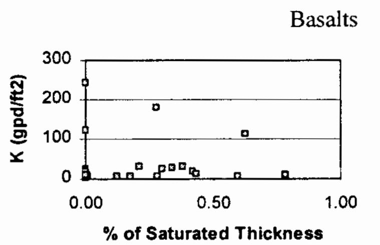


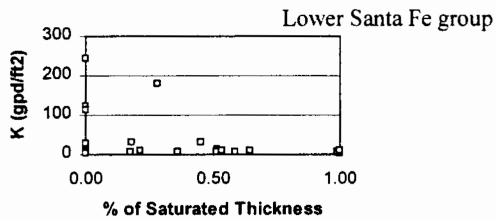
13

Hydrostratigraphic units and permeability



14





15

Possible explanations:

1. Established stratigraphic units do not capture major variations in permeability

2. Permeability variations within the defined stratigraphic units are greater than permeability variations between these units

2. Lithologic contacts were incorrectly identified in older wells

3. Permeability data reported for these wells is inaccurate

16

Summary

1. There are very low correlations between permeability indicators for a given well and % saturated thickness of any given hydrostratigraphic unit

2. Preliminary modeling suggests that enlarging the extent of a high permeability "Los Alamos aquifer" significantly beyond areas with well control compromises our ability to correctly simulate east-west head gradients.

17

Current activities

1. Collect permeability data from pump tests on wells screened in a single hydrostratigraphic unit

2. Increase our focus on plateau-wide conceptual model of hydrostratigraphy

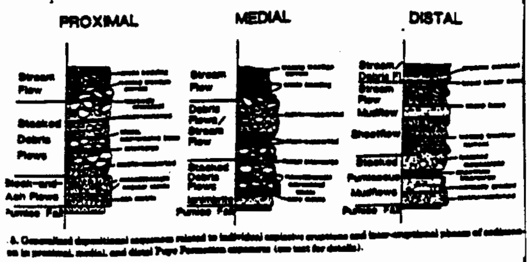
3. Consider feedback between flow modeling and geologic modeling
   alternative conceptual geologic models?

4. Incorporate facies-based models of heterogeneity within sedimentary units (Puye formation, Santa Fe group)

18

Facies-based approach to modeling permeability

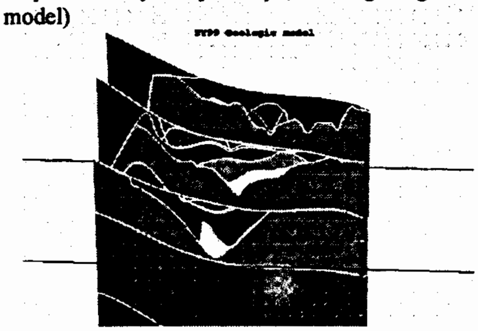
When modeling flow and transport through complex sedimentary rocks with multiple facies (stream channels, overbank deposits, colluvium, lake beds, etc.) there will *never* be enough data to predict exact flowpaths and flow velocities at the km-scale. Therefore, we must shift to a probabilistic approach incorporating as much data as possible.



19

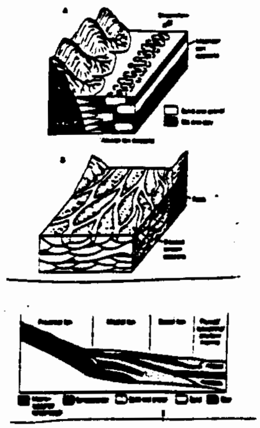
Steps in facies-based stochastic modeling

1. Identify first-order, deterministic controls on permeability and porosity (current geologic model)

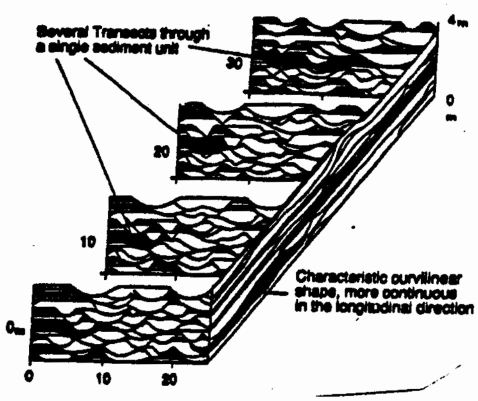


20

2. For some units (Puye formation, Santa Fe group) create a conceptual model of sub-unit facies distributions, based on drill-hole and outcrop information.

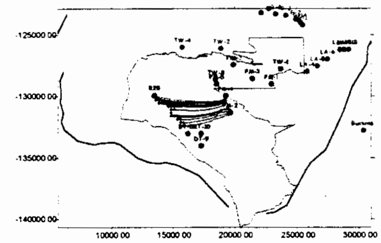


3. Using available data, quantify spatial statistics of each facies and generate numerical realizations of permeability variations within the unit based on "facies" statistics.



99

4. Using a number of realizations of the permeability models and the 3-D numerical flow and transport model, estimate means and ranges for travels times of interest in the regional aquifer.



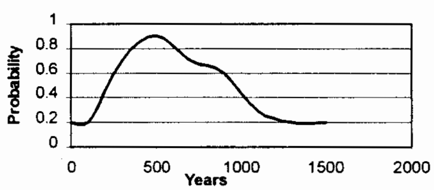
Deterministic approach

provides range of values

Travel times: 90, 749, 759, 1428 years

Stochastic facies-based approach provides

range
probablities
most likely travel times



AQUIFER TESTING IN PAJARITO PLATEAU WELLS

Stephen G. McLin

Water Quality and Hydrology Group (ESH-18)
Los Alamos National Laboratory

presented at

Groundwater Annual Meeting FY99
Ghost Ranch, NM

March 29, 2000

lc/

Types of Aquifer Tests

1. Pumping & Recovery Tests

2. Slug Injection – Slug Withdrawal Tests

3. Testing in WestBay Monitoring System

4. Analyses of Water Level Fluctuations

5. Injection Tests Using Dipole Configuration

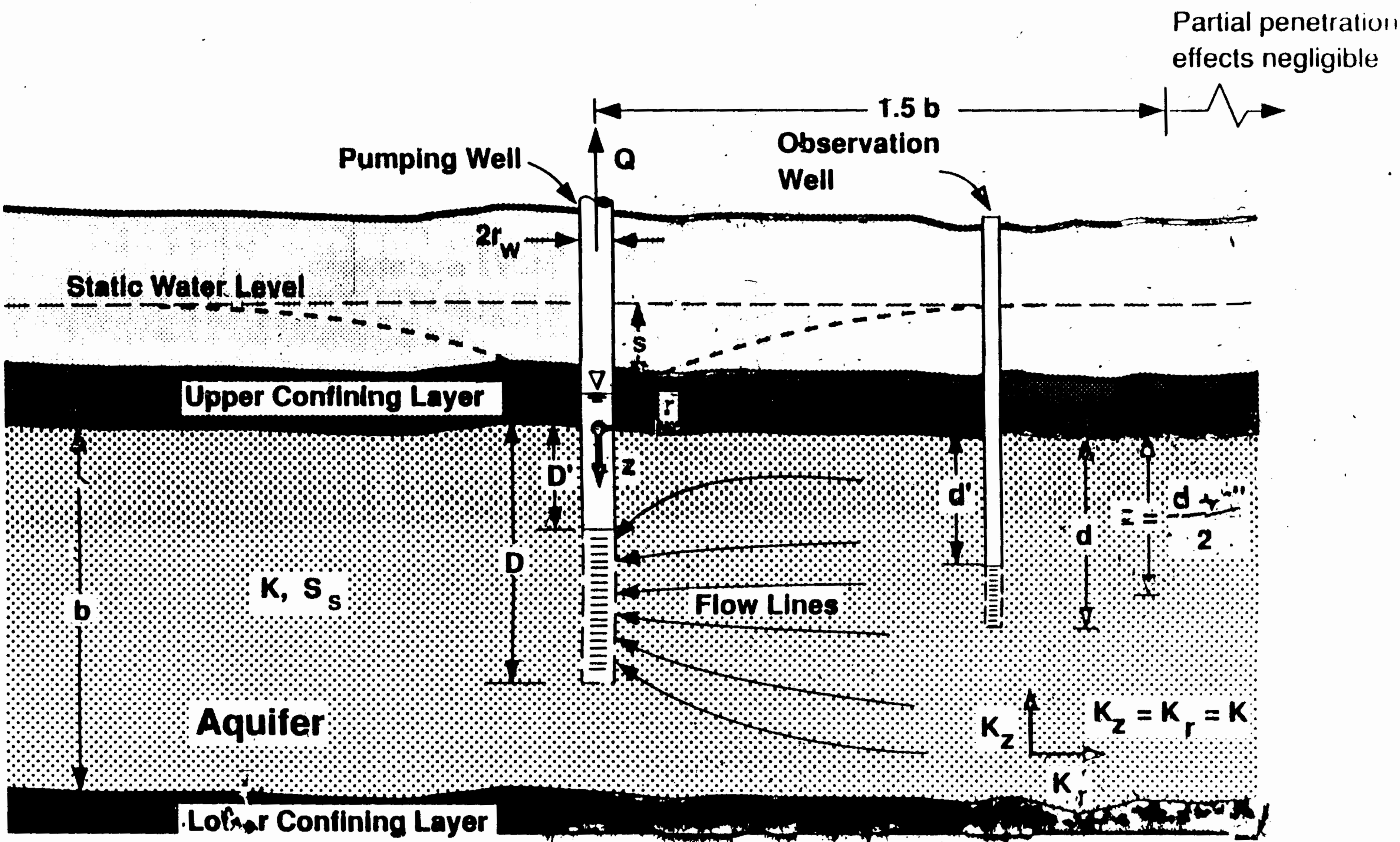


Figure 5.5. Flow to a well partially penetrating a confined aquifer.

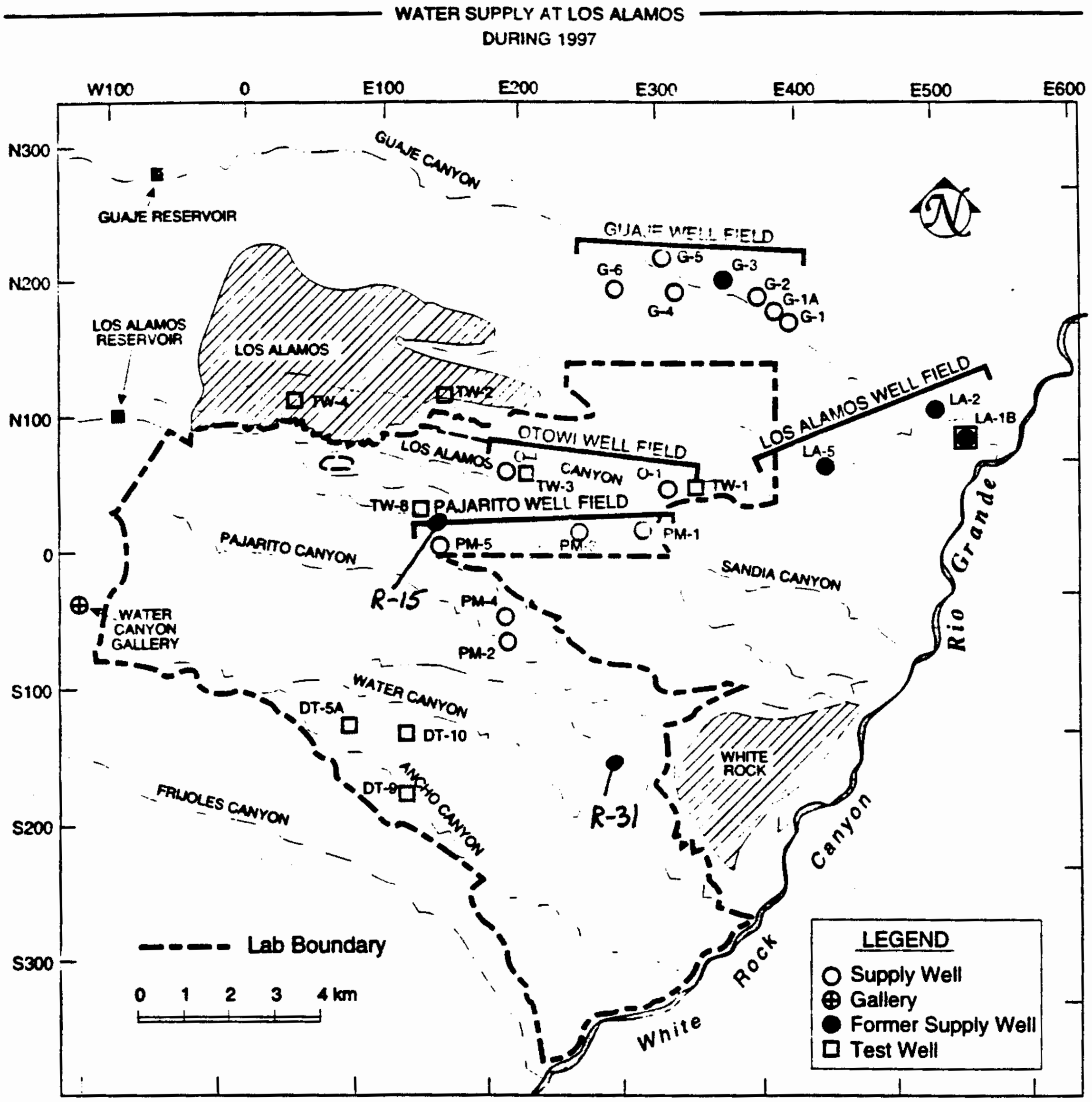


Fig. 1. Locations of reservoirs, well fields, water supply wells, and the water gallery supply. Letter designations indicate wells in the Guaje (G), Pajarito Mesa (PM), and Otowi (O) well fields. Ownership of the Los Alamos (LA) well field was transferred to San Ildefonso Pueblo in 1992.

