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Los Alamos National Laboratory

GROUNDWATER INTEGRATION TEAM QUARTERLY MEETING

October 16-18, 2001

VIEWGRAPH PRESENTATIONS

13575

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Quarterly Meeting
October 16-18, 2001

Tuesday, October 16
Cities of Gold Casino Hotel, Pojoaque

8:30	Introduction (Charlie Nylander)
8:45	Groundwater Integration Team (GIT) Subcommittee Status Reports ▪ Information Management (Kendra Henning) ▪ Well Construction (John McCann) ▪ Geochemistry (Pat Longmire)
9:45	Break
10:00	GIT Subcommittee Status Reports (continued) ▪ Hydrology (David Rogers) ▪ Modeling (Bruce Robinson)
10:40	Performance Review (Charlie Nylander)
12:00	Lunch
1:00	Interface between ER Risk Assessment and Hydrogeologic Workplan (Diana Hollis/Charlie Nylander)
1:30	DQO Iteration Overview ▪ Geology (David Vaniman/Greg Cole) ▪ Geochemistry (Pat Longmire)
2:30	Break
2:45	DQO Iteration Overview (continued) ▪ Vadose Zone Hydrology and Modeling (David Rogers/Bruce Robinson) ▪ Regional Aquifer Hydrology and Modeling (Elizabeth Keating)
3:45	Wrap up
4:00	Adjourn

Wednesday, October 17
Cities of Gold Casino Hotel, Pojoaque

8:30	DQO Iteration Proposal (Charlie Nylander)
10:30	Break
10:45	FY02 Schedule and Planning Session (Charlie Nylander)
11:30	Lunch
1:00	External Advisory Group session with stakeholders
3:00	Response to stakeholder concerns (Charlie Nylander)

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Quarterly Meeting
October 16-18, 2001

Thursday, October 18
LATA Conference Room

9:00	EAG closeout meeting with Managers
10:30	EAG close out meeting with GIT
12:00	Lunch
1:00	EAG working session

Groundwater Integration Team Subcommittee Report

Information Management

K. Henning

October 16, 2001

Quarterly GIT Meeting

Well Construction Subcommittee Report

John McCann

October 16, 2001

Overview

- Drilling Accomplishments During the Last 6 Months
- Planned Drilling Activities
- Status of Quarterly Sampling Activities
- Status of Reporting Activities

Drilling Accomplishments Last 6 Months

- Subcontractor tasked to take responsibility for QA and more proactive project management
- Completed the construction and implementation of the baseline for DP-funded wells
- Completed FY01 with positive schedule and cost variances which incorporated BCPs to reflect efficiencies gained in the drilling program

Drilling Accomplishments Last 6 Months

Well	Watershed	Date Drilled	T.D. (ft)	No. Screens
R-5	LA/Pueblo	May 01	902	4
MCOBT-8.5	Mortandad	Jun 01	740	P&A'd
MCOBT-4.4	Mortandad	Jun 01	767	1
CdV-R-37-2	Water/Valle	Aug 01	1664	4

Drilling Accomplishments Last 6 Months

Well	Watershed	Date Drilled	T.D. (ft)	No. Screens
R-13	Mortandad	Oct 01		1
R-8	LA/Pueblo			

Planned Drilling Activities

- **Drilling schedule FY 02:**
  1. **Finish R-13**
  2. **R-8**
  3. **R-14**

Regional Well Sampling Status

Well	Watershed	Date Drilled	T.D. (ft)	No. Screens	Sampling Activity	Reporting Activity
R-25	Water/Valle	Feb 99	1942	9	1st quarter complete Nov 00 2nd quarter complete May 01 3rd quarter 4th quarter	Well Completion Report scheduled Oct 01
R-15	Mortandad	Sep 99	1107	1	1st quarter complete Feb 00 2nd quarter complete Sep 00 3rd quarter complete Feb 01 4th quarter complete May 01	Well Completion Report Dec 00 Geochem Report scheduled Dec 01
R-9	LA/Pueblo	Sep 99	771	1	1st quarter complete Feb 00 2nd quarter complete Sep 00 3rd quarter complete Feb 01 4th quarter complete May 01	Well Completion Report Dec 00 Geochem Report scheduled Mar 02
R-12	Sandia	Jan 00	886	3	1st quarter complete Sep 00 2nd quarter complete Mar 01 3rd quarter complete Jun 01 4th quarter complete Sep 01	Well Completion Report Dec 00 Geochem Report scheduled Apr 02

Regional Well Sampling Status

Well	Watershed	Date Drilled	T.D. (ft)	No. Screens	Sampling Activity	Reporting Activity
R-31	Ancho	Feb 00	1103	5	1st quarter complete Dec 00 2nd quarter scheduled Fall 01 3rd quarter 4th quarter	Well Completion Report scheduled Oct 01
R-9i	LA/Pueblo	Mar 00	323	2	1st quarter complete Sep 00 2nd quarter complete Feb 01 3rd quarter complete Jun 01 4th quarter completed Sep 01	Well Completion Report Dec 00 Geochem Report scheduled Mar 02
R-19	Pajarito	Mar 00	1903	7	1st quarter complete Sep 00 2nd quarter complete Mar 01 3rd quarter complete Jun 01 4th quarter complete Sep 01	Well Completion Report Dec 00 Geochem Report scheduled May 02
CdV-15-3	Water/Valle	Apr 00	1722	6	1st quarter complete Dec 00 2nd quarter complete Apr 01 3rd quarter complete Jul 01 4th quarter scheduled Oct 01	Well Completion Report Oct 01

Regional Well Sampling Status

Well	Watershed	Date Drilled	T.D. (ft)	No. Screens	Sampling Activity	Reporting Activity
R-22	Pajarito	Oct 00	1489	5	1st quarter complete Mar 01 2nd quarter complete Jun 01 3rd quarter complete Sep 01 4th quarter scheduled Dec 01	Well Completion Report scheduled Nov 01
R-7	LA/Pueblo	Jan 01	1097	3	1st quarter complete June 01 2nd quarter scheduled Oct 01 3rd quarter scheduled Jan 02 4th quarter scheduled Apr 02	Summary Complete
R-5	LA/Pueblo	May 01	902	4	1st quarter 2nd quarter 3rd quarter 4th quarter	

Reporting Schedule

Well Completion Rpts	Due Date
R-25	Oct 01
R-31	Oct 01
R-22	Nov 01
R-7	Feb 02
R-5	Jun 02
MCOBT 4.4	Nov 02
Geochem Rpts	
R-15	Dec 01
R-9/R-9i	Mar 02
R-12	Apr 02

STATUS REPORT FOR GEOCHEMISTRY SUBCOMMITTEE, GROUNDWATER INTEGRATION TEAM

BY

PATRICK LONGMIRE, DALE COUNCE, BRENT NEWMAN,
KELLY BITNER, JENNIFER KOFOED,
DAVID ROGERS, AND DEBORAH STEVEN

OCTOBER 16, 2001

OBJECTIVES OF PRESENTATION

Present a summary of geochemical investigations conducted at Los Alamos National Laboratory and on the Pajarito Plateau since June 2001.

Topics of interest include:

- **Quarterly Groundwater (Characterization) Sampling**
- **Focused Analyte Suites for R Wells**

R-WELL SCREENS, SAMPLING PORT DEPTHS, AND SAMPLING ROUNDS (10/16/01)

- **R-5** — **Four Screens; 169 ft, 375 ft, 678 ft, and 860 ft; 0 Rounds**
- **R-7** — **Three Screens; 378 ft, 744 ft, and 915 ft; 2 Rounds**
- **R-9** — ***Single Screen*; 700 ft; 4 Rounds**
- **R-9I** — **Two Screens; 199 ft and 279 ft; 4 Rounds**
- **R-12** — **Three Screens; 468 ft, 507 ft, and 811 ft; 4 Rounds**
- **R-13** — ***Single Screen*; 940 ft; 0 Rounds**
- **R-15** — ***Single Screen*; 1015 ft; 4 Rounds**
- **R-19** — **Seven Screens; 844 ft (dry), 909 ft, 1190 ft,1412 ft, 1586 ft, 1730 ft, and 1834 ft; 4 Rounds**

R-WELL SCREENS, SAMPLING PORT DEPTHS, AND SAMPLING ROUNDS (10/16/01)

- **R-22** — Five Screens; 906 ft, 962 ft, 1273 ft, 1379 ft, and 1449 ft; 3 Rounds
- **R-25** — Eight Screens; 755 ft, 892 ft, 1063 ft, 1192 ft, 1303 ft, 1406 ft, 1605, and 1796 ft; 3 Rounds
- **R-31** — Five Screens; 439 ft, 515 ft, 666 ft, 827 ft, 1007 ft; 2 Rounds
- **MCO-BT-4.4** — *Single Screen*; 493 ft; 0 Rounds
- **CDV-15** — Six Screens; 624 ft (dry), 806 ft (dry), 980 ft (dry), 1254 ft, 1350 ft, 1640 ft; 3 Rounds
- **CDV-37** — Three Screens; 378 ft, 744 ft, and 915 ft; 0 Rounds

SUMMARY OF CONSTITUENTS OF INTEREST IDENTIFIED AT R-WELLS (01-03/01)