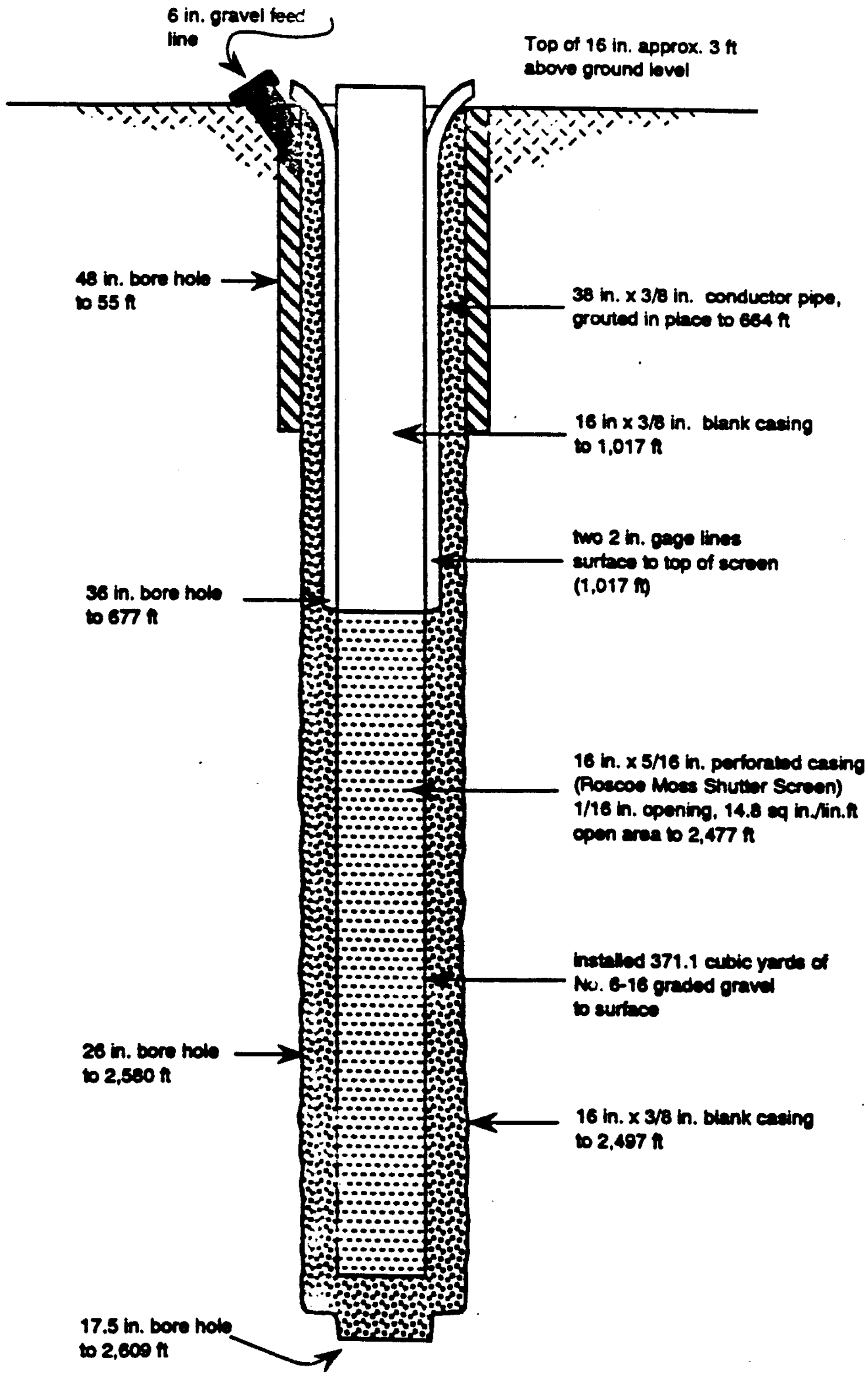
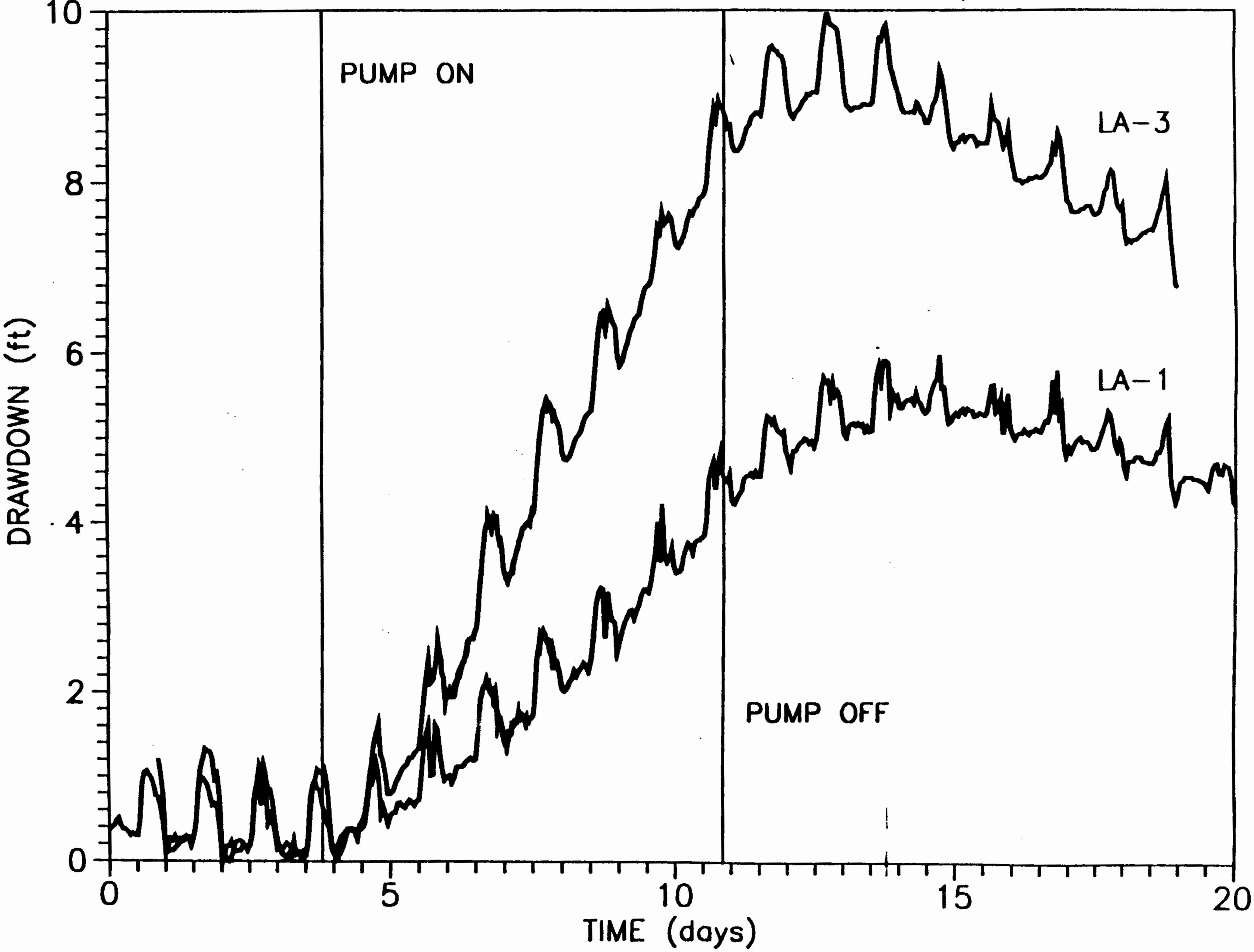


Fig. 7. Construction details of Well Otowi-1.

PUMP TEST IN WELL LA-2: MARCH 16 - APRIL 10, 1992



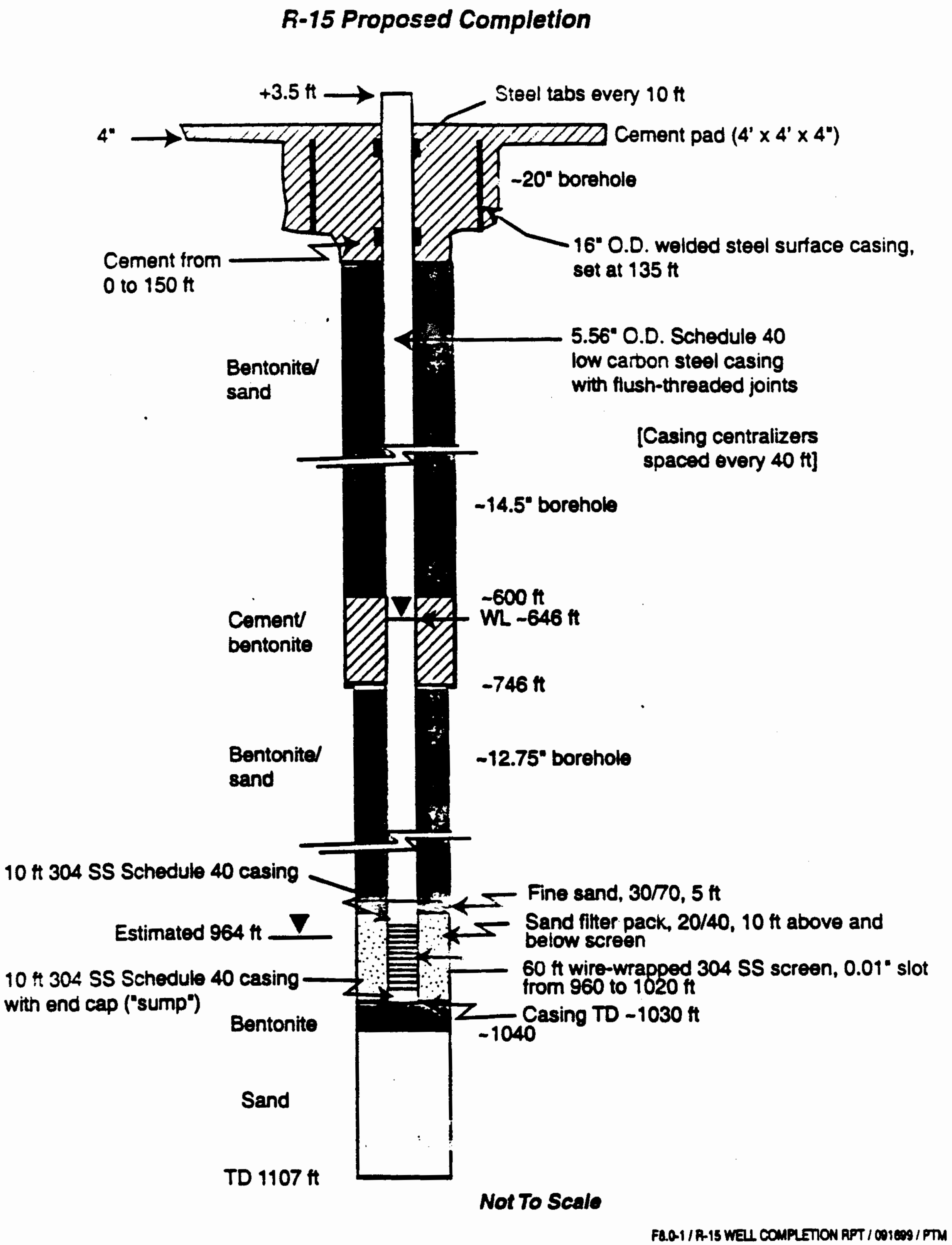
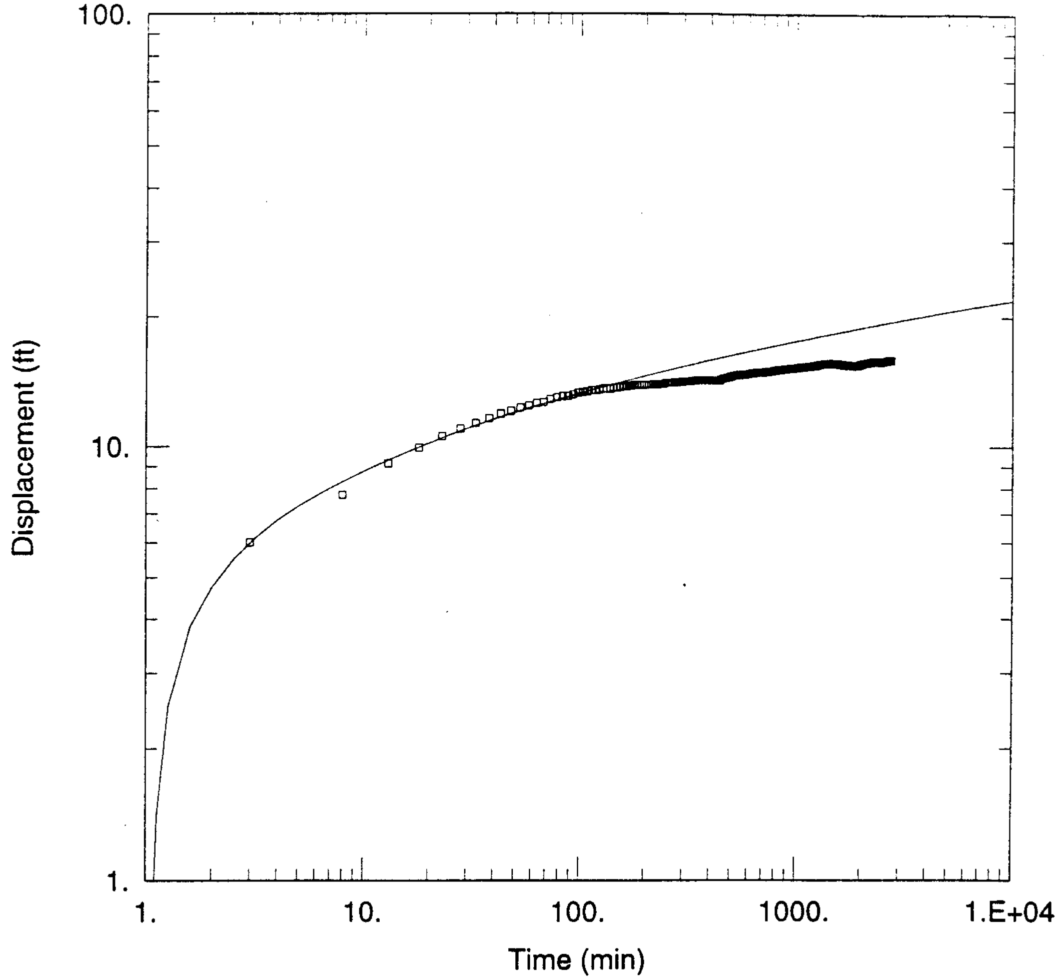


Figure 8.0-1. **As-built well completion diagram of well R-15**



R-15 PUMP TEST

Data Set: D:\WINSITU\INSITU\R-15\R15P.AQT
Date: 03/22/00 Time: 12:29:15

PROJECT INFORMATION

Project: Pump Test at Q = 11.7 gpm
Test Location: Screen: 960-1020 ft BGS
Test Date: 2-19-2000

AQUIFER DATA

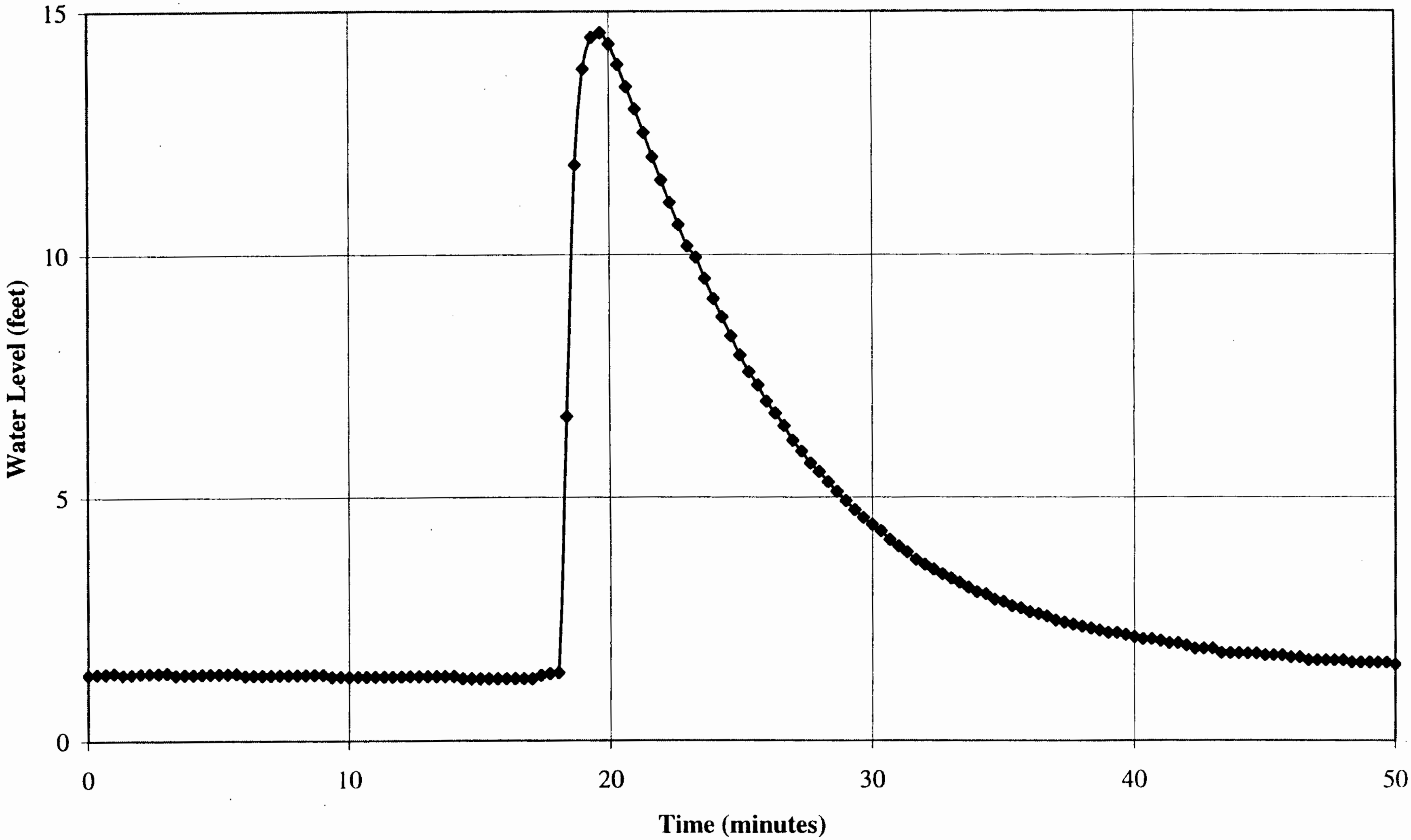
Saturated Thickness: 60. ft Anisotropy Ratio (Kz/Kr): 1.