Well	Zone	Sample	Chemical	Concentration
CdV-15	Perched	Well	ND	
CdV-15	Regional	Well	ND	
CDV-37	Perched	Borehole	ND	
CDV-37	Regional	Borehole	ND	
R-9I	Perched	Well	Tritium	246 and 167 pCi/L
R-9	Regional	Well	Tritium	13.73 pCi/L
R-12	Perched	Well	Tritium	189 and111 pCi/L
R-12	Regional	Well	Tritium	64 pCi/L
R-15	Regional	Well	Tritium	2.17 pCi/L
		Well	Sr-90	1.51 mg/L
		Well	Nitrate (N)	2.4 mg/L
		Well	Perchlorate	1.54 μg/L

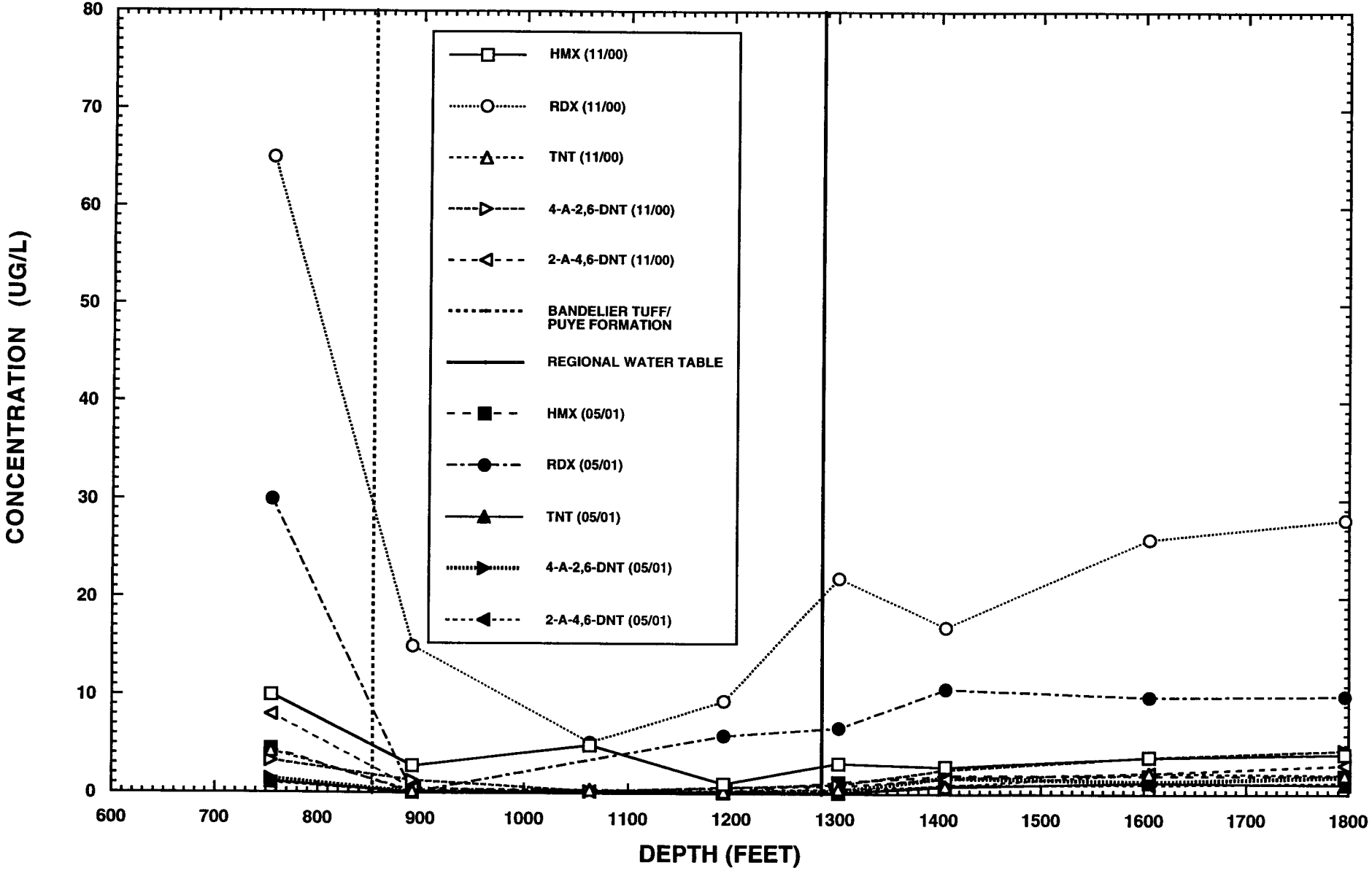
ND means not detected.

SUMMARY OF CONSTITUENTS OF INTEREST IDENTIFIED AT R-WELLS (01-07/01)

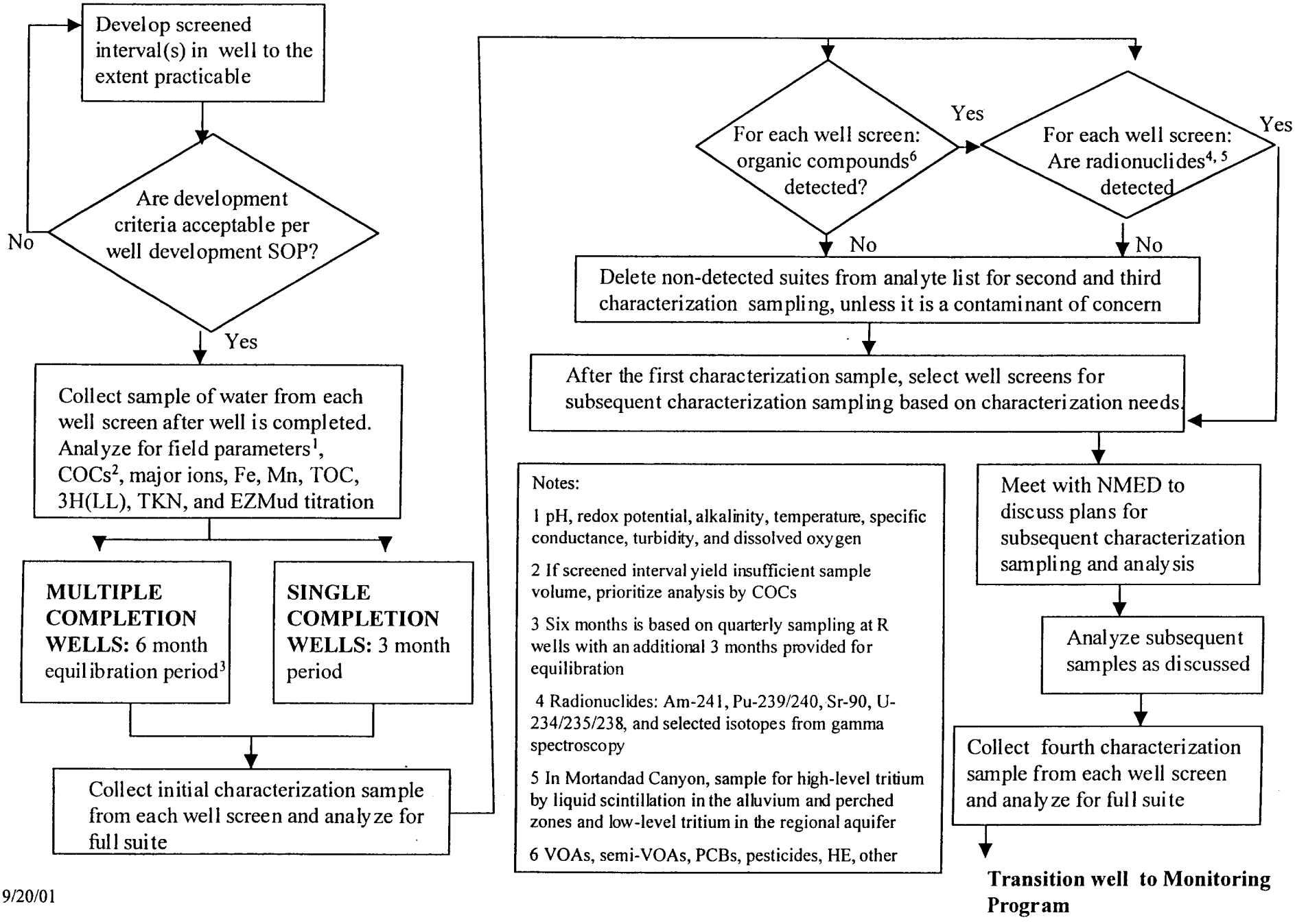
Well	Zone	Sample	Chemical	Concentration
R-19	Perched	Well	ND	
R-19	Regional	Well	ND	
R-22	Regional	Well	Tritium	2.01, 76.6 pCi/L, ND 0.11 and 3.54 pCi/L
			Tc-99	4.9 (3) and 4.3 (5) pCi/L
			U	15.2 (F) and 16 (NF) μg/L
R-25	Perched	Well	Tritium	52.0, 55.2, 38.3 pCi/L
R-25	Perched	Well	HMX, RDX, TNT	4.50, 30, 1.10 μg/L
R-25	Perched	Well	TCE, Toluene	1.4, 3.6 μg/L
R-25	Regional	Well	HMX, RDX, TNT	1.9, 10.7, and 1.2 μg/L
R-25	Regional	Well	Tritium	17.2, 14.4, 10.8, 11.4 pCi/L
MCOBT-4.4, Perched		Borehole	Tritium	2,020 pCi/L
			Nitrate(N)	12.7 mg/L
			Perchlorate	145 μg/L

ND means not detected, (3) means screen number, F means filtered, and NF means non filtered.