SOLUTION

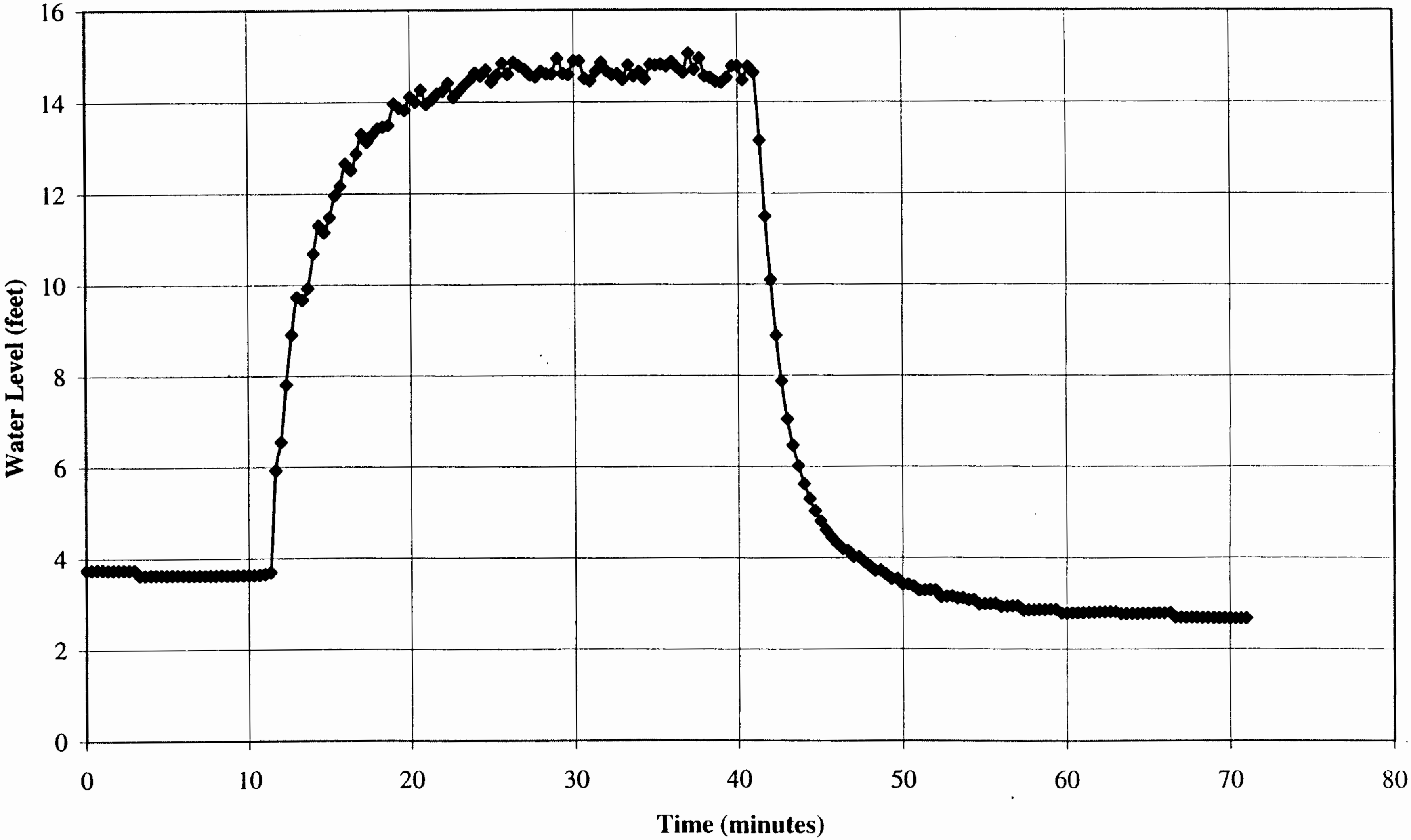
Aquifer Model: Confined
Solution Method: Theis

T = 94.96 ft^2/day
S = 0.01242

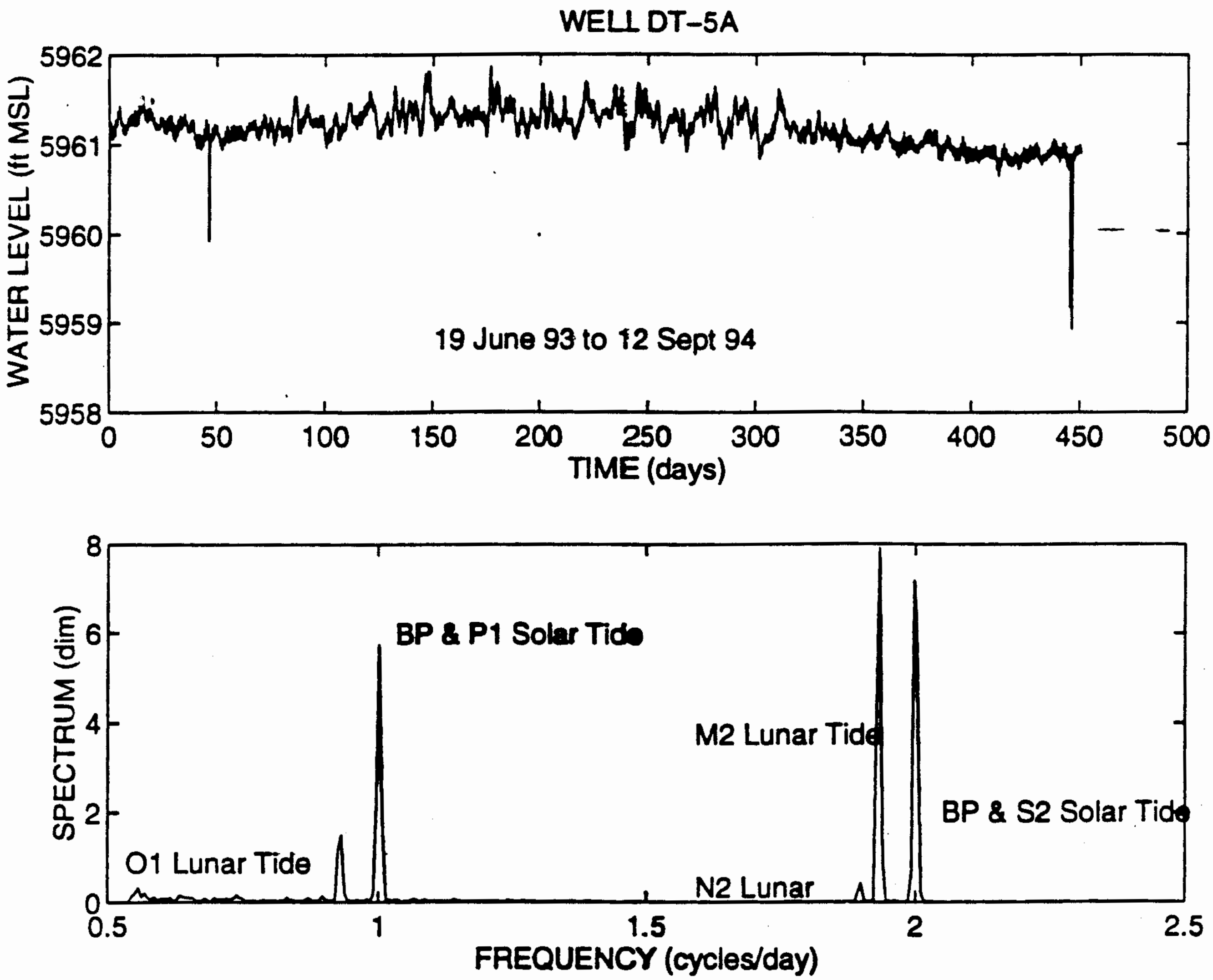
R-31 Straddle-Packer Injection Test - Screen 3



R-31 Straddle-Packer Injection Test - Screen 5



110



WELL DT-5A
WATER LEVEL (ft MSL)
5962
5961
5960
5959
5958
19 June 93 to 12 Sept 94
0
50
100
150
200
250
300
350
400
450
500
TIME (days)
SPECTRUM (dim)
8
6
4
2
0
BP & P1 Solar Tide
M2 Lunar Tide
BP & S2 Solar Tide
O1 Lunar Tide
N2 Lunar
0.5
1
1.5
2
2.5
FREQUENCY (cycles/day)

Stable Isotopes and Anions as Vadose Zone Tracers

Hydrogeologic Characterization Program
Annual Meeting
March 30, 2000

Brent D. Newman and D. Eli Ludwig
EES-15, Los Alamos National Laboratory

Why look at vadose zone tracers?

- Can provide information on flowpaths and processes occurring in the vadose zone.
- Can confirm hydrologic behavior by providing estimates of downward flux and residence times
- Give us a *in situ* "picture" of the variations in hydrologic conditions with depth
- Can provide information on connectivity between saturated zones

What kind of tracers do we use?

- Stable Isotopes ($\delta^{18}O$,δD) of vadose zone pore waters.
  - Can be used to examine timing and elevation of recharge
  - Sensitive to evaporation
- Anions (negatively charged ions in vadose zone pore waters)
  - Chloride is a good tracer for water movement, and can be used in some cases to estimate residence times and vertical flux rates
  - Bromide, fluoride, nitrate, nitrite, oxalate, phosphate, sulfate-other ions that can represent the *in situ* chemistry and hydrology of the vadose zone
  - Some anions (e.g., nitrate) can be used to assess impacts of laboratory releases on the vadose zone
- Examples using R-9, R-12, R-15, MCO-7.2, and R-25

Stable Isotopes

- δD or $\delta^{18}O$ (in permil) = $[(R_{sample} - R_{std}) / R_{std}] * 1000$

  Where R is the $^{18}O/^{16}O$ or $^{2}H/H$ ratio

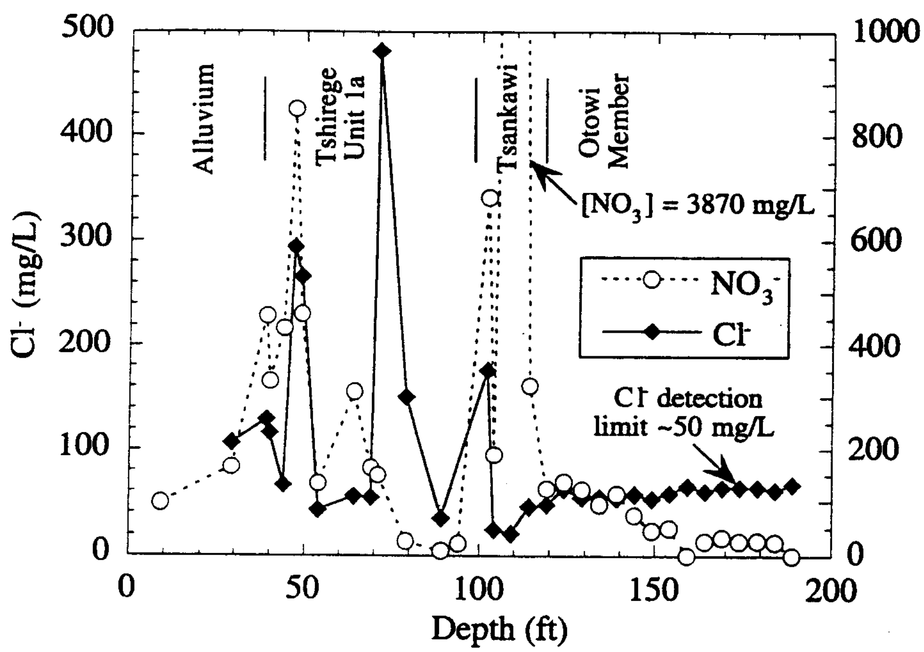
  Bigger values are called "heavy", smaller values are called "light"
- Stable Isotopes vary as a result of processes instead of time like radio-isotopes.
  - For hydrologic environments at LANL, the main processes that control stable isotope compositions are the temperature of precipitation, elevation, and evaporation.

Nitrate Pore Water and Cumulative Concentrations For Five Boreholes

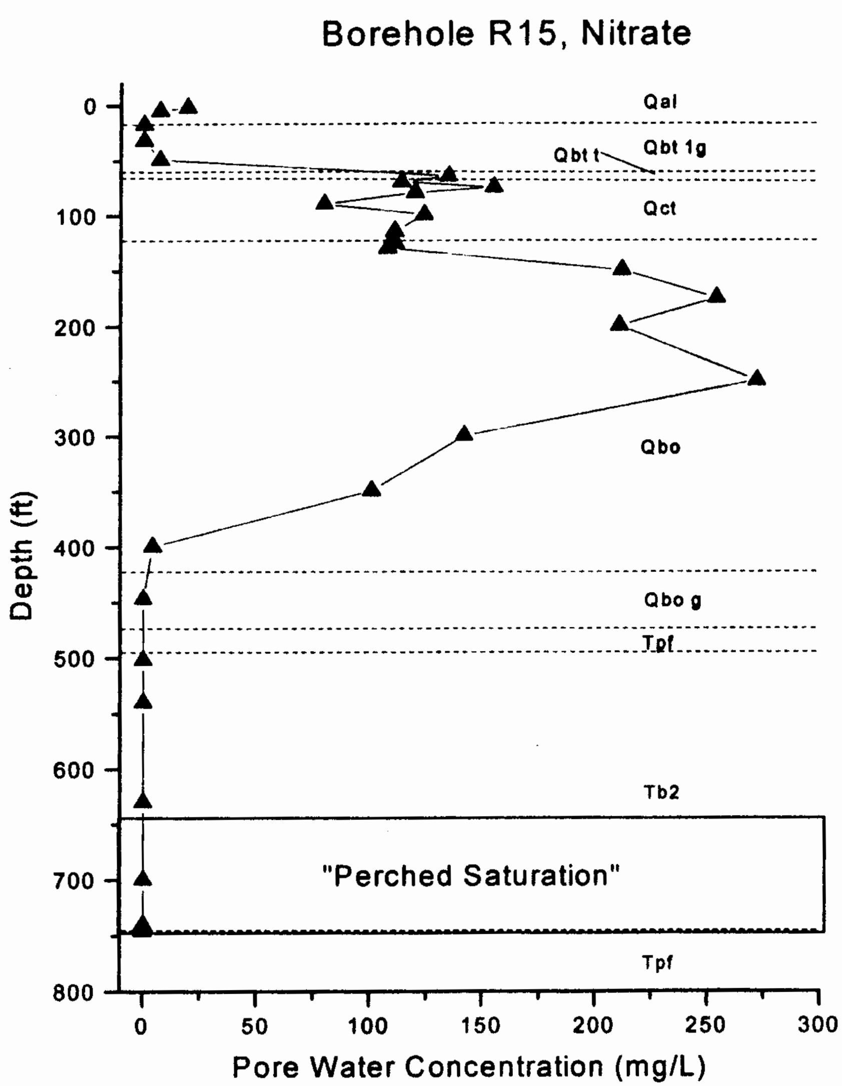
NITRATE				
Borehole	Average Conc.*	Max Conc.*	Cum. to 132 ft +	Cum. to 667 ft +
MCO-7.2	96	584	720	TS
R-15	82	272	766	3398
R-9	6	18	1	57
R-12	1	16	13	41.1
R-25	0	0.6	0	1.2

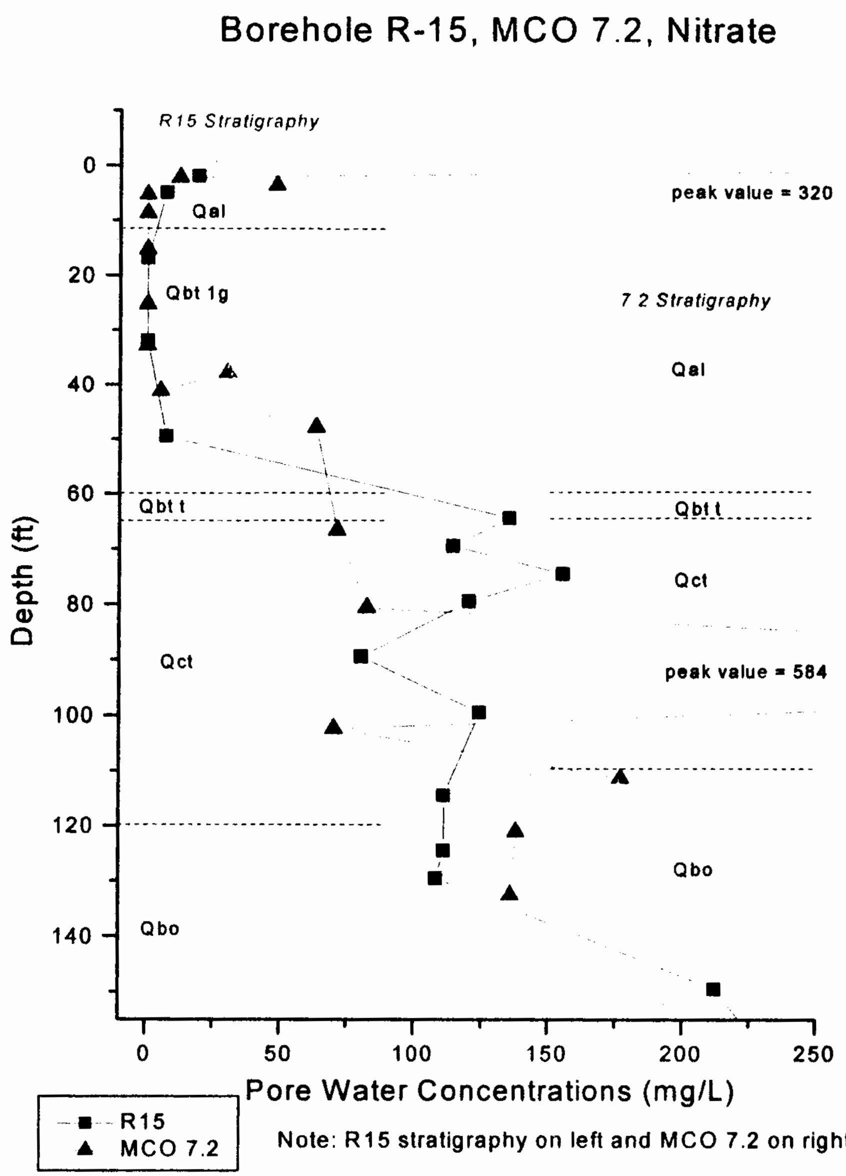
* (mg/L) + (g/M^2)

TS - (too shallow), the max depth of the borehole does not reach the 667 ft depth, which is the deepest data from R-25



From Rogers and Gallaher (1995)

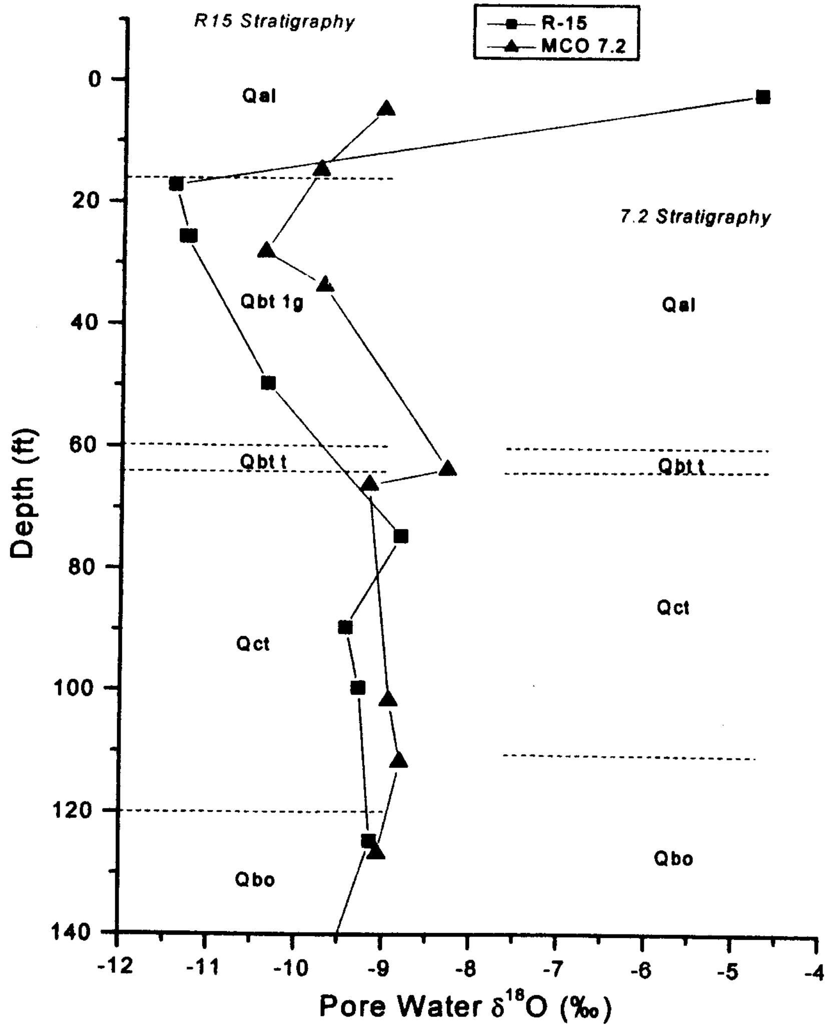




Note: R15 stratigraphy on left and MCO 7.2 on right.

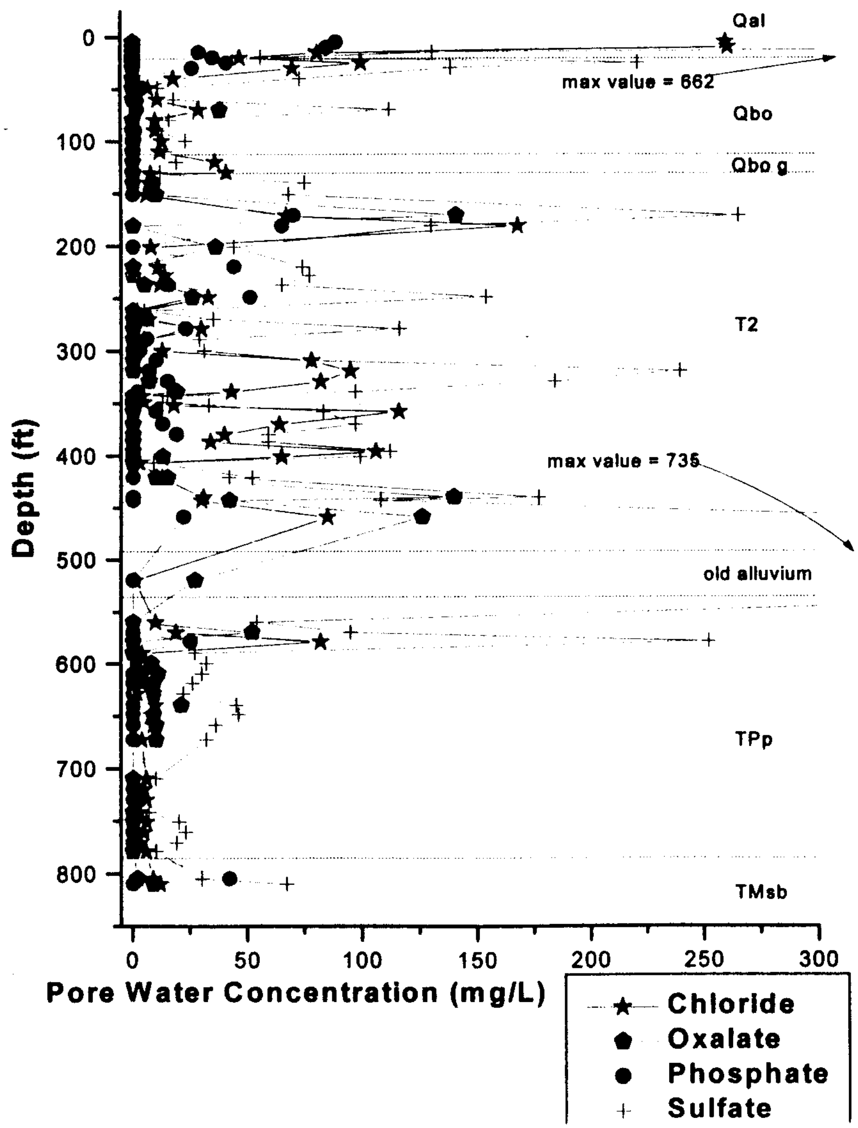
115

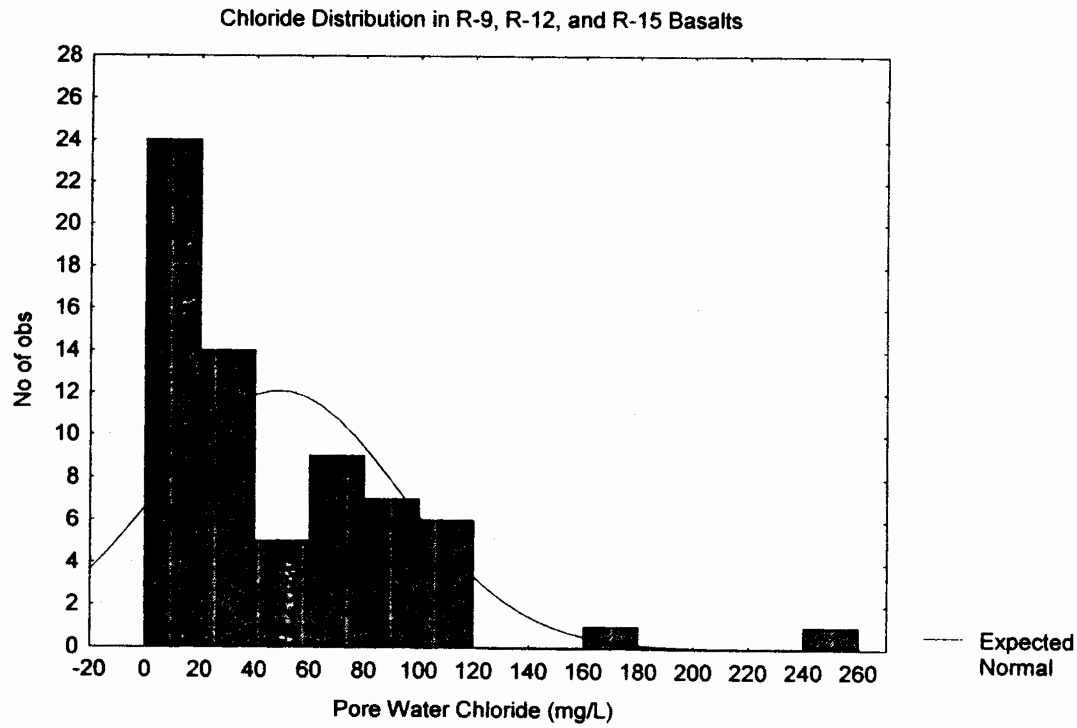
Borehole R-15, 7.2, δ18O



Note: R15 stratigraphy on left and MCO 7.2 on right.

Borehole R12, Pore Water Concentration





Chloride Mass Balance Method

- $R = P^*Cl_p / Cl_{vw}$
  - where R is the downward flux, P is the average annual precipitation, Cl_p is the average chloride concentration in precipitation, Cl_{vw} is the average chloride concentration in the vadose zone.
- $A = Cl_{vwi}/(P^*Cl_p)$
  - where A is the residence time (age), Cl_{vwi} is cumulative chloride in the vadose zone, and the other terms are as above.

- Flux is inversely proportional to chloride content in the rock.
- Age or residence time is proportional to chloride content in the rock.

Chloride Mass Balance Assumptions

- Flow occurs largely as downward piston flow.
- Atmospheric chloride deposition has been constant and is the sole source of chloride to the system.
- Chloride uptake by plants is negligible.

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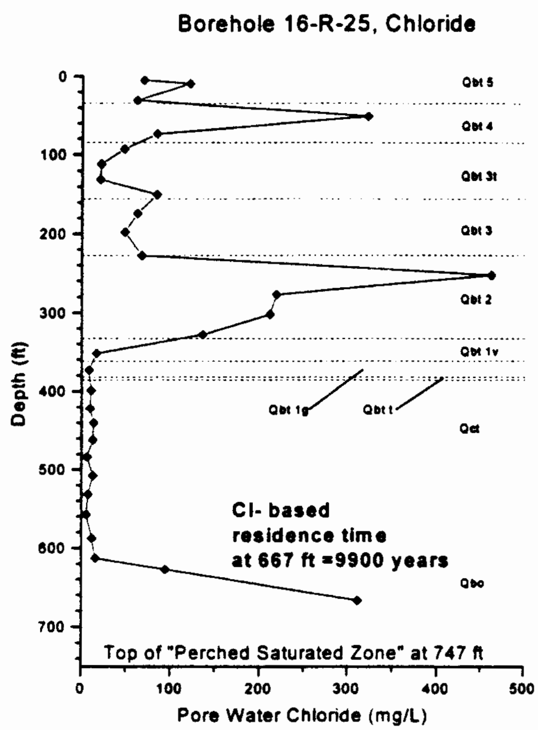
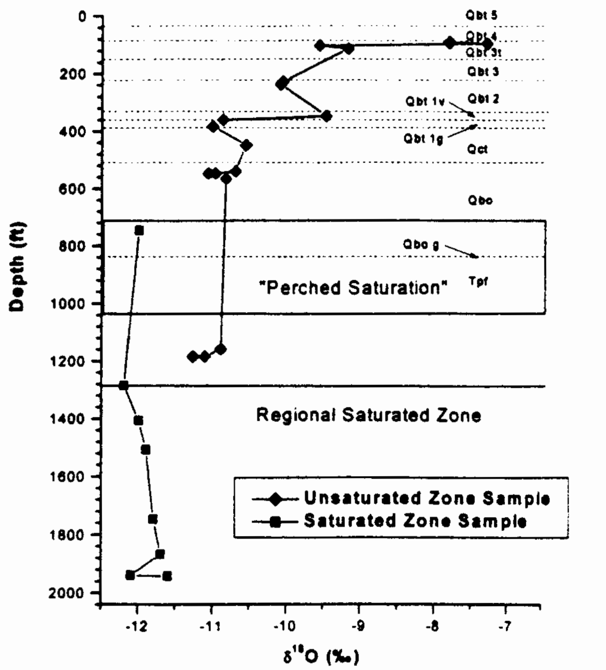
VG-97-000(13)



Borehole 16-R-25, Depth vs Delta 18 Oxygen



Conclusions

- **Stable isotope and anion tracers are one of the few ways that we can evaluate hydrologic and geochemical processes in the vadose zones encountered by the R-well drilling project.**
  - **They can provide qualitative information about flow paths**
  - **They can be used quantitatively to estimate vertical flux rates and residence times.**
  - **They can be used to assess how contaminants are moving through the vadose zone.**

Acknowledgements

- Contributions by Andrew Campbell, Dale Counce, Emily Kluk, Pat Longmire, and Stephanie Maes are appreciated.

Recharge to the regional aquifer

Elizabeth Keating
Ed Kwicklis

1

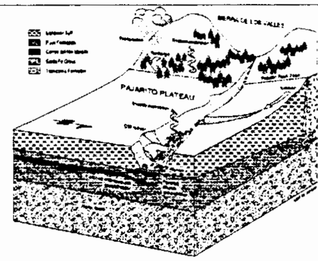
Presentation outline

- Definition of recharge
- Overview of estimates of recharge *amounts*
- Overview of methods used to estimate *location* of recharge and degree of mixing

2

Recharge : water that enters the regional aquifer at the water table

Precipitation - (runoff + evaporation + transpiration)



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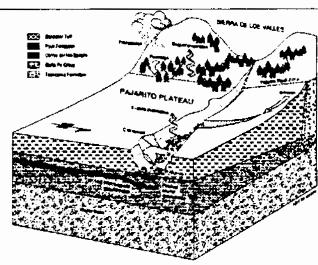
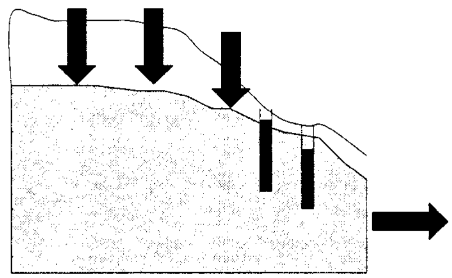
Importance of determining recharge

1) Water supply
2) Impact to the regional aquifer by near-surface contamination



4

3. Improved constraints on aquifer permeability



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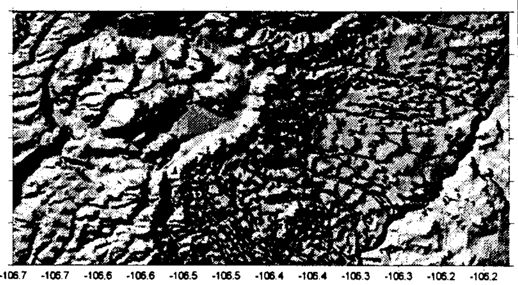
Where is recharge occurring?