PRELIMINARY ANALYTICAL RESULTS FOR HIGH EXPLOSIVE COMPOUNDS AND DEGRADATION PRODUCTS MEASURED AT R-25 (11/00 AND 05/01).



Hydrogeologic Characterization Sampling Strategy



Notes:

1 pH, redox potential, alkalinity, temperature, specific conductance, turbidity, and dissolved oxygen

2 If screened interval yield insufficient sample volume, prioritize analysis by COCs

3 Six months is based on quarterly sampling at R wells with an additional 3 months provided for equilibration

4 Radionuclides: Am-241, Pu-239/240, Sr-90, U-234/235/238, and selected isotopes from gamma spectroscopy

5 In Mortandad Canyon, sample for high-level tritium by liquid scintillation in the alluvium and perched zones and low-level tritium in the regional aquifer

6 VOAs, semi-VOAs, PCBs, pesticides, HE, other

9/20/01

SUMMARY

Geochemistry subcommittee members have collected characterization groundwater samples from R-7, R-9, R-9I, R-12, R-15, R-19, R-22, R-25, and CDV-15. Borehole water samples have been collected from R-13, CDV-37, and MCOBT-4.4.

Constituents of interest in R wells include nitrate (MCOBT-4.4 and R-15), perchlorate (MCOBT-4.4 and R-15), and HE compounds (R-25).

Groundwater with measurable tritium occurs at MCOBT-4.4, R-9, R-9I, R-12, and R-25. These wells contain groundwater less than 60 years of age.

Relevant and meaningful analyte suites, based on well-specific data quality objectives, are proposed for R wells.

SUPPLEMENTAL MATERIAL FOR GEOCHEMISTRY SUBCOMMITTEE

ANALYTICAL METHODS EPA SW846

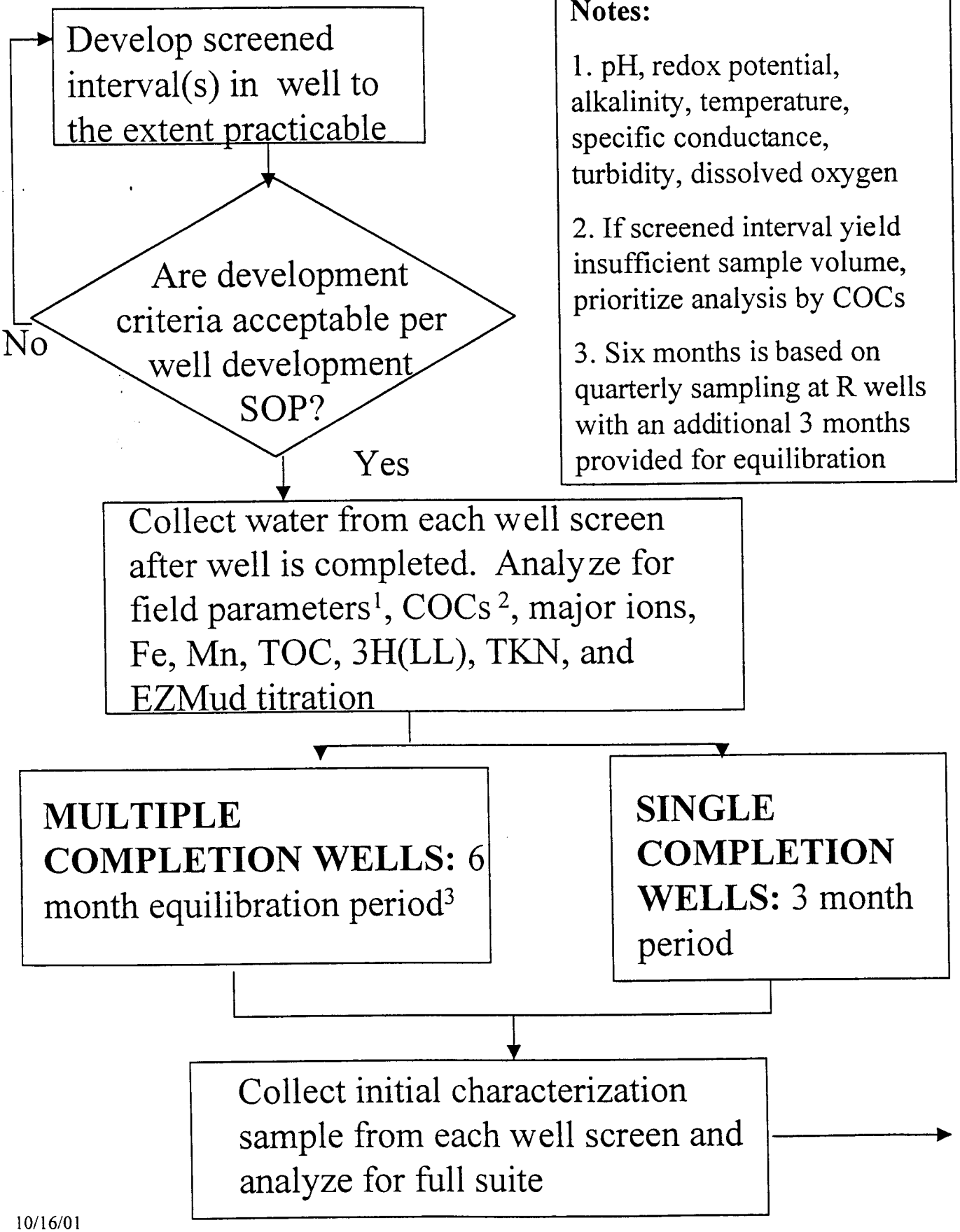
- Metals- Inductively Coupled Plasma Optical Emission Spectroscopy and Inductively Coupled Plasma Mass Spectrometry
- Anions- Ion Chromatography
- Organic Compounds- Gas Chromatography and Gas Chromatography-Mass Spectrometry
- High Explosive Compounds- High Pressure Liquid Chromatography and Diode Array Detector
- Radionuclides- Alpha Spectrometry, Gas Proportional Counting, Gamma Spectroscopy, Direct Counting, Electrolytic Enrichment
- Stable Isotopes- Isotope Ratio Mass Spectrometry

SAMPLING PROTOCOLS AT R-WELLS

- Purge single completed wells, removing at least 3 well bore volumes; measure field parameters; collect; filter; and preserve (if required).

- Collect groundwater samples at multicompleted wells; measure field parameters; filter; and preserve (if required). Groundwater samples are collected using the Westbay Instruments at a rate of four liters per hour (one trip per hour).

Hydrogeologic Characterization Sampling Strategy (1 of 3)

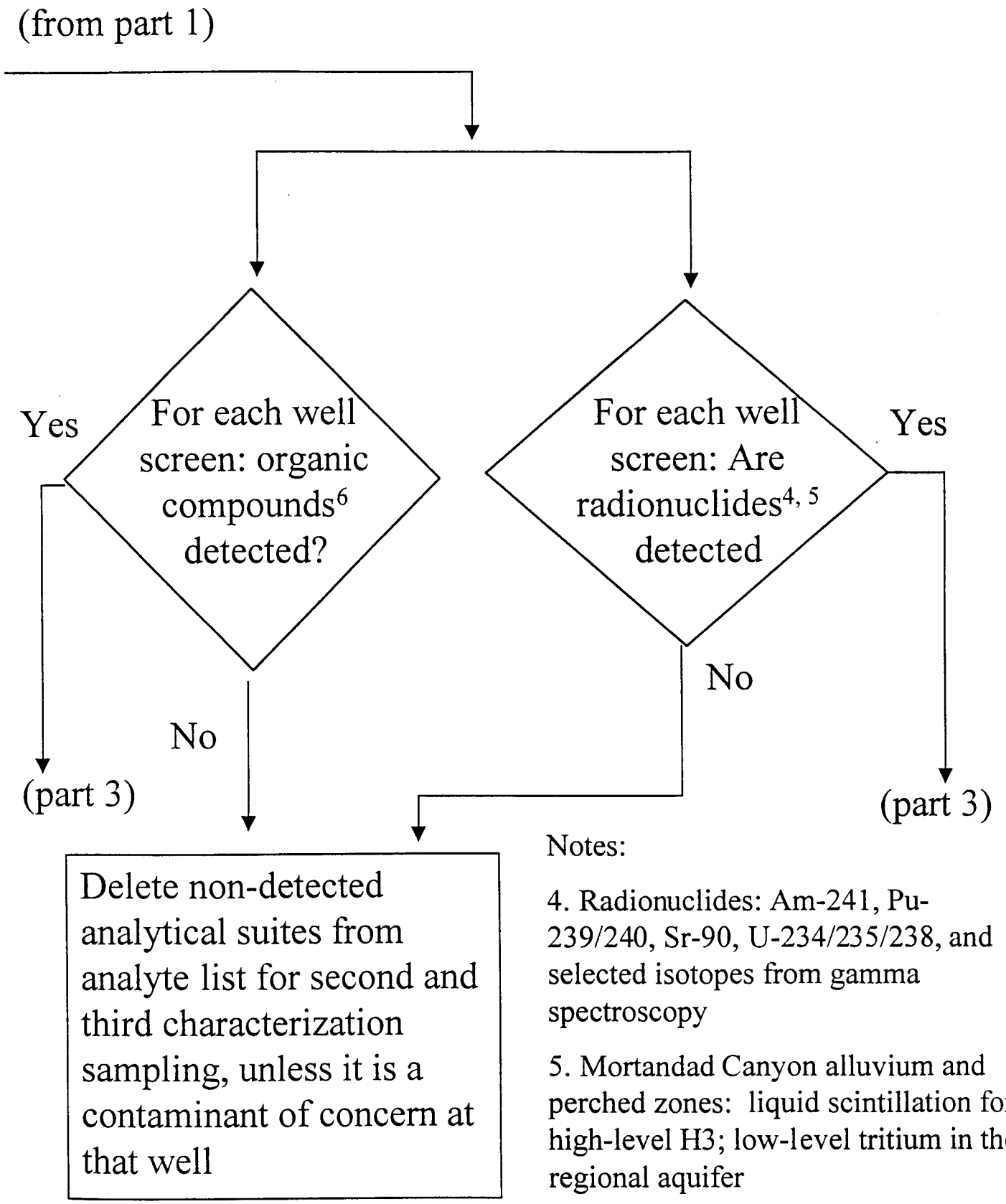


Notes:

1. pH, redox potential, alkalinity, temperature, specific conductance, turbidity, dissolved oxygen
2. If screened interval yield insufficient sample volume, prioritize analysis by COCs
3. Six months is based on quarterly sampling at R wells with an additional 3 months provided for equilibration

10/16/01

Hydrogeologic Characterization Sampling Strategy (2 of 3)



Notes:

4. Radionuclides: Am-241, Pu-239/240, Sr-90, U-234/235/238, and selected isotopes from gamma spectroscopy

5. Mortandad Canyon alluvium and perched zones: liquid scintillation for high-level H3; low-level tritium in the regional aquifer

6. VOAs, semi-VOAs, PCBs, pesticides, HE, other

10/16/01

Hydrogeologic Characterization Sampling Strategy (3 of 3)

(from part 2)

↓

After the first characterization sample, select well screens for subsequent characterization sampling based on characterization needs.

↓

Meet with NMED to discuss plans for subsequent characterization sampling and analysis.

↓

Analyze subsequent samples as discussed.

↓

Collect fourth characterization sample from each well screen and analyze for full suite.

↓

Transition well to Monitoring Program

Full Suite Analysis

- **Radionuclides** (non filtered)
  - Low-level tritium (non filtered)
  - Strontium-90
  - Uranium and plutonium isotopes
  - Americium-241
  - Gross alpha, beta, gamma
  - Gamma spectroscopy

Full Suite Analysis

- **Metals (non-filtered)**
  - ICPOES analysis: Al, Ba, B, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, SiO_2, Ag, Sr, Na, V, and Zn.
  - ICPMS analysis: Sb, Be, Cd, Tl, and U.
  - CVAA analysis: Hg
- **General Inorganics (filtered and non-filtered)**
  - Alkalinity (HCO_3^- and CO_3^{2-}), Br^-, PO_4^{3-}, HN_4^+, Cl^-, F^-, TKN, NO_3^-, NO_2^-, $C_2O_4^{2-}$, ClO_4^-, and SO_4^{2-}

Full Suite Analysis

- **Organic Compounds** (non-filtered)
  - Volatiles
  - Semivolatiles (PCBs [only in Sandia Canyon and around Area G], PAHs, pesticides)
  - Select Appendix VIII and IX constituents
  - High explosive compounds and degradation products
  - Total Organic Carbon
  - Dissolved Organic Carbon fractionation

ANALYTES FOR R-WELL HYDROGEOLOGIC CHARACTERIZATION SAMPLING

Radionuclides (Filtered and Non Filtered Samples)

Low-level tritium (non filtered only), strontium-90, uranium and plutonium isotopes, americium-241, gross α, β, and γ, and gamma spectroscopy.

Inorganic Constituents (Filtered and Non Filtered Samples)

Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, SiO_2, Ag, Sr, Na, Tl, U, V, and Zn (Sb, Be, Cd, Tl, and U are analyzed by ICPMS, others by ICPOES, Hg by CVAA).

Alkalinity (HCO_3^- and CO_3^{2-}), Br^-, PO_4^{3-}, HN_4^+, Cl^-, F^-, TKN, NO_3^-, NO_2^-, $C_2O_4^{2-}$, ClO_4^-, and SO_4^{2-}

Field Parameters

pH, redox couples (measured and calculated), Eh (flow through cell), temperature, specific conductance, turbidity, dissolved oxygen (in line sampling).

Organic Compounds (Non Filtered Samples)

Volatile, semivolatile (PCBs, PAHs, Pesticides), select Appendix VIII and IX constituents, high explosive compounds and degradation products, TOC, and Dissolved Organic Carbon (DOC) fractionation.

Stable Isotopes (Non Filtered Samples)

δDeuterium, δ^{15}Nitrogen, δ^{13}Carbon (special cases), and δ^{18}Oxygen.

Analyte list is subject to change depending on site-specific contaminants and data quality objectives for each well.

Sampling Strategy from R-Wells

Prioritize sampling in Westbay-completed wells (for purposes of hydrogeologic characterization, all sampling ports in each well may not be sampled on a repetitive basis after initial sampling).

Analyze for inorganic constituents at each R Well on a quarterly basis for FY2001.

If organic compounds (VOCs, SVOCs, and HE Compounds) are not detected in the initial groundwater samples, then they will not be analyzed in any subsequent characterization sampling. Selected analytes, including those from Appendix VIII and IX, may be sampled on subsequent characterization pursuant to the specific "constituents of concern" for the R Well.

If radionuclides (Am-241, Pu-238, Pu-239/240, Sr-90, and selected isotopes from gamma spectroscopy) are not initially detected (activity is < MDA and/or < $\pm 3\sigma$), then they will not be analyzed in subsequent characterization sampling. Uranium isotopes are the exception due to natural occurrence (analyze for both dissolved and total isotopic U). Continue to analyze for total (non-filtered) gross α, β, and γ after initial sampling to evaluate presence of total radionuclides (Am-241, Cs-137, Pu-238, Pu-239,240, Sr-90, and selected gamma-emitting isotopes).

Analyze for low-level tritium (direct counting or electrolytic enrichment) only on non-filtered samples. In Mortandad Canyon, sample for high-level tritium by liquid scintillation in the alluvium and perched zones and low-level tritium in the regional aquifer.

Continue to perform quarterly sampling at each R Well in FY2001, following the recommendations provided above. For FY2002, revise sampling frequency.

EZMUD CHEMISTRY

EZMUD consists of a long-chain polymer containing many functional groups, which include polyacrylamide/polyacrylate (PHPA) copolymer and hydrocarbon molecules.

Some molecules tentatively identified in EZMUD include undecane ($C_{11}H_{24}$), 2,6-dimethyl-undecane ($C_{13}H_{28}$), 2-methyl-decane ($C_{11}H_{24}$), tridecane ($C_{13}H_{28}$), and tetradecane ($C_{14}H_{30}$).

EZMUD adsorbs onto aquifer material to enhance borehole stability.

EZMUD has a negative charge density of 30% (0.3 mol per mol of polymer), which enhances the polymer's ability to adsorb cations.

EZMUD is strongly hydrophobic (high molecular weight polymer), which probably has the ability to partition organic compounds such as RDX, HMX, and TNT.

The nitrogen functional groups in EZMUD mimic nitro (NO_2-) and amino (NH_2-) functional groups present in high explosive (HE) compounds and associated degradation products. False positives have been reported for HE compounds and degradation products in the wells.

EZMUD has a low aqueous solubility under near-neutral pH conditions. Nitric acid (pH1), sulfuric acid (pH1), and sodium hypochlorite (bleach) (oxidizing agent, electron acceptor) can be used to break down EZMUD.

Aggressive well development helps to dissociate EZMUD without adding additional chemicals to the well.

CONCEPTUAL REACTION MODEL OF EZ MUD OXIDATION AT R-22

anaerobic microbes + iron(III) + sulfate + EZ Mud (organic substrate) $\rightarrow$

iron(II) + hydrogen sulfide + alkalinity

Reduction Reactions (anaerobic conditions)

iron(III) solids reduce to iron(II) aqueous species

sulfate reduces to hydrogen sulfide

Oxidation Reaction

EZ Mud (C-H-O-N copolymer) $\rightarrow$ inorganic carbon ($H_2CO_3^0$ and HCO_3^-)

R WELL EQUILIBRATION TIME BASED ON SULFATE REDUCTION (09/20/01)

R Well	Screen(s)	Completion Date	Sampling Date	Sulfate Concentration	Equilibration Time (mo)
R-7	3	02/01	05/30/01	<1 mg/L	>3
R-12	1	01/00	03/14/01	<1 mg/L	>15
R-19	5 and 6	04/00	04/03-05/01	<1 mg/L	>12
R-22	1, 2, 4, and 5	11/00	06/19-25/01	<1 mg/L	>7

SELECTED SOLUTE CHEMISTRY OF R-22 (SCREEN 5 - 1,449 FT)

	Borehole (11/11/00)	Completed Well (Sampling Dates) (03/06/01)	(06/26/01)
Alkalinity (mg/L $CaCO_3$)	86.1	150	150
Chloride (mg/L)	3.47	4.2	2.70
Fluoride (mg/L)	0.40	0.41	0.35
Sulfate (mg/L)	8.66	<1	<1
Iron (mg/L)	-	4.3	2.1
TOC (mgC/L)	-	13	6.1

Turbidity: 3.1 NTU; pH: 7.01; Temperature: 19.0 C for 03/06/01.
Turbidity: 3.6 NTU; pH: 6.90; Temperature: 22.7C for 06/26/01.