What is the rate of recharge?



Approaches:

1. Water budgets:
    a) Pajarito Plateau
    b) individual canyons
2. Groundwater modeling
3. Geochemical tracers

6

Water budgets

Pajarito Plateau water budget analysis
(Kwicklis, 1999)

Precipitation

Runoff

ET estimates

* site-specific data collected by LANL
* general model developed by Troendle and Leaf, 1980

25 - 38 mm/yr

Los Alamos Canyon
water budget analysis
(Gray, 1997)

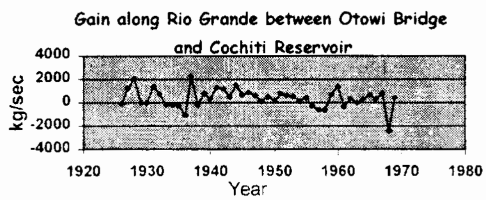
100 - 200 mm/yr

7

Regional aquifer flow modeling

1. Assumption of steady-state conditions pre-1945.

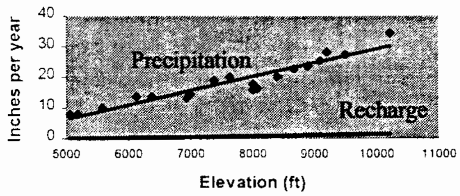
Outflow to Rio Grande =Inflow from recharge

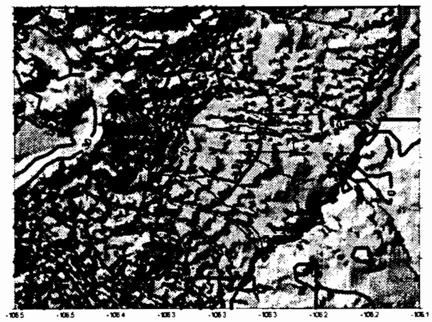


Average baseflow discharge= 366 kg/s (13 cfs)

2. Consistency between water level and aquifer permeability data

8





Consistent with baseflow, permeability, and water level data

- insufficient data to locate the groundwater divide

9

Summary

1) Groundwater flow models, constrained by water level and baseflow data, predict recharge rates varying from 0 to 30 mm/yr

2) Plateau-wide water budget probably overestimates recharge (missing sinks?)

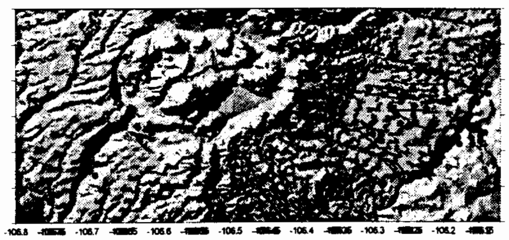
3) Locally, recharge rates may be much higher (e.g. 100 - 200 mm/yr)

4) Permeability, water level, and streamflow data are inadequate to delineate the location of the groundwater divide to the west.

10

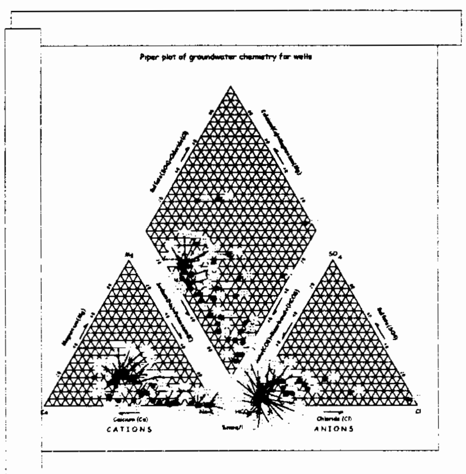
Location of recharge - geochemical tracers

1. Major ions (Ca, Na, HCO3-, etc.)
2. Oxygen isotopes



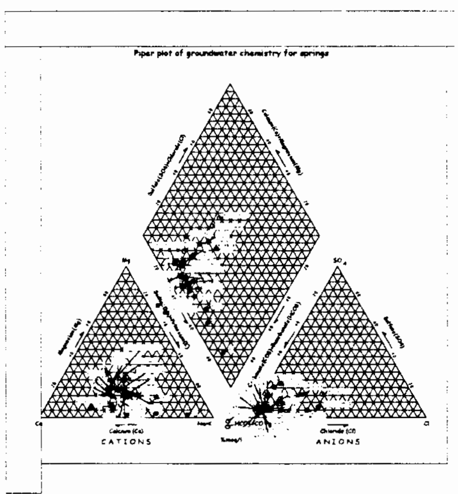
Shevenell, Goff, et al., 1987
Blake, Goff, et al., 1995
Goff, unpublished data

11



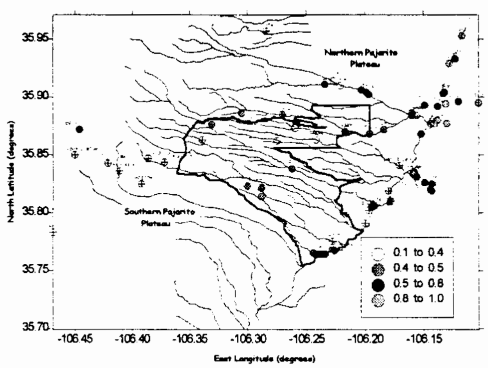
Piper plot of water chemistry for wells in the vicinity of the Pajarito Plateau.

12



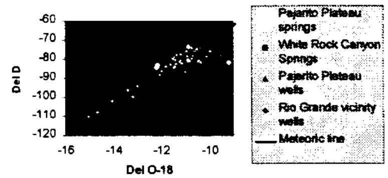
Piper plot of water chemistry for springs in the vicinity of the Pajarito Plateau. Blue circles are springs in the central and western plateau; red circles are in the eastern plateau and along White Rock Canyon.

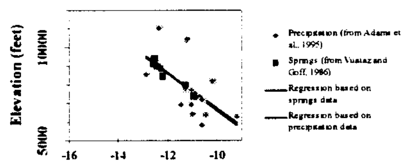
13



Ratio of sodium (meq/l) to total cations (meq/l) for wells and springs in the Pajarito Plateau and vicinity; open circles denote wells, and crossed circles denote springs.

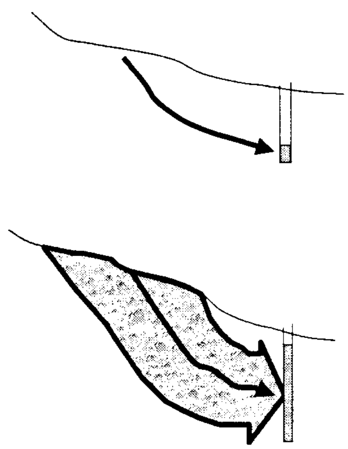
14



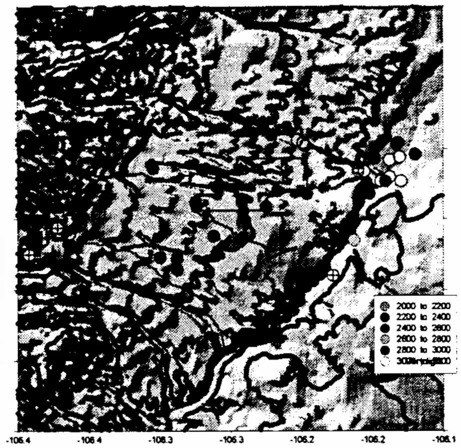


Using oxygen isotope data to predict recharge elevations

Bounding Case 1



Predicted recharge elevations



1. Most waters are predicted to have recharged in the upper elevations

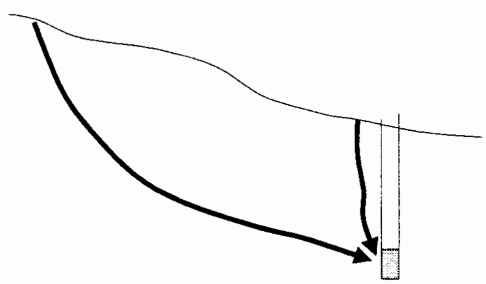
2. Some very light waters near the Rio Grande were probably recharged 10,000's of years ago in a cooler climate

17

Using oxygen isotope data to predict recharge elevations

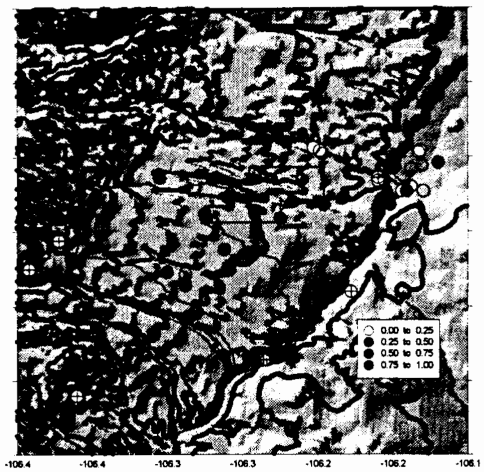
Bounding Case 2

Mixing of high elevation and "local" (vertical) recharge



18

Predicted fraction of local (vertical) recharge



19

Summary

1. Different methods yield differing estimates of recharge rates on the Pajarito Plateau. Further analysis of baseflow to the Rio Grande and water budget elements such as ET is necessary to provide better constraints.

2. Insufficient chemistry data exists to the west of the Pajarito Plateau to delineate recharge areas using tracers.

3. Oxygen isotope data is consistent with a conceptual model of recharge predominately to the west, with some component of "local" or vertical recharge locally.

4. Groundwater flow modeling suggests that the area to the west of LANL and east of the Valles Caldera may contribute most of the recharge water to the aquifer.

20

HYDROCHEMISTRY OF PERCHED INTERMEDIATE ZONES AND REGIONAL AQUIFER, LOS ALAMOS, NEW MEXICO

BY

PATRICK LONGMIRE[1] AND DALE COUNCE[1]

MARCH 29-31, 2000

1. EES-1, LOS ALAMOS NATIONAL LABORATORY

1

OBJECTIVES OF PRESENTATION

Present a status report on the distribution of anions, tritium, and nitrogen isotopes (^{15}N and ^{14}N) in groundwaters (alluvial, perched intermediate, and regional aquifer) found at the Laboratory and surrounding areas.

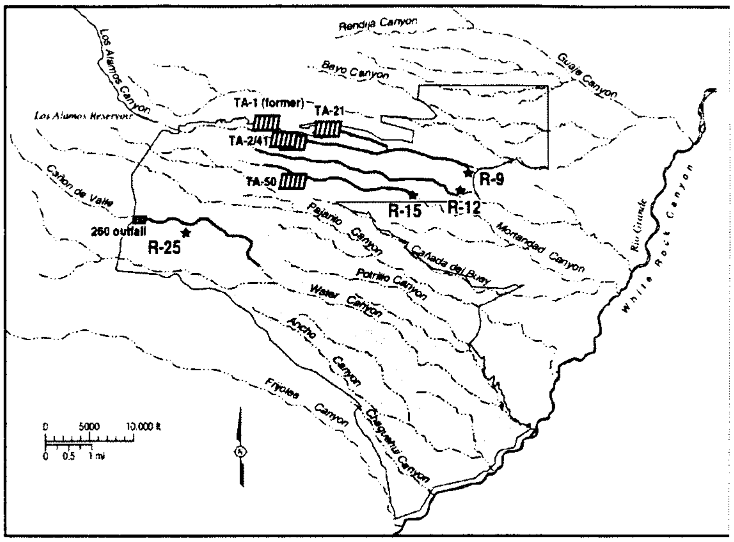
Present hydrochemical data and information-supporting line-source of recharge to perched intermediate zones and the Regional Aquifer.

Topics of interest include:

1. R-9,
2. R-12,
3. R-15,
4. R-25, and
5. other groundwaters and springs.

2

LANL Discharge Sources Relevant to R-9, R-12, R-15, and R-25



ANALYTES OF INTEREST

Major anions (ion chromatography)

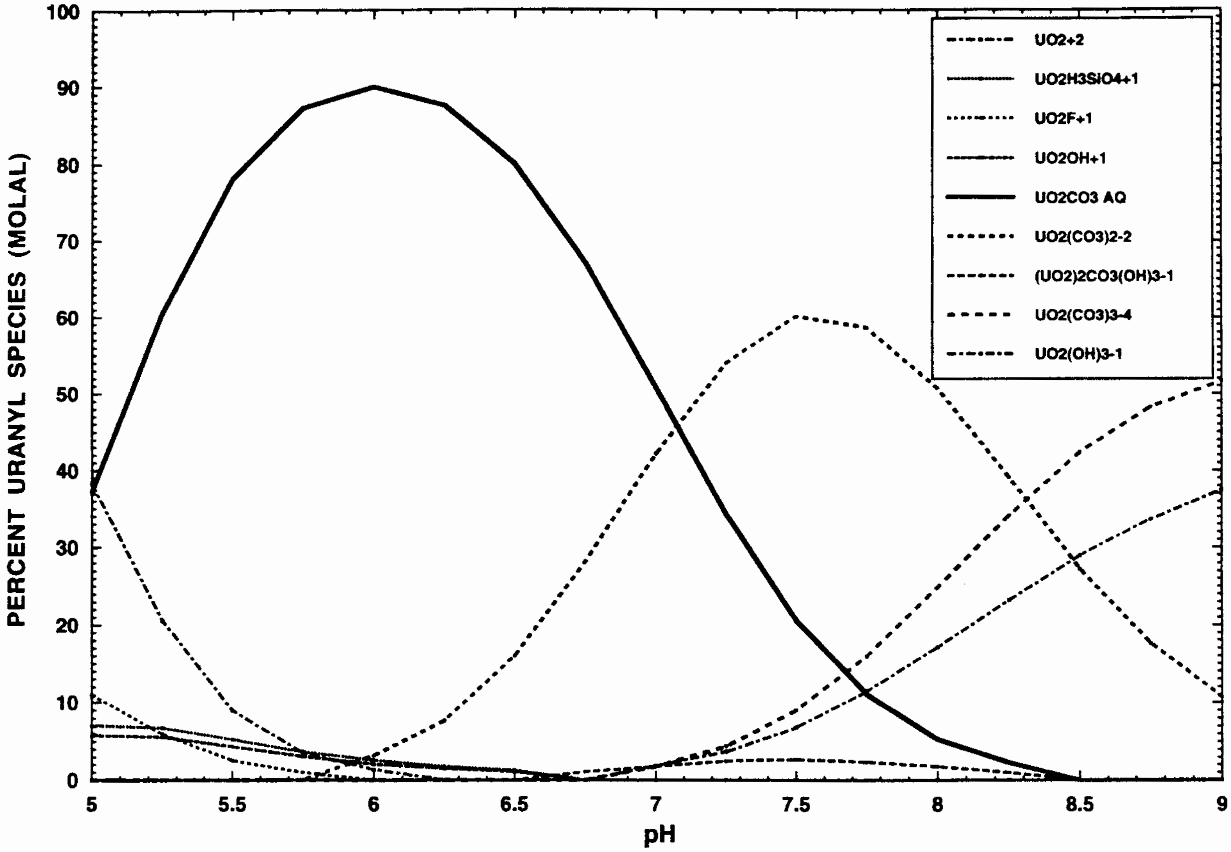
Uranium (Laser induced kinetic phosphorimetric analysis and inductively coupled plasma-mass spectrometry)

Tritium (direct counting and electrolytic enrichment)

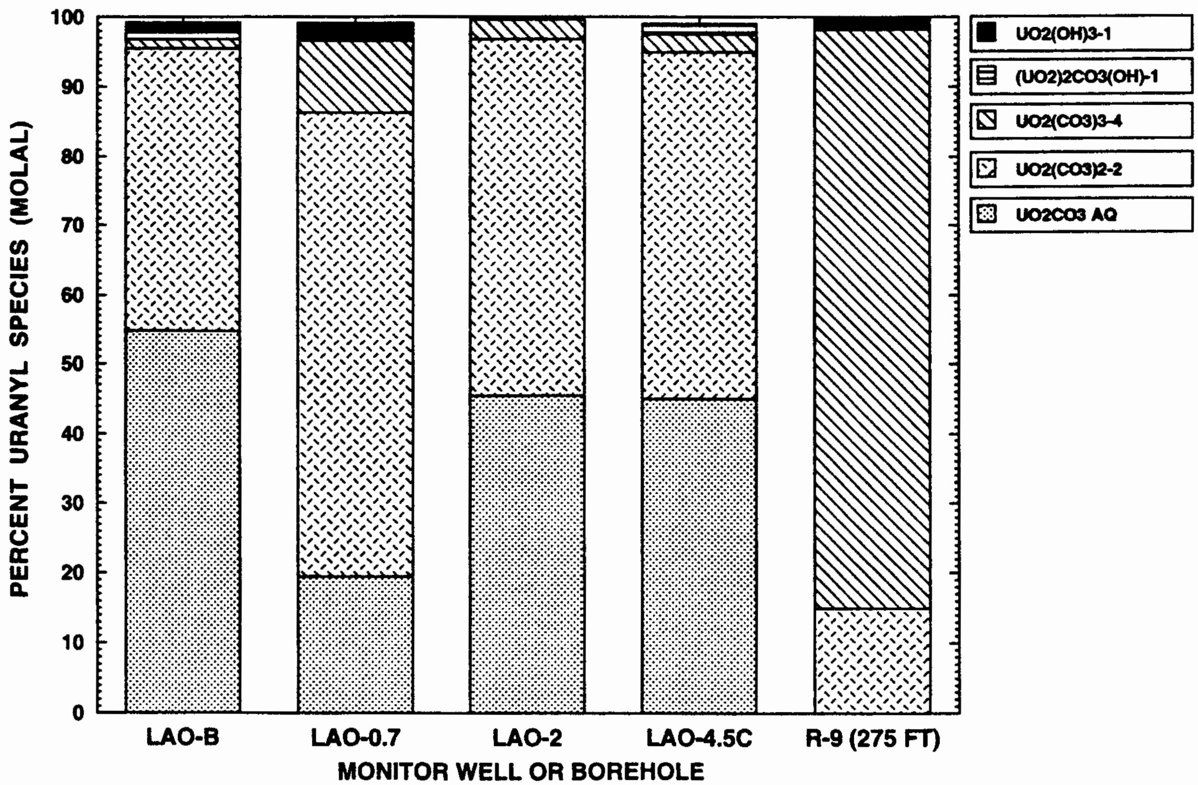
Hydrogen, nitrogen, and oxygen isotopes (isotope ratio mass spectrometry)

High pressure liquid chromatography (HPLC) for HE analyses

DISTRIBUTION OF URANYL SPECIES IN BACKGROUND ALLUVIAL GROUNDWATER, UPPER LOS ALAMOS CANYON, LOS ALAMOS, NEW MEXICO (LOG UO2 = -9.03 m, LOG TOT CO3 = -3.21 m, LOG F = -5.50 m, LOG H4SIO4 = -3.28 m, TEMPERATURE = 4.4C).



PERCENT URANYL SPECIES IN ALLUVIAL AND BASALT GROUNDWATER, UPPER LOS ALAMOS CANYON, LOS ALAMOS, NEW MEXICO (LAO-B, pH = 6.91, LOG UO2 = -9.03 m, ALKALINITY = 30.5 MG/L CaCO3; LAO-0.7, pH = 7.4, LOG UO2 = -9.26 m, ALKALINITY = 45 MG/L CaCO3; LAO-2, pH = 6.6, LOG UO2 = -9.38 m, ALKALINITY = 91 MG/L CaCO3; LAO-4.5C, pH = 6.9, LOG UO2 = -8.55 m, ALKALINITY = 46 MG/L CaCO3; BOREHOLE R-9, pH = 8.79, LOG UO2 = -6.69 m, ALKALINITY = 97.7 MG/L CaCO3).



SPECIATION REACTIONS DESCRIBING URANYL NITRATO AND URANYL CARBONATO COMPLEXES RELEVANT TO UPPER LOS ALAMOS CANYON.

Reaction (TA-21 historical discharges and groundwater chemistry)

$UO_2(NO_3)_2^0 + 2HCO_3^- = UO_2(CO_3)_2^{2-} + 2NO_3^- + 2H^+$

$UO_2(CO_3)_2^{2-} + HCO_3^- = UO_2(CO_3)_3^{4-} + H^+$

GROUNDWATER CHEMISTRY OF BOREHOLE R-9, UPPER LOS ALAMOS CANYON (FILTERED SAMPLES) (COMPILED BY P. LONGMIRE, 12/05/98)

Saturated Zone (depth in ft)	Chloride[1] (ppm)	Nitrate[1] (ppm)	Oxalate[1] (ppm)	Uranium[2] (ppb)	Tritium[3] (pCi/L)
Basalt					
180	29.2	<0.01	<0.02	1.18	346.7± 12.4
275	25.5	0.82	3.03	48.4	106.3± 7.0
Puye Formation					
579	13.2	2.41	<0.02	2.08± 0.28	2.71 ± 0.58
615	177	0.76	2.85	2.17 ± 0.30	30.3 ± 2.0
624	20.2	1.97	0.48	1.41± 0.19	13.93 ± 0.90
Santa Fe Group					
688	7.67	0.78	0.30	1.63± 0.22	14.43 ± 0.96

1. Chloride and nitrate (as N) analyzed by ion chromatography (IC) at LANL and Paragon Analytics, Inc., Fort Collins, Colorado. Oxalate analyzed by ion chromatography (IC) at LANL.

2. Uranium in basalt analyzed by thermal ionization mass spectrometry (TIMS) at LANL and uranium in Puye Fm. analyzed by laser-induced kinetic phosphorimetry (LIKP) at Paragon with an error of 2 standard deviations.

3. Tritium analyses (non-filtered samples) conducted by the University of Miami using direct counting and low-level electrolytic enrichment with an error of two standard deviations.

THE Kd CONCEPT

A measure of the ratio of the amount of the element bound to the solid phase relative to the amount that is in solution.

1. **Empirical value measured in laboratory experiment or determined from nonfiltered and filtered water samples.**
2. **Concentrations of suspended uranium in perched zone are 0.112 mg/kg.**
3. **Concentrations of dissolved uranium in perched zone are 0.048 mg/L (Proposed EPA MCL for uranium is 0.020 mg/L).**
4. **Kd has the units of volume per mass. (ml/g, cm^3/g, or L/kg).**

For R-9, Kd = 0.112 mg/kg U/0.0484 mg/L U

Kd = 2.31 L/kg or 2.31 ml/g for U.

THE RETARDATION EQUATION

Kd is related to the transport velocity of the adsorbate to that of water by determining the retardation factor, R_f.

The retardation equation is:

$$R_f = 1 + \frac{pKd}{n}$$

Where p = bulk density (g/cm^3) and n = effective porosity (V_{void}/V_{total}).

$$R_f = 1 + \frac{2.5 g/cm^3 (2.31 cm^3/g)}{0.30}$$

R_f = 20. ***Uranium at R-9 is predicted to migrate 1/20 the rate of average groundwater flow in the lower perched zone (275 ft).***

GROUNDWATER CHEMISTRY OF BOREHOLE R-12, SANDIA CANYON (FILTERED SAMPLES) (COMPILED BY P. LONGMIRE, 12/05/98)

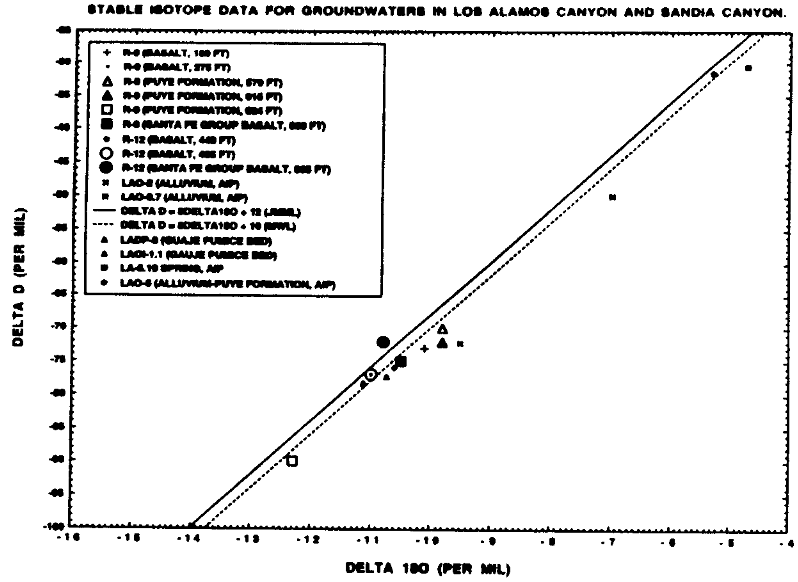
Saturated Zone (depth in ft)	Chloride[1] (ppm)	Ammonium[1] (ppm)	Nitrate[1] (ppm)	Oxalate[1] (ppm)	Uranium[2] (ppb)	Tritium[3] (pCi/L)
Basalt-Perched Zone(s)						
443	31.5	<0.02	4.9	<0.02	2.51$\pm$ 0.34	254.7$\pm$ 16.6
464	200	13.5	0.21	<0.02	2.04$\pm$ 0.28	208.1$\pm$ 7.0
495	33.4	0.26	5.5	<0.02	2.46$\pm$ 0.34	249.3$\pm$ 8.3
Santa Fe Group-Basalt						
805	10.1	0.02	0.46	<0.02	4.08$\pm$ 0.56	46.9$\pm$ 1.6

Chloride and nitrate (as N) analyzed by ion chromatography (IC) at LANL and Paragon Analytics, Inc., Fort Collins, Colorado. Ammonium (as N) analyzed by ion specific electrode (ISE) at LANL. Oxalate analyzed by ion chromatography (IC) at LANL.

2. Uranium in basalt analyzed by laser-induced kinetic phosphorimetry (LIKP) at Paragon with an error of 2 standard deviations.

3. Tritium analyses (non filtered samples) conducted by the University of Miami using direct counting and low-level electrolytic enrichment with an error of two standard deviations.

STABLE ISOTOPE DATA FOR GROUNDWATERS IN LOS ALAMOS CANYON AND SANDIA CANYON.



Tritium Activity in Groundwater Zones at R-15

Depth (ft)	Sample Date	Activity (pCi/L)	Analytical Laboratory	Geologic Formation
Perched Zones				
482 (drilling mud)	06/25/99	57.5 ± 9.6	Univ. Miami[a]	Puye Fm.
646	07/22/99	3,770 ± 850	CST-9	basalt
646	07/22/99	4,151	Univ. Miami[b]	basalt
Regional Aquifer				
1,007	08/23/99	220 ± 620	CST-9	Puye Fm.
1,007	08/23/99	<3.192 ± 9.576	Univ. Miami[b]	Puye Fm.
1,100	08/28/99	1.21 ± 0.70	Univ. Miami[a]	Puye Fm.

Analytical error is ±1 standard deviation. LANL and University of Miami perform LSC and direct counting methods, respectively, for measuring tritium activity in these groundwater samples.

a Data provided by LANL.

b Data provided by DOE Oversight Bureau.

HIGH EXPLOSIVE CHEMISTRY OF R-25 SCREENING GROUNDWATER SAMPLES.

Sample Depth (ft)	Sampling Zone	RDX[1] (ug/L)	HMX (ug/L)	4-A-2,4-DNT (ug/L)	2-A-4,6-DNT (ug/L)	TNB (ug/L)	TNT (ug/L)
Otowi Mem.							
747	Upper	**12**	<1	0.38	0.51	<0.26	<0.25
Puye Fm							
867	Upper	**63**	8.3	3.7	5.2	2.2	**19**
1,047	Upper	**84**	12	4.6	5.7	<2.5	**5.3**
1,137	Wet/Dry	**50**	9.2	4.3	2.9	<1.3	<1.3
1,181	Wet/Dry	**4.2**	<1	<0.25	0.43	<0.26	<0.25
1,287	Reg. Aq.	<0.84	<1.0	<0.25	<0.25	<0.26	<0.25
1,407	Reg. Aq.	**62**	9.7	<1.3	2	<1.3	**7.1**
1,507	Reg. Aq.	**4.4**	<1	<0.25	<0.26	<0.26	<0.25
1,607	Reg. Aq.	**15**	2.6	5	0.46	<0.26	0.84
1,747	Reg. Aq.	<0.84	<1	<0.25	<0.25	<0.25	<0.25
1,867	Reg. Aq.	0.97	<1	<0.25	<0.25	<0.26	<0.25
1,939	Reg. Aq.	<0.84	<1	<0.25	<0.25	<0.26	<0.25
1,940 (air lifted)	Reg. Aq.	**8.8**	1.5	1.7	0.69	<0.26	0.77
1,940 (bailer)	Reg. Aq.	**9.6**	1.6	1.8	0.79	<0.26	1.1
1,942	Reg. Aq.	**5.9**	<1	1.1	<0.25	<0.26	0.64
EPA HA[2] (µg/L)		*2*	*400*				*2*

1. RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), 4-A-DNT (4-amino-2.6-dinitrotoluene), 2-A-DNT (2-amino-4,6-dinitrotoluene), TNB (1,3,5-trinitrobenzene). and TNT (2,4,6-trinitrotoluene) analyzed by high pressure liquid chromatography (HPLC) (EPA Method 8330) at Paragon Analytics, Inc., Fort Collins, Colorado.
2. USEPA (Region 6) lifetime health advisory level. Reg. Aq. means Regional Aquifer.

OXYGEN AND HYDROGEN STABLE ISOTOPE DATA COLLECTED AT R-25 AND SELECTED SPRINGS.

DEPTH (FT)	FORMATION	δD (permil)	$\delta^{18}O$ (permil)
747	Otowi Member	-77	-12.0
1,286	Puye Formation	-82	-12.2
1,407	Puye Formation	-79	-12.0
1,507	Puye Formation	-80	-11.9
1,747	Puye Formation	-76	-11.8
1,867	Puye Formation	-76	-11.7
1,940	Puye Formation	-79	-12.1
1,942	Puye Formation	-80	-11.6
Upper Cañon de Valle Spring	Tschicoma Fm/Bandelier Tuff	-75	-11.9
Water Canyon Gallery	Bandelier Tuff	-74	-11.9
Apache Spring	Tschicoma Fm/Bandelier Tuff	-76	-12.2

Analyses for R-25 performed by Geochron Laboratories, Cambridge, Massachusetts. Analysis for springs performed by Western Michigan University. D/H standard = 0.000316 and $^{18}O/^{16}O$ standard = 0.0039948 (double atom ratio for both standards) provided by Geochron.

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR PUEBLO CANYON AND LOS ALAMOS CANYON (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	NO_3-N	NH_4-N	Delta $^{15/14}N$-NO_3	Delta $^{15/14}N$-NH_4
Pueblo Canyon				
TW-4	0.28	<0.05	-2.5	-
TW-2A	0.77	0.31	+0.8	+11.0
Bayo Plant otfl	3.01	11.5	+2.9	+11.9
PAO-4	0.04	-	+18.6 (2)	+8.5 (2)
POI-4	3.75	<0.05	+19.5	-
APCO-1	0.47	0.77	+25.4	+24.3
Stream-Bayo STP	-	-	7.8 (2)	-
TW-1A	<0.02	0.29	24.6 (2)	-
TW-1	5.3	0.04	17.2 (3)	-
TW-1	5.57	<0.05	+14.9	-
Stream @SR4	1.25	0.14	+29.7	+14.4
Los Alamos Canyon				
Basalt Spring	4.5	0.02	34.2 (2)	-
LA Spring	2.8	<0.02	2.8 (2)	-

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR HNO3, LOS ALAMOS CANYON, SANDIA CANYON, MORTANDAD CANYON, AND TA-50 (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	NO_3-N	NH_4-N	Delta $^{15/14}N$-NO_3	Delta $^{15/14}N$-NH_4
Los Alamos and Sandia Canyons				
R-9 (579 ft)	2.4	0.07	+3.0 (2)	-
TA-3	1.5	0.12	+32.4 (2)	-
R-12 (443 ft)	4.9	<0.02	+15.2 (3)	-
R-12 (464 ft)	0.21	13.5	+21.3 (2)	+1.3 (2)
R-12 (495 ft)	5.5	0.26	+20.3 (2)	-
R-12 (801 ft)	0.46	0.02	+11.3 (2)	-
HNO_3 STD	5.7	<0.02	+1.0 (4)	-
Mortandad Canyon				
TA-50	67.3	4.73	+2.1 (2)	-
R-15 (646 ft)	<0.01	0.06	-6.2 (2)	-
R-15 (1,100 ft)	<0.01	0.03	+5.4	-

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

17

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR R-25 AND SELECTED BACKGROUND SURFACE WATER AND SPRINGS (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	**NO_3-N**	**NH_4-N**	**Delta $^{15/14}N$-NO_3**	**Delta $^{15/14}N$-NH_4**
R-25				
747 ft	**0.95**	**0.03**	**+3.1**	**-**
867 ft	**0.90**	**0.03**	**+2.8**	**-**
1286 ft	**0.32**	**0.02**	**+2.6**	**-**
1407 ft	**0.51**	**<0.02**	**+4.3**	**-**
1607 ft	**0.42**	**<0.02**	**+2.5**	**-**
1747 ft	**0.31**	**<0.02**	**-0.6**	**-**
1867 ft	**0.20**	**<0.02**	**+1.1**	**-**
1942 ft	**0.25**	**<0.02**	**+0.3**	**-**
LA Reservoir	**0.04**	**-**	**-2.4**	**-**
Upper Pajarito Canyon	**0.01**	**-**	**-2.4 (2)**	**-**
Water Canyon Gallery	**0.10**	**-**	**0**	**-**
Apache Spring	**0.35**	**-**	**-0.5 (2)**	**-**

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

18

CONCLUSIONS

Mobile species (anions and tritium), of natural and anthropogenic origins occur within perched intermediate zones (R-9, R-12, R-15, and R-25) and the regional aquifer (R-9, R-12, and R-25?).