SELECTED SOLUTE CHEMISTRY OF R-22 (SCREEN 5 - 1,449 FT)

	Completed Well (03/06/01)	
TKN (mg/L)	1.9	
DOC (mgC/L)	8.4	
Hydrophobics-total (mgC/L)	5.8	
Acids		4.3
Neutrals		1.5
Bases		0
Hydrophilics-total (mgC/L)		2.5
Acids		1.4
Neutrals		0.6
Bases		0.5

Turbidity: 3.1 NTU; pH: 7.01; Temperature: 19.0 C

LANL GIT Action Plan for June 2001 EAG Recommendations

Recommendation 6-01-19: Avoid the expense of devoting the cost of an entire R well for the sole purpose of acquiring hydraulic data.

The EAG states that reliable hydraulic conductivity data can not be achieved by locating and R well close to a municipal well and conducting a pumping test in the municipal well and using the R well for observation. At least two observation wells are necessary to achieve reliable and independent enhancement of hydraulic conductivity estimates; however, the cost of investing in two observation wells for this sole purpose is prohibitive.

Proposed Action 6-01-19:

At present, no wells are planned with the singular purpose of obtaining hydrologic information.

QUARTERLY REPORT ON HYDROLOGY
W. Stone, October 2001

WELLS

MCOBT-4.4
Development incomplete due to pump problems; last turbidity = 56 NTU.

Appropriate pump has been selected.

Final development/testing (if possible) will occur when pump obtained.

MCOBT-8.5
Basalt dry; well abandoned.

CdV-R-37-2
Completed well development.

Conducted straddle-packer/slug-injection tests on bottom two screens (results not analyzed yet).

R-13
Before construction, composite water-level stabilized at 833 ft BGS with 208 ft of open hole (casing to 850 ft; TD = 1058)

Construction was just completed; not developed or tested yet.

Well Reports
Prepared hydrology and well-development sections for well-completion reports for R-22 and R-31.

Revised hydrology and well-development sections for well-completion reports for R-25 and CdV-R-15-3.

GENERAL

Some things were also accomplished that are not related to a specific well:

Drafted a report on the hydrologic testing to date.

Advised on the content and format of modules for well construction, development and testing in ER's database.

Made an inquiry to Baski Inc. about the availability of systems for pumping water from between packers; received quote and got authorization to order.

GIT Modeling Subcommittee Report

Bruce Robinson
Elizabeth Keating
Kay Birdsell
Marc Witkowski
Diana Hollis

October 16, 2001

Modeling Subcommittee Activities

- Participation in DQO Meetings
- Los Alamos Canyon Model
  - Sensitivity study using alternate conceptual model for alluvial groundwater
- Regional Aquifer Model
- First Order Groundwater Assessment

Regional Aquifer Model: Recent Activities

- Further development of facies models for Puye and Santa Fe Group: integrating geostatistical models with water level data from R-wells, using 2-D cross-section models.
- Uncertainty analysis, focusing on how much flow might be entering/leaving the regional aquifer from the north, west, and south?
- Incorporation of recent water level data from R-wells, resulting in much better estimates of large-scale permeability of the Puye Formation.
- Travel time calculations and capture zone analyses in support of First order GW Assessment Project
- Particle tracking simulations in support of "Using a Probabilistic Model of Flowpaths in the Regional Aquifer to Site Surveillance Wells on the Pajarito Plateau" - asking the question, can the results of a 3-D process-level model be distilled into a more simple probabilistic model: preliminary answer: no

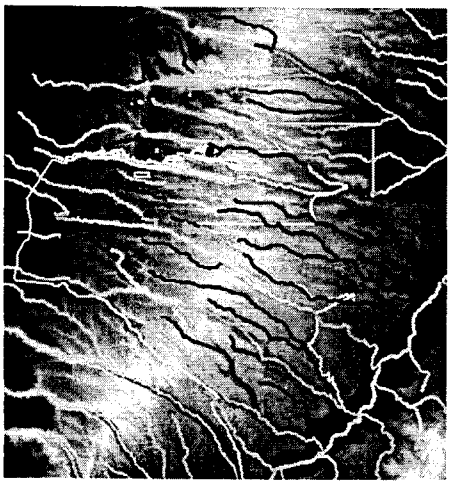
First Order Groundwater Pathway Assessment

- Goal: rank contaminants of potential risk-significance to groundwater receptors on a site-wide basis
- Approach: Use GIS tools to synthesize information from contaminant sources and hydrogeologic data to assess transport times and pathways. Components of the analysis include:
  - Percolation rates
  - Vadose Zone flow and transport
  - Regional Aquifer flow and transport
  - Contaminant sources

First Order Groundwater Pathway Assessment: Technical Approach

- Percolation Rates
  - Categorize canyon drainages with respect to observable properties (location of headwaters, presence of alluvial GW, etc.), assign percolation rates based on other modeling and data collection efforts
- Vadose zone flow and transport
  - Construct simple vertical pathway model locally at a large number of locations across the Plateau, compute vadose zone travel time to the water table at each location
- Regional aquifer flow and transport
  - Use regional aquifer model to track pathways from municipal water supply wells back to the water source, identifying locations where recharging fluids might contain Laboratory contaminants
- Contaminant sources
  - Outline source term areas for key contaminants based on Water Quality Database entries for the alluvial, intermediate, and regional aquifer wells

Percolation Indices for Canyon Drainages



Legend

- Percolation Index 1
- Percolation Index 2
- Percolation Index 3
- Percolation Index 4
- Percolation Index 5
- Percolation outside AOI
- Lab Boundary

Digital Elevation Model

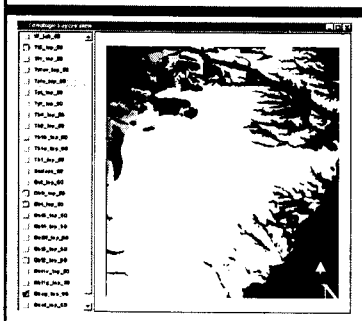
High: 9870 ft

Low: 5350 ft

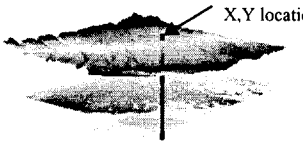
N W E S

Preliminary results

GIS Log Tool for Determining Local Hydrostratigraphy



Geologic layer information stored as Arc/Info grids are loaded via the lithologic log tool into a viewing window within ArcView. The user then selects the appropriate lithologic tool and clicks on a location, within the domain of the geologic model, and a table describing the elevations of all geologic layers encountered is generated.

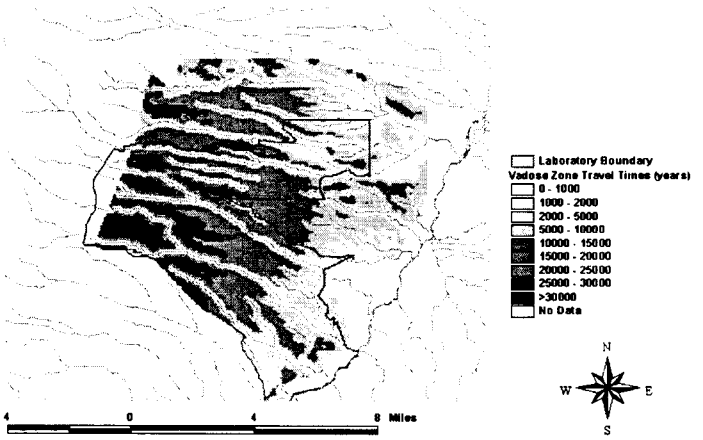


X,Y location selected

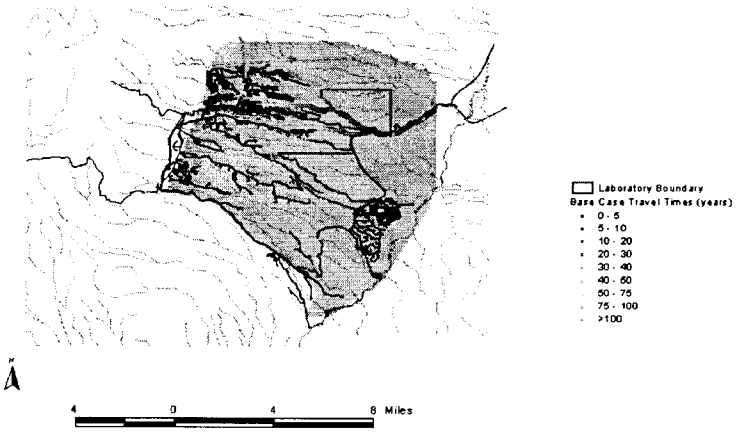
Figure shows three geologic layers and how they are intersected in three dimensional space by a point selected at the surface.

This table is used as input to the groundwater models.

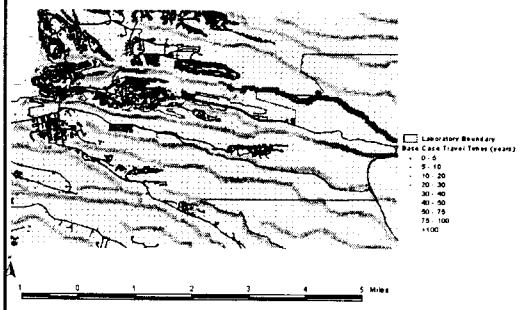
Vadose Zone Travel Times: Full Scale



Vadose Zone Travel Times: Rapid Canyon Percolation



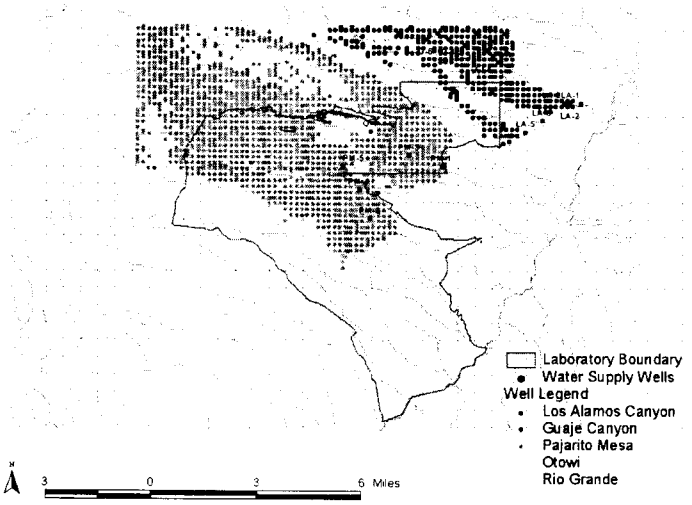
Vadose Zone Travel Times: Impact of Percolation Rate



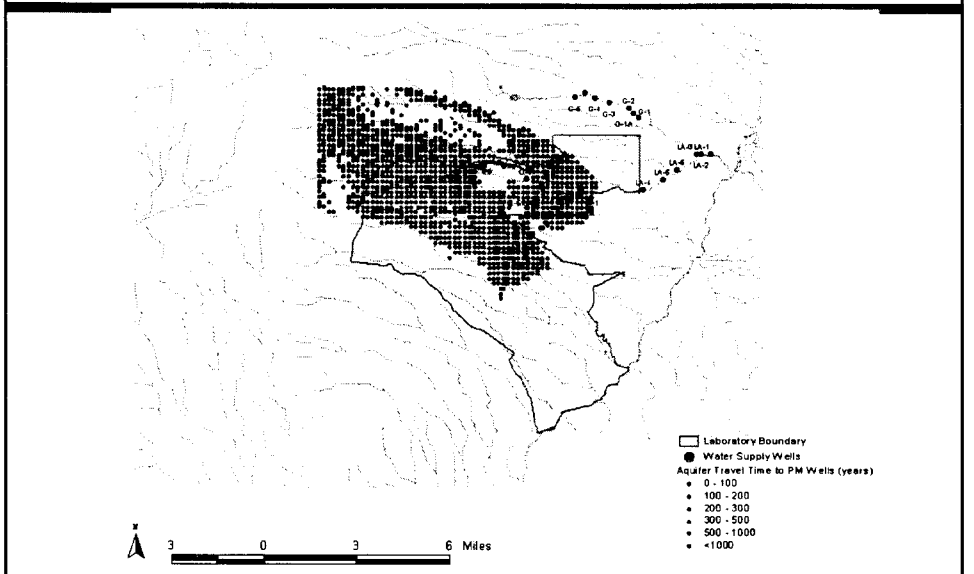
Base Case Percolation Scenario

High Flux Percolation Scenario

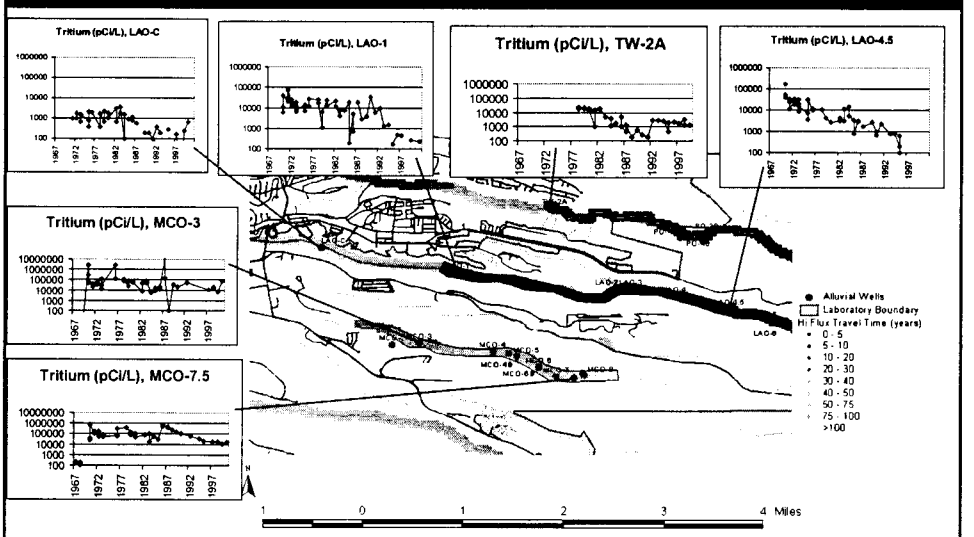
Regional Aquifer Source Locations for Water Reaching Water Supply Wells



Regional Aquifer Travel Times to PM Wells



Zones of Past Tritium Contamination in Alluvial Groundwater



Review of LANL Hydrogeologic Characterization Program FY01

Charles Nylander
Program Manager
ESH-18

Performance Review Outline

- Program Description
- Regulatory Framework
- FY01 Accomplishments and Issues
- FY01 Budget Performance
- FY02 Proposed Budget

Program Description

- **Goal:** Develop a refined understanding of the hydrogeologic setting adequate to implement detection monitoring or groundwater monitoring waivers
- **Scope:** described in the Hydrogeologic Workplan:
  - **32 regional aquifer wells; 51 alluvial wells**
  - **Data management/stakeholder data access**
  - **Hydrologic modeling**

Regulatory Framework

- **1990 EPA/NMED RCRA Operating Permit:** Task III, Section A.1 requires evaluations of hydrogeologic conditions
- **1995 GWPMP**: recognize groundwater issues due to inadequate characterization
- **1995 NMED letters**: inadequate characterization and denial of groundwater monitoring waiver

FY01 Accomplishments

Field-Based Activities

- Completed 3 Hydrogeologic Workplan wells (R-22, R-7, R-5) and 3 investigation wells (MCOBT-8.5 and -4.4 and CdV-R-37-2)
- Started drilling 2 Hydrogeologic Workplan wells (R-13, R-8)

FY01 Accomplishments (cont.)

Field-Based Activities (cont.)

- Conducted 4 rounds of quarterly sampling at R-15, R-9, R-12, R-9i, R-19
- Drilling program completed FY01 with positive schedule and cost variances to include baseline change proposals reflecting drilling program efficiencies

FY01 Accomplishments (cont.)

Analytical Activities

- Initiated study of Buckman well field to evaluate potential for Laboratory impacts
- Held several meetings with NMED to provide detailed information about modeling
- Compiled and analyzed well log information and outcrop data to develop numerous geostatistical formulations of the Puye Formation

FY01 Accomplishments (cont.)

Analytical Activities (cont.)

- Integrated water level data from R wells into regional flow model calibration process
- Evaluated uncertainty in flow directions in western portion of LANL -- water level data near R-25 was determined to be extremely important
- Conducted uncertainty analysis on lateral fluxes to aquifer beneath LANL

FY01 Accomplishments (cont.)

Information Management

- Completed the migration of stream flow data (25 stations 1994-2000) into WQDB
- WQDB used to produce annual Environmental Surveillance Report
- Completed chain of custody and sample tracking system features

FY01 Accomplishments (cont.)

Information Management (cont.)

- Improved automatic loading of lab chemistry data into WQDB with new parser
- Completed migration of 30+ years of ESH-18 analytical chemistry data
- Implemented advanced chemistry data screening tool comparing new results to historical averages

FY01 Accomplishments (cont.)

Information Management (cont.)

- Well construction database design completed
- ER-ESH data exchange pilot project underway

FY01 Accomplishments (cont.)

QA and Reports

- Published Well Completion Reports for R-9, R-9i, R-12, R-15, R-19
- Completed peer review drafts of Well Completion Reports for R-25, R-31
- Drilling program peer review conducted by Schlumberger

FY01 Accomplishments (cont.)

QA and Reports (cont.)

- External Advisory Group (EAG) reviewed sampling SOPs
- Prepared and presented technical papers for the National Groundwater Association conference

FY01 Accomplishments (cont.)

QA and Reports (cont.)

- Supported Value Engineering study, IG investigation, and internal audit
- Commented on NMED low flow sampling position paper

FY01 Accomplishments (cont.)

Project Management

- Completed negotiations with Prime Contractor to submit and perform against its own Quality Management Plan
- Completed construction and implementation of the DP-funded well drilling baseline
- Supported Laboratory efforts to conclude the unallowable cost issue for R-25

FY01 Accomplishments (cont.)

Project Management (cont.)

- Conducted iteration of groundwater characterization DQO process to assure the project remains on track
- Hosted a portion of NM Bureau of Mines Decision Makers tour
- Held GIT bi-weekly meetings, 3 quarterly meetings, and the Annual Meeting

Issues

- Analytical Strategy
- Well Development
- Unallowable Costs
- Value Engineering Study
- Data Turnaround and Transfer to Regulators
- Budget

Issue: Analytical Strategy

- Determining when samples are representative
- Frequency of analytical suites on subsequent samples
- Analysis for dissolved and total constituents
- Analytical methods

Analytical Strategy Issue Resolution

- Developed analytical strategy that features:
  - -- an initial sample when the well is completed to be analyzed for geochemical parameters indicative of impacts of drilling fluids and contaminants of concern
  - -- equilibration period for multiple completion wells
  - -- full suite analysis of samples collected after the equilibration period

Analytical Strategy Issue Resolution (cont.)