Under oxidizing conditions, uranium(VI) is stable as uranyl carbonato complexes (anions) in groundwater and surface water, which are semi-sorbing.

The main sources of nitrate found in surface waters and groundwaters at LANL and surrounding areas include natural sources, treated sewage effluents, and discharges of dissociated nitric acid.

Groundwater older than 60 years typically have tritium activities less than 2 pCi/L.

Hydrogen, nitrogen, and oxygen isotopes are tools that should be used with other geochemical data and information to evaluate source(s) of nitrate and other contaminants found in groundwater. Know the source-term chemistry!

19

SUPPLEMENTAL MATERIAL HYDROCHEMISTRY PRESENTATION

20

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR BACKGROUND SURFACE WATERS AND GROUNDWATERS (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	NO_3-N	NH_4-N	Delta $^{15/14}N$-NO_3	Delta $^{15/14}N$-NH_4
LAC reservoir	0.04	-	-2.4	-
LAO-B	<0.01	0.02	+0.1	-
LAC creek	0.04	-	-2.3	-
UPC creek	0.01	-	-2.4 (2)	-
WCG	0.10	-	0.0	-
Apache Spring	0.35	-	-0.5 (2)	-
Pajarito Spring	0.82	-	-1.3	-
Doe Spring	0.19	-	+1.9	-
Spring 10	0.44	-	-1.6	-
Spring 9B	0.33	-	-0.2	-
Otowi-4	0.38	-	-7.6	-
Guaje-5	0.72	-	-6.1	-

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR BACKGROUND SURFACE WATERS AND GROUNDWATERS (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	NO_3-N	NH_4-N	Delta $^{15/14}N$-NO_3	Delta $^{15/14}N$-NH_4
LAOI-1.1	0.35	0.04	-6.0	-
Sacred Spring	0.27	<0.05	-4.0	-
Rio Grande	<0.01	-	+1.3	-
La Mesita Spring	2.95	<0.05	-1.0	-

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR LOS ALAMOS CANYON AND SANDIA CANYON (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	NO_3-N	NH_4-N	Delta $^{15/14}N$-NO_3	Delta $^{15/14}N$-NH_4
Los Alamos Canyon				
LAO-0.6	0.31	<0.05	+7.6	-
LAO-1.6G	0.62	<0.05	-1.3	-
DP Spring	0.28	<0.05	+2.9	-
LAO-2	0.60	<0.05	+1.4	-
TW-3	0.57	<0.05	-3.2	-
LAO-3A	0.62	<0.05	-3.5	-
Basalt Spring	3.47	<0.05	+30.2	-
LA Spring	3.18	<0.05	+3.6	-
LLAO-5	1.53	<0.05	+7.3	-
Otowi Spring	0.35	<0.05	-1.6	-
Sandia Canyon				
R-12 (801 ft)	0.97	<0.5	+6.6	-

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES[1] FOR MORTANDAD CANYON, INCLUDING TA-50 (CONCENTRATIONS OF NITRATE AND AMMONIUM IN MILLIGRAMS/LITER, NITROGEN ISOTOPES IN PARTS PER THOUSAND OR PERMIL).

Location	NO_3-N	NH_4-N	Delta $^{15/14}N$-NO_3	Delta $^{15/14}N$-NH_4
Mortandad Canyon				
TA-50 Plant	14.9	1.96	+5.0	+13.0
TA-50 otfl	17.7	3.86	+2.3	+8.4
GS-1	15.4	2.69	+2.1	+8.0
MCO-3	37.8	<0.05	+2.3	-
MCO-4B	13.2	<0.05	-4.7	-
TW-8	0.23	<0.05	-2.5	-
MCO-5	15.4	<0.05	-4.5	-
MCO-6	17.5	<0.05	-4.9	-
MCO-7	18.2	<0.05	-9.2	-
MCO-7.5B	13.7	<0.05	-12.1	-
MCWB-6.5E	17.0	<0.05	-8.5	-
MCWB-7.7B	22.4	<0.05	-37.9	-
MT-3	37.8	<0.05	-15.7	-
MT-4	20.7	<0.05	-29.5	-

1. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas.

OXIDATION-REDUCTION BOUNDING CONDITIONS FOR LOWER PERCHED WATER WITHIN BASALT, BOREHOLE R-9, UPPER LOS ALAMOS CANYON, NEW MEXICO.

Reaction	Eh (mV), pH 8.79 (25C)
$H_2O + NO_2^- = NO_3^- + 2H^+ + 2e^-$	+383
$3H_2O + NH_4^+ = NO_3^- + 10H^+ + 8e^-$	+240
$2H_2O + 3HCO_3^- + USiO_4(c) = UO_2(CO_3)_3^{4-} + H_4SiO_4^0 + 3H^+ + 2e^-$	-92
$3H_2O + Fe^{2+} = Fe(OH)_3(am) + 3H^+ + e^-$	-168
$2H_2O + 3HCO_3^- + USiO_4(am) = UO_2(CO_3)_3^{4-} + H_4SiO_4^0 + 3H^+ + 2e^-$	-356

THE RETARDATION CONCEPT

Average Flow Velocity (ft/yr)	(1941-1999)	Uranyl Migration (ft)
10	580	29
50	2,900	145
100	5,800	290
150	8,700	435
200	11,600	580
250	14,500	725
300	17,400	870

Discharges of uranium into upper Los Alamos Canyon (former TA-1, TA-2, and TA-21) have occurred since 1941.

SURFACE COMPLEXATION MODELING OF R-9 GROUND WATER: DIFFUSE LAYER MODEL

The diffuse-layer adsorption model considers solution speciation and aqueous ion activities. The model uses the electric double-layer (EDL) theory. EDL theory assumes that the + or – surface charge of a sorbent in contact with solution generates an electrostatic potential that declines rapidly away from the sorbent surface. The potential is the same at the zero (sorbent surface) and d (solution) planes.

The concentration of hydrous ferric oxide (HFO) at 275 ft is 1.46 g/L.

The specific surface area of HFO is 600 m^2/g.

Model uranyl sorption with one surface containing two sites, high energy (s) (8.2×10^{-5} mol active site HFO/L) and low energy (w) (0.003 mol active site HFO/L). The estimated intrinsic constants for uranyl sorption (Langmuir, 1997) include:

$Fe^{s}OH + UO_2^{2+} = Fe^{s}OHUO_2^{2+}$ ($\log K_1 = 5.2$) and

$Fe^{w}OH + UO_2^{2+} - H^{+} = Fe^{w}OUO_2^{+}$ ($\log K_2 = 2.8$).

SURFACE COMPLEXATION MODELING OF R-9 GROUND WATER: DIFFUSE LAYER MODEL

The DLM predicts that 112 ppb total uranium in the 275 ft perched zone at pH 9 occurs as

57.5 percent uranyl bound as $SO2UO_2^{+}$ (64 ppb sorbed U),

5.1 percent uranyl bound as $UO_2(CO_3)_2^{2-}$ (7 ppb dissolved U), and

36.6 percent uranyl bound as $UO_2(CO_3)_3^{4-}$ (41 ppb dissolved U) (calculated total dissolved U is 48 ppb, measured dissolved U is 48.4 ppb).

The Kd, based on the DLM, is

(U sorbed M)/(U dissolved M) X (10^3mg/g)/(1.46 mg/ml),

($10^{-6.57}$ M)/($10^{-6.70}$ M) X (10^3mg/g)/(1.46 mg/ml),

$Kd_{(DLM)}$ = 926 ml/g.

OXIDATION-REDUCTION REACTION FOR PERCHLORATE (ClO_4^-)

$4H_2O + Cl^- = 8e^- + ClO_4^- + 8H^+$

Eh = 1.39V – 0.0592pH

Upper Stability of Water

Eh = 1.23V – 0.0592pH

Perchlorate should dissociate (reduction of Cl^{7+} to Cl^-) in water, however, the four oxygen-chlorine bonds control rate of reduction. Therefore, perchlorate persists in aqueous solution. Twelve ppb of perchlorate (screening data) is observed in R-15 (646 ft zone) in Mortandad Canyon.

NITROGEN REDOX CHEMISTRY

Reaction	E° (volts)	Eh (volts) pH = 7
$NO_3^- + 6H^+ + 5e^- = 0.5N_2(g) + 3H_2O$	1.24	0.713
$NO_3^- + 2H^+ + 2e^- = NO_2^- + H_2O$	0.845	0.431
$NO_3^- + 10H^+ + 8e^- = NH_4^+ + 3H_2O$	0.882	0.364
$NO_2^- + 8H^+ + 6e^- = NH_4^+ + 2H_2O$	0.892	0.340

Assumptions: $[NO_3^-] = 10^{-3}$ M, $PN_2 = 0.8$ bar, $[NO_3^-] = [NO_2^-]$, $[NO_3^-] = [NH_4^+]$

TRITIUM ACTIVITIES AND MOISTURE CONTENTS IN R-15 CORE SAMPLES, MORTANDAD CANYON.

Depth (ft)	Tritium Activity (pCi/g)	Tritium Activity (pCi/L)	Moisture Content (wt. %)	Hydrogeologic Unit
22.3	0.665	69.2	9.42	Tshirege Member
39.8	0.077	5.3	6.49	Tshirege Member
59.8	11.64	2,374	16.94	Tshirege Member
69.8	7.78	3,021	27.97	Cerro Toledo interval
84.8	6.39	1,132	15.05	Cerro Toledo interval
104.8	3.99	502	11.18	Cerro Toledo interval
114.8	5.7	621	9.82	Cerro Toledo interval
144.8	12.11	2,852	19.06	Otowi Member
169.8	18.3	3,199	14.88	Otowi Member
229.8	2.88	567	14.46	Otowi Member
269.8	4.97	952	16.08	Otowi Member
319.8	21.8	5,338	19.67	Otowi Member
379.8	22.2	5,405	19.58	Otowi Member
414.8	0.216	54.3	20.08	Otowi Member

TRITIUM ACTIVITIES IN R-25 GROUNDWATER.

Depth (ft)	Sampling Zone	Sample Date	Activity (pCi/L)
Otowi Member			
747	Upper Saturated Zone	09/30/98	77.2 + 2.9
Puye Formation			
867	Upper Saturated Zone	10/09/98	81.4 + 2.9
1,184	Wet/Dry Zone	12/03/98	44.7 + 1.6
1,286	Regional Aquifer	12/18/98	3.77 + 0.35
1,407	Regional Aquifer	01/07/99	72.8 + 2.6
1,607	Regional Aquifer	02/03/99	32.6 + 1.3
1,747	Regional Aquifer	02/12/99	1.02 + 0.32
1,867	Regional Aquifer	02/20/99	1.85 + 0.29
1,940	Regional Aquifer	02/23/99	14.46 + 0.54
1,942	Regional Aquifer	02/26/99	8.11 + 0.41

Analytical error is 1 standard deviation. University of Miami performed both direct counting and electrolytic enrichment methods for measuring tritium activities in the above groundwater samples.

STABLE ISOTOPE NOTATION

$$\delta^n \text{ stable isotope sample} = \left(\frac{\delta^n \text{ sample}}{\delta^n \text{ standard}} - 1\right)1000$$

Isotope ratios are reported in permil (‰) or parts per thousand.

n is mass of stable isotope ratio.

Refinements in Understanding of the Vadose Zone From Injection Test Data

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Modeling Objectives

Assess the validity of conceptual and numerical model for fluid flow in the Bandelier tuff

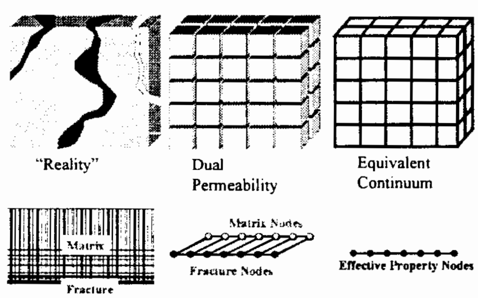
- Flow exhibits both gravity drainage and moisture movement via capillary forces
- Matrix percolation under unsaturated conditions - long travel times
- Fractures are dry - not conduits for flow

Why is it Important to Validate?

- Validation is an exercise in confidence building
- Model behavior has an influence on the risk assessment predictions for contaminated sites
  - Travel times - much longer if percolation through matrix rock is correct
  - Characterization of fracture networks is extremely difficult - if flow is through the matrix, fractures do not need to be characterized

3

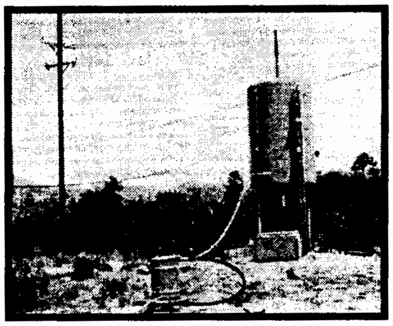
Conceptual and Numerical Models for Flow Through Unsaturated, Fractured Tuff



4

TA-50 Water Injection Tests

Storage Tank and Constant-Head Device

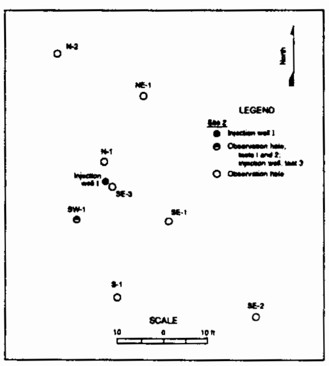


- Performed in 1960's to explore the possibility of constructing injection wells for water disposal
- Primary goal: determine flow rates and conditions that water can be injected into unsaturated Bandelier Tuff
- Related goal: monitor the movement of fluids from the injection zone into the adjacent tuff
- Data are available to interpret the results of the injection tests

Purtymun, W. D., E. A. Enyart, and S. G. McLin, 1989. *Hydrologic Characteristics of the Bandelier Tuff as Determined Through an Injection Well System*, LANL Report LA-11511-MS.

Testing History

Site 2 Injection and Observation Wells



Site 1

- Four tests of 50-140 hr duration to design the subsequent experiments

Site 2

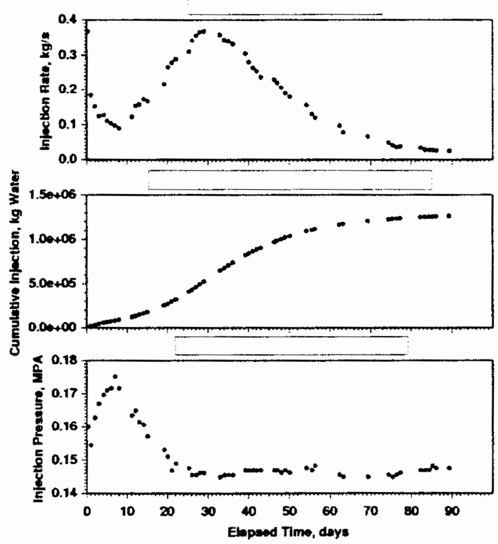
- Three longer duration tests in which moisture monitoring was carried out to investigate moisture movement through the tuff
- Test 1: 89 days of injection and moisture monitoring - numerical modeling of this test has been performed

Injection History - Test 1

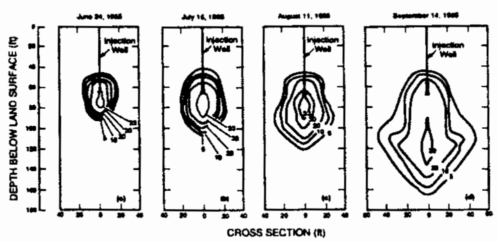
Injection Rate

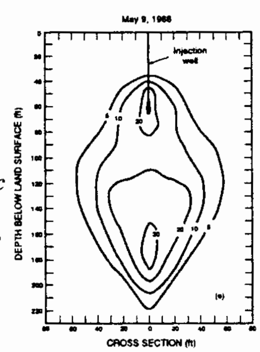
Cumulative Mass Injected

Injection-Zone Pressure



Contours of the Water Content During and After Test 1





Fluid injection rates and pressures mimic the behavior under "high-stress" hydrologic conditions: analogous to flow beneath a pond or wet canyon.