- Developed analytical strategy that features (cont.):
  - -- with NMED input, option to delete suites not detected in full suite analysis if not contaminants of concern for subsequent sampling events
  - -- final characterization sample has full suite analysis
- Analytical strategy discussed with NMED and revised per NMED comments and submitted for NMED approval

Issue: Well Development

- Well development has not been completely effective at removing drilling additives
- Equipment limitations have hampered the well development process such that screened intervals could not be isolated and pumped
- Impacts of incomplete well development have included false positives for acetone and HE, and perturbations of the geochemical system

Well Development Issue Resolution

- Well development SOPs are followed and development continues until the water reaches $\leq$5 NTU (acceptable under EPA's Technical Enforcement Guidance Document)
- Packer system with pump above the isolated interval has been specified for procurement for well development

Well Development Issue Resolution (cont.)

- Groundwater samples are analyzed for parameters indicative of drilling additive influences to evaluate potential effects on water chemistry
- Single completion wells are purged prior to sampling until field parameters indicate groundwater is representative

Issue: R-25 Unallowable Costs

- Additional time and expense to repair screens 3 and 9 and to recover well from "dropped tremie pipe" incident has been challenged by DOE as an unallowable cost
- The Laboratory has been required to submit information to DOE explaining and justifying the additional costs
- DOE is still considering further action regarding the potential unallowable costs

R-25 Unallowable Costs Issue Resolution

- DOE must weigh the facts and explanations provided by the Laboratory to determine if they will take further action regarding unallowable costs
- The Laboratory has continued to prepare for the administrative/judicial actions on the part of DOE

Issue: Value Engineering Study

- DOE/AL requested a Value Engineering (VE) study of the Hydrogeologic Characterization Program
- The VE Team were on-site for 4 days and were provided an orientation briefing, field trip to well site, and access to individuals for interviews

Issue: Value Engineering Study (cont.)

- The Draft VE Report contained factual errors and the specific recommendations appear to be based on misunderstanding of regulatory requirements and objectives of the program
- The VE recommendations, if published unrevised, potentially could disrupt funding, stakeholder relations, and result in noncompliance with environmental operating permits

Value Engineering Study Issue Resolution

- Comments on the Draft Report submitted to DOE recommending significant revisions
- Resolution pending DOE action

Issue: Data Turnaround and Transfer to Regulators

- ERDB is not fully functional and capable of electronic data transfers
- Efforts required to comply with data request from NMED created a backlog of data to be processed (validated and approved for release) and confounded continuing progress on electronic data transfer

Issue: Data Turnaround and Transfer to Regulators (cont.)

- Groundwater data from characterization sampling was caught in the data backlog
- Groundwater data could not be transmitted to NMED in a timely manner

Data Turnaround and Transfer to Regulators Issue Resolution

- Most groundwater data caught in the backlog have been transmitted to NMED
- The backup in data processing is not expected to occur again
- ER Project has placed high priority on making ERDB fully operational

Issue: Budget

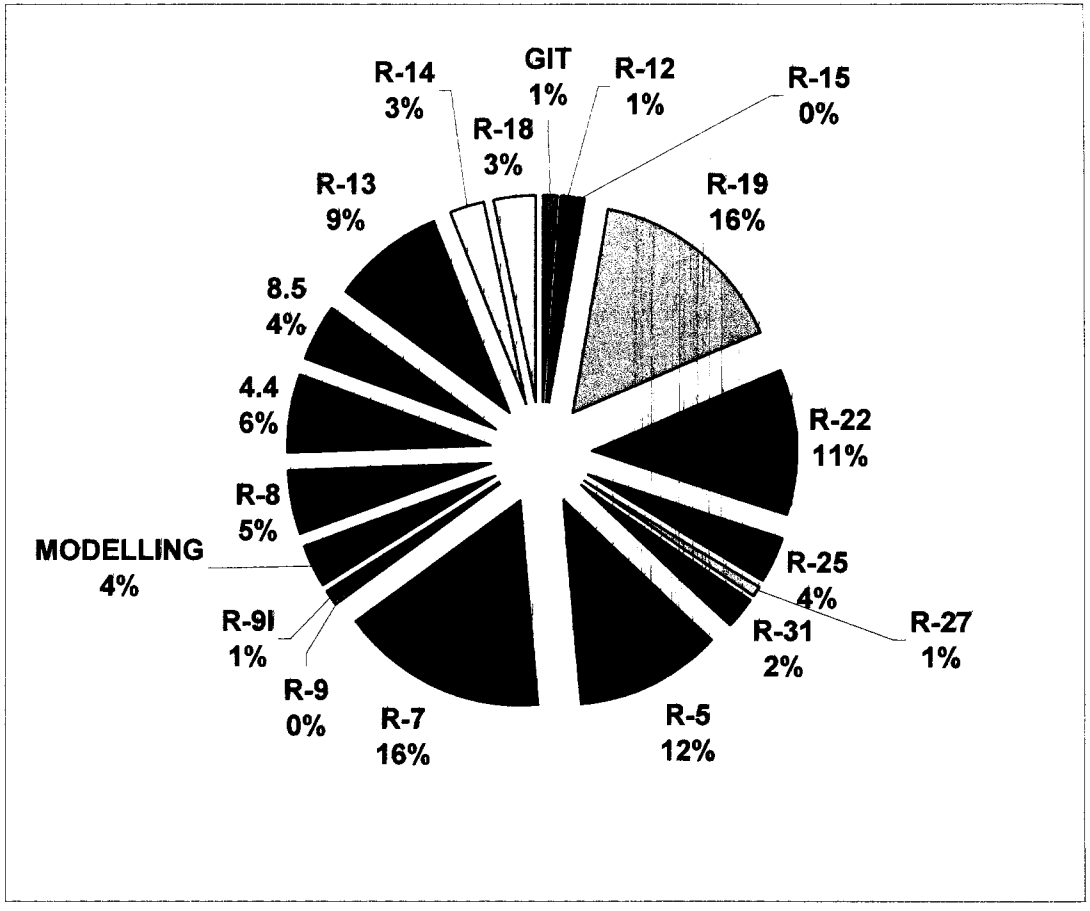
- Funding from DP has been inadequate to maintain the schedule of the Hydrogeologic Workplan
- Request for increased funding was submitted to the Readiness in Technical Base Facilities (RTBF) to allow drilling and installation of 3 DP-funded wells per year

Budget Issue Resolution

- Response from RTBF for FY02/FY03 budget pending
- Continue to work to decrease cost of well drilling and installation

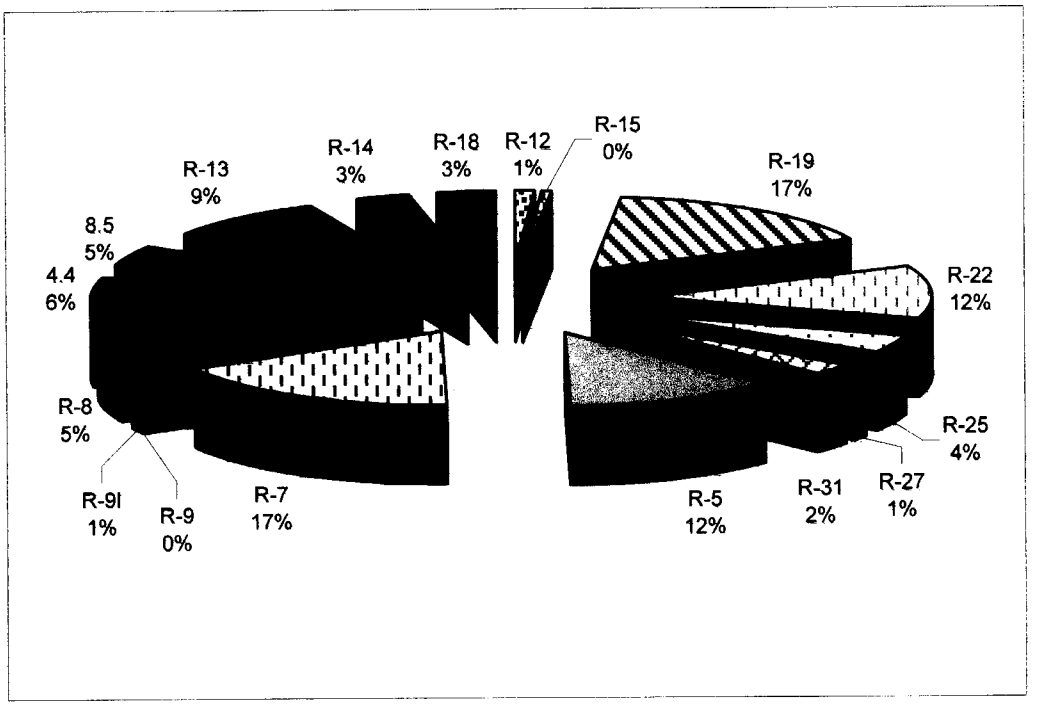
FY 01 DP and ER FUNDED WELLS COSTS

ACTIVITY/WELL	DP FUNDED	ER FUNDED	FY 01 TOTAL
DEFAULT	$126,598		$126,598
GIT	$126,843		$126,843
R-12		$115,900	$115,900
R-15	$9,207	$39,202	$48,409
R-19		$1,623,337	$1,623,337
R-22		$1,166,153	$1,166,153
R-25	$386,591		$386,591
R-27		$91,381	$91,381
R-31	$242,167		$242,167
R-5	$1,217,512		$1,217,512
R-7		$1,675,205	$1,675,205
R-9		$29,991	$29,991
R-9I		$87,523	$87,523
MODELLING	$365,006		$365,006
R-8	$498,624		$498,624
4.4		$634,775	$634,775
8.5		$457,914	$457,914
R-13		$926,763	$926,763
R-14	$288,525		$288,525
R-18	$330,775		$330,775
Grand Total	**$3,591,847**	**$6,848,143**	**$10,439,990**