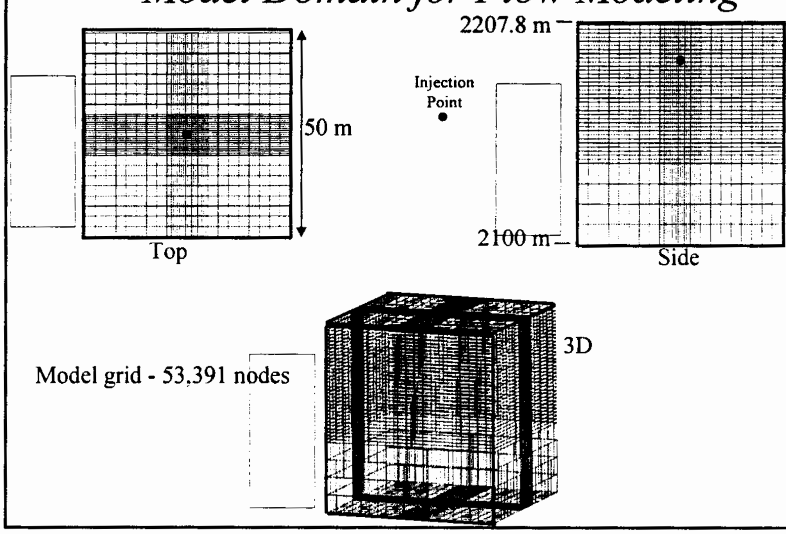
Moisture Movement During Test 1

Date		Vertical Movement (m/day)	
From	To	5% Moisture	30% Moisture
06-17-65	06-24-65	1.2	1.1
06-24-65	10-25-65	0.24	0.24
10-25-65	11-19-65	0.12	0
11-19-65	12-22-65	0.061	0.061
12-22-65	05-09-66	0.006	0.18

Date		Horizontal Movement (m/day)
From	To	
06-17-65	07-16-65	0.24
07-16-65	08-11-65	0.15
08-11-65	09-14-65	0.061
09-14-65	11-19-65	0.030
11-19-65	05-09-66	0.061

Table V. from Purtymun, W. D., E. A. Enyart, and S. G. McLin, 1989. *Hydrologic Characteristics of the Bandelier Tuff as Determined Through an Injection Well System*, LANL Report LA-11511-MS.

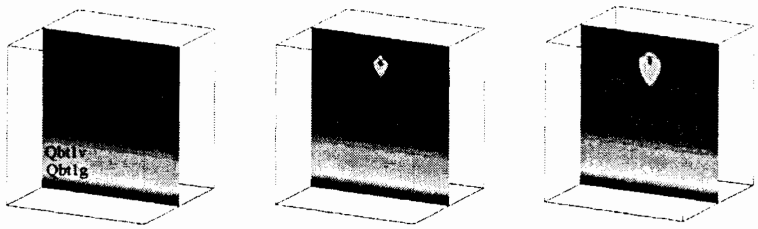
Model Domain for Flow Modeling



Test 1 Water Injection Test Simulation

Background and Initial Phase

Fluid saturation - dry (red) to wet (blue)



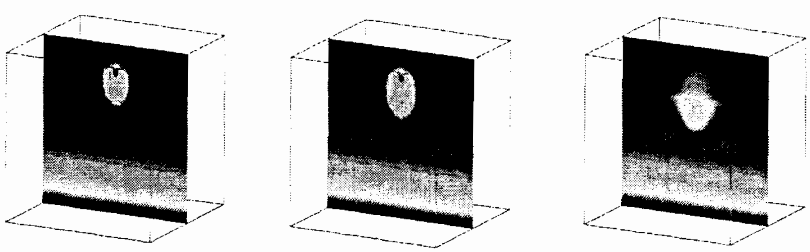
Background | Day 7 June 24,1965 | Day 29 July 16, 1965

11

Test 1 Water Injection Test Simulation

Final Phase and Post-Injection Period

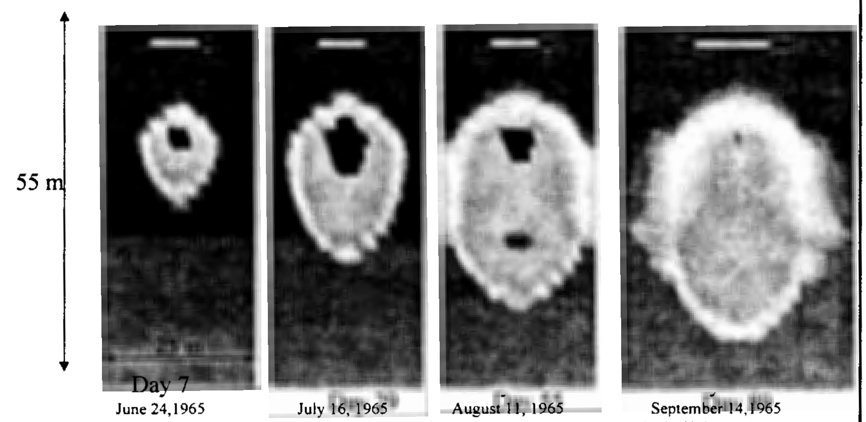
Fluid saturation - dry (red) to wet (blue)



Day 55 August 11, 1965 | Day 89 September 14,1965 End of injection phase | Day 327 May 9, 1966

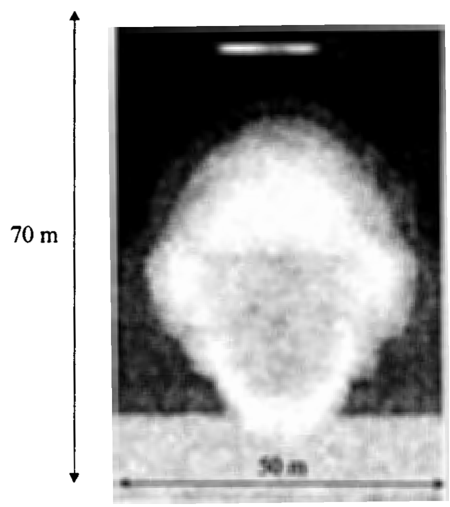
12

Test 1 Model Predictions of Water Content Profile During Injection Phase



13

Test 1 Model Predictions of Water Content Profile at the End of the Monitoring Period (327 days)



14

Comparison of Model and Observations for Extent of Moisture Movement

Date		Vertical Movement of 5% Contour (m/day)	
From	To	Data	Model
06-17-65	06-24-65	1.2	1.4
06-24-65	10-25-65	0.24	0.19
10-25-65	11-19-65	0.12	0.080
11-19-65	12-22-65	0.061	0.061
12-22-65	05-09-66	0.006	0.029

Date		Horizontal Movement (m/day)	
From	To	Data	Model
06-17-65	07-16-65	0.24	0.28
07-16-65	08-11-65	0.15	0.04
08-11-65	09-14-65	0.061	0.03
09-14-65	11-19-65	0.030	0.08
11-19-65	05-09-66	0.061	0

Date	Upward Movement (m above injection point)	
	Data	Model
09-14-65	4.3	8
05-09-66	7	10

15

Ongoing Work

- Examine the influence of hydrologic property values on model results
  - Constant properties, using different property sets
  - Heterogeneous property fields
- Attempt to match data with other conceptual models
  - discrete fracture - high-permeability feature running through the injection region
  - dual permeability models

16

Conclusions

- Effective continuum model without fractures is adequate to explain the data
- Open question - do discrete fracture and dual permeability models also fit the data?
- Implications for risk assessment
  - Travel times - percolation through matrix rock suggest long travel times and more effective sorption
  - Characterization of fracture networks may not be necessary for the Bandelier tuff

LANL Environmental Restoration (ER) Project's Approach to Risk Assessment of Contaminants Found in Groundwater

Diana Hollis

LANL ER Project

Presentation Contents

- Regulatory/Statutory Framework
- Philosophy
- Conceptual Model of Groundwater Risk
- Approach
- Implementation

Regulatory/Statutory Framework

- ER is responsive to the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- ER Project is responsible for corrective actions at sites contaminated before 1986
- Corrective actions complicated by presence of both
  - hazardous (NMED-regulated) and radioactive (DOE-regulated) contaminants,
  - Historic (ER) and operational (DP) contaminants

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Regulatory/Statutory Framework

- ER Project uses a risk-based approach to corrective actions, as endorsed by EPA and NMED
- Risk-based corrective action process is appropriate because it
  - applies equally to hazardous and radioactive contaminants, and ER and DP contaminants
  - ensures protectiveness independent of administrative boundaries

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Philosophy

- Corrective actions for contamination in groundwater is borrowed from EPA
- Focus attention and resources on groundwater contamination that poses the greatest risk to human health and/or the environment

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Philosophy

- In a hydrologic system as complex as LANL's, groundwater remediation will be very expensive
- Understand the system to ensure that remediation decisions provide the greatest risk reduction within the system
- Best decisions provide the greatest real risk reduction per dollar invested

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Philosophy

"Risk-based decision-making offers a scientifically sound and administratively effective way to respond to the pressures for timely action at large numbers of sites and efficient use of both public and private resources. It is important to recognize that risk-based decision-making is not intended to be primarily a money-saving tool, even though its use may save money in many cases. At high-risk sites, risk-based cleanups could cost more than those based on other procedures for establishing cleanup goals."

Conceptual Model of Groundwater Risk

- Regional aquifer recharge is dominated by underflow from the Sierra de los Valles
- Surface-water infiltration through wet mesas and along wet canyons may contribute to recharge
- Recharge through dry canyons and mesas is insignificant
- Residence times of groundwater increase with depth
- Concentration of sorptive minerals increases with age

Conceptual Model of Groundwater Risk

- Concentrations of soluble contaminants decrease along groundwater flow path through adsorption, dispersion, precipitation, degradation and mixing
- Adsorption is particularly important for decreasing concentrations of many long-lived radionuclides [Cs-137, U-233, 234, 235, 238, Pu-238, 239, 240, Am-241and metals (lead, mercury, zinc)] along the flow path

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Conceptual Model of Groundwater Risk

- Exposures to groundwater contamination occur only when groundwater becomes accessible by
  - surface discharge
  - pumping
- Humans may be directly exposed to groundwater contamination within groundwater through ingestion and immersion
- Humans may be indirectly exposed to groundwater contamination through ingestion of plants and animals that have been directly exposed

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Conceptual Model of Groundwater Risk

- Ingestion exposures are greater than immersion exposures *except* for tritium
- Direct exposures are more severe than indirect exposures where both occur, *except* for the limited number of contaminants that bioaccumulate
- Direct exposures to contaminated groundwater occur at supply wells and springs downgradient from contaminant sources, and at the Rio Grande

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Conceptual Model of Groundwater Risk

- Concentrations of contaminants in well water are lower than concentrations in groundwater due to wide screened interval
- Concentrations of contaminants in groundwater from the Laboratory that may discharge into the Rio Grande are lower than maximum concentrations within the regional aquifer due to dispersion and mixing
- Present-day concentrations of contaminants in well water and in the Rio Grande are below applicable standards and risk thresholds

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Approach

- "Decouple" corrective actions for surface contamination and shallow groundwater from corrective actions for deep groundwater to ensure "parallel progress"
- Integrate investigations of regional aquifer contamination with hydrogeologic characterization project (R-wells)
- Use hydrology models to assimilate "R-well data" into a conceptual exposure model to support risk assessment

Approach

"EPA believes that... use of fate and transport models to establish risk levels can be appropriate ... EPA today [September 24, 1996] announces that it is changing its 1987 policy ... under RCRA to allow use of fate and transport models…"

Approach

"EPA's risk reduction goal is to reduce the threat from carcinogenic contaminants such that, for any medium, the excess risk of cancer to an individual exposed over a lifetime generally falls within a range from 10^{-6}... to 10^{-4}. For non-carcinogens, the hazard index should generally not exceed one."

Approach

"Cleanup should generally achieve a level of risk within the 10^{-4} to 10^{-6} carcinogenic risk range based on the reasonable maximum exposure for an individual. (T)he upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."

Approach

"If a dose assessment is conducted at the site then 15 millirem per year (mrem/yr) effective dose equivalent (EDE) should generally be the maximum dose limit for humans. This level equates to approximately 3 x 10^{-4} increased lifetime risk and is consistent with levels generally considered protective in other governmental actions, particularly regulations and guidance developed by EPA in other radiation control programs."

Approach

- ER uses data and calibrated site-specific hydrology models to calculate contaminant concentrations as a function of location and time
- ER uses standard EPA risk assessment guidance and parameters to calculate potential cancer risk, hazard index and radiological dose associated with modeled contaminant concentrations

Approach

- When contamination is found in R-wells,
  - compare concentrations to MCLs, if available
  - compare to risk-based thresholds based on availability, concentration, and toxicity under current conditions
- If potential risk under current conditions is found to exceed EPA thresholds
  - determine source of contamination
  - meet with appropriate administrative authority to determine information management and risk mitigation action(s)

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Approach

- In iterative manner as R-well data are collected and hydrology model(s) evolve(s), evaluate cumulative risk of all contaminants present in groundwater accessible by common receptor
- If cumulative risks are determined to exceed EPA risk thresholds at any location or time, determine optimal mitigation actions

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Approach

- Focus and phase corrective action(s) on risk-significant contaminants
- While attention to some contamination may be deferred in this approach, deferred action is ***not*** the goal of the approach

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Approach

- The ER Project will propose monitored natural attenuation (MNA, a.k.a. intrinsic remediation, passive remediation) where it meets risk-reduction objectives in conjunction with active remediation
- Where MNA is proposed, the ER Project will have sufficient site-specific data to support models used to demonstrate the long-term effectiveness

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Approach

Monitored natural attenuation refers to "naturally-occurring processes (e.g., biodegradation, dispersion, dilution, adsorption, and volatilization) in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants…"

Approach

- ER recommendations for MNA as a component of corrective measures for groundwater will be supported by three lines of evidence:
  - Measured reduction in contaminant concentration along downgradient flow path
  - Measured loss of contaminant mass along downgradient flow path
  - Laboratory data and/or geochemical modeling results supporting degradation and decay rates

Approach

"Risk-based decision-making does not require multiple studies of site characteristics, cleanup options, or other factors at all sites. In all cases, data collection and analysis need not be more elaborate or extensive than is necessary to provide scientifically and technically sound answers to the questions at hand--to perform an initial site assessment; to provide data needed for exposure assessment; to provide a basis for establishing cleanup goals."

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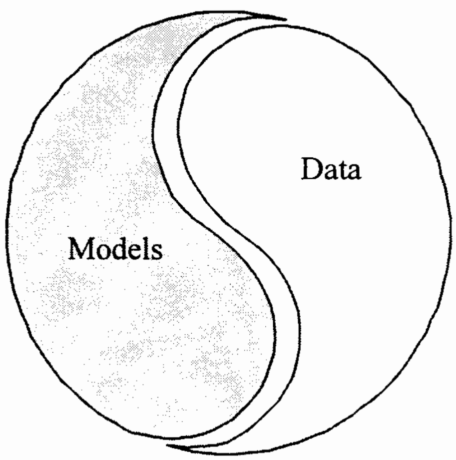
Approach



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Implementation

- Continue installation of R-wells as planned until and unless priorities change
- Continue installation of intermediate wells as planned for until and unless priorities change
- Continue to collect and analyze samples for hydrologic, geologic, and geochemical data to reduce uncertainties in groundwater transport models

Implementation

- Develop and update mesa (low-moisture regime) vadose zone hydrology model (FY1999+)
- Develop and update canyon (high-moisture regime) vadose zone hydrology model (FY2000+)
- Develop and update vadose zone and saturated zone geochemistry models (FY2000+)
- Develop and update surface water and alluvium models (FY2001-2002+)
- Couple surface and and vadose zone models with regional aquifer model (FY2001-2003+)