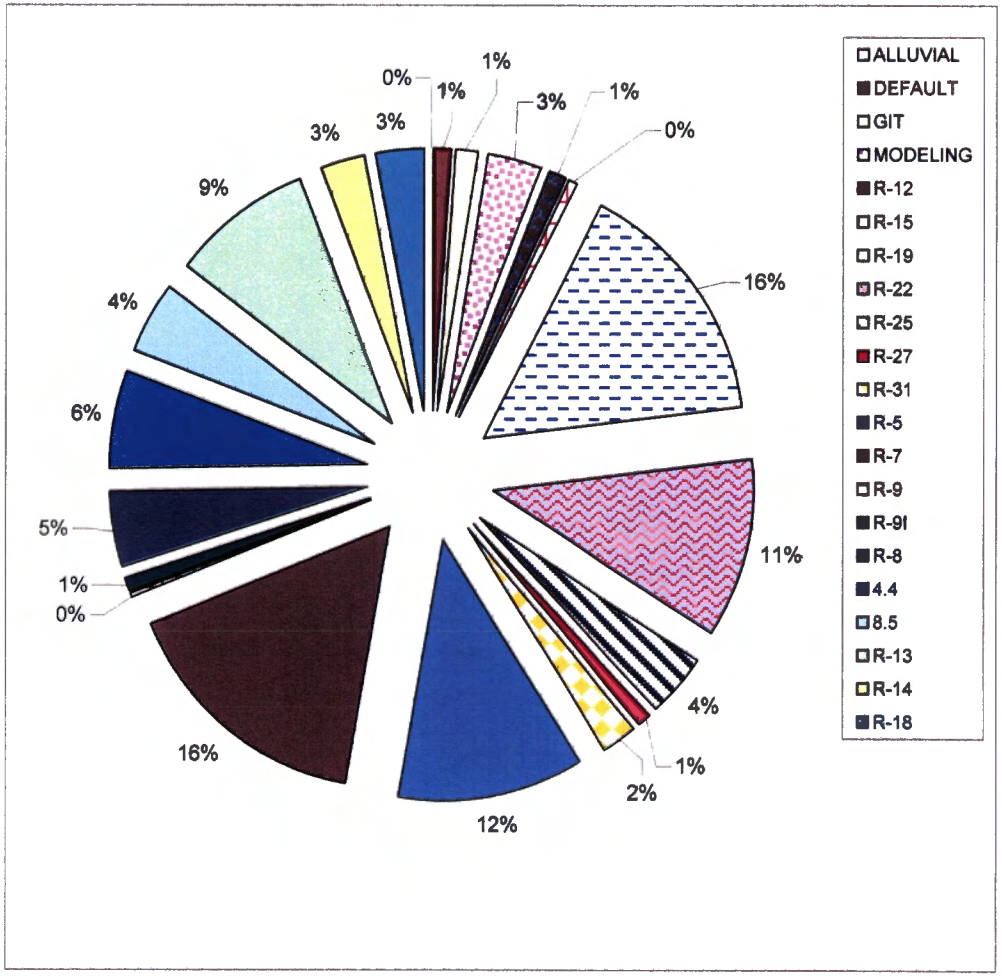
FY 01 DP and ER FUNDED WELLS

WELL	COST
R-12	115,900
R-15	48,409
R-19	1,623,337
R-22	1,166,153
R-25	386,591
R-27	91,381
R-31	242,167
R-5	1,217,512
R-7	1,675,205
R-9	29,991
R-9I	87,523
R-8	498,624
4.4	634,775
8.5	457,914
R-13	926,763
R-14	288,525
R-18	330,775
TOTAL	9,821,543



TOTAL COST OF PROGRAM - FY 97-01

FY COST	FY				
WELL/ACTIVITY	FY 97/98	FY 99	FY 00	FY 01	Grand Total
ALLUVIAL	3,231,000	372,747			3,603,747
DEFAULT	8,185	-3,931	-17,113	126,598	113,740
GIT	38,825	26,507	37,240	126,843	229,415
MODELING	254,923	268,017	314,072	365,006	1,202,018
R-12		234,659	1,129,031	115,900	1,479,589
R-15	21,000	1,141,431	415,926	48,409	1,626,766
R-19			2,717,391	1,623,337	4,340,728
R-22			724,535	1,166,153	1,890,688
R-25	1,181,907	2,879,351	587,212	386,591	5,035,060
R-27			12,672	91,381	104,053
R-31		119,612	1,766,118	242,167	2,127,897
R-5		3,635	21,809	1,217,512	1,242,956
R-7			331,139	1,675,205	2,006,344
R-9		85,033	455,692	29,991	570,717
R-9I			277,683	87,523	365,206
R-8				498,624	498,624
4.4				634,775	634,775
8.5				457,914	457,914
R-13				926,763	926,763
R-14				288,525	288,525
R-18				330,775	330,775
Grand Total	4,735,840	5,127,062	8,773,408	10,439,990	29,076,299



Integrated Risk-Based Decision Strategy for Groundwater Protection and Monitoring

Presented by
Diana Hollis (LANL ER)

October 16, 2001

What's Being Integrated?

- EM/ER & NNSA/ESH missions
- RCRA "Operations" and Corrective-Action groundwater protection objectives
- DOE ESH and LTES groundwater protection objectives
- EPA and DOE risk-based decision-making guidance
- Multiple potentially-interacting sources of groundwater contamination
- Protection from past, present and future releases

October 16, 2001

Why is it Needed?

- Traditional RCRA Corrective Action Process *alone* neither efficient nor effective for LANL groundwater protection
  - Applies only to RCRA-regulated constituents
  - Conducted on a site-by-site basis
  - Considers a time horizon of less than 100 years
  - Does not consider cumulative impacts of releases from multiple sources

October 16, 2001

Why is it Needed?

- Integrated *risk-based* decision-making process
  - Applies to both RCRA-regulated constituents and radionuclides
  - Is conducted on a site-wide basis
  - Considers a time horizon of 1000 years
  - Considers cumulative impacts from multiple sources

October 16, 2001

What's risk-based decision-making?

"A process that uses risk assessment and exposure methodology to make determinations about the extent and urgency of remediation actions."

- EPA OSWER Directive 9610.17

October 16, 2001

What's risk-based decision-making?

"An iterative streamlining process that uses a tiered approach and site classifications to screen and address sites based on relative risk ."

- ASTM
E 1793-95

October 16, 2001

What's risk-based decision-making?

- The focus is on gathering data necessary to make sound technical decisions
- Data collection is based on explicit identification of decision inputs

October 16, 2001

What's risk-based decision-making?

- Key steps
  - Identify potential problem and performance standards
  - Conduct initial site assessment
  - Identify likely actions that may be taken based on the initial site assessment
  - Develop DQOs to determine what information is necessary and sufficient to evaluate effectiveness of likely actions in context of performance standards
  - Obtain needed information (empirical or interpretive)
  - Iterate on data collection, interpretation and actions until performance standards are met

October 16, 2001

How do we do it?

- Establish integrated site-wide, all-sources performance standards for groundwater
  - source control (e.g., reduction, removal, treatment, stabilization)
  - MCLs, ACLs, dose limits, etc.
  - ***final risk goal*** (i.e, the level of protection to be achieved and maintained by LANL, the locations where protection must be ensured, the time frame during which the final risk goal must be demonstrated, and the level of confidence that must be demonstrated)

October 16, 2001

How do we do it?

- Identify likely actions and remedies (end-states) intended to meet performance standards, including
  - source removals and source reductions
  - water use restrictions on LANL property
  - vadose-zone monitoring
  - perched aquifer monitoring
  - regional groundwater monitoring network

October 16, 2001

How do we do it?

- Develop integrated data quality objectives based on performance standards and anticipated end-state
  - identify decisions for which the outcome affects the ability to meet the performance standards
  - develop decision rules to determine necessary and sufficient information to demonstrate the efficacy of anticipated end-state in meeting the performance standards

October 16, 2001

How do we do it?

- Apply decision rules to existing information (data and models) to determine specific additional information needed to "prove" efficacy of anticipated end-state
- Conduct screening assessment to identify sources that may affect ability to meet performance standards under, using
  - ER "nature and extent" data
  - quarterly groundwater sampling data
  - simple groundwater contaminant transport models

October 16, 2001

How do we do it?

- Use screening assessment to group sources or contaminants that are
  - high priority due to likelihood of exceeding performance standards "soon"
  - medium priority due to likelihood of exceeding performance standards "later"
  - low priority due to unlikelihood of exceeding performance standards "ever"

October 16, 2001

How do we do it?

- Conduct cumulative groundwater impacts assessment for high- and/or medium-priority sources
  - model contaminant migration through vadose zone and regional aquifer to anticipated monitoring wells
  - evaluate and interpret results in context of performance standards; if performance standards exceeded,
    - conduct sensitivity and value-of-information analyses to decide what information (e.g., field data or model revision) or action (e.g., additional source reduction or revised end-state) is needed to ensure compliance
    - collect information or conduct action
  - iterate until performance standards are met

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How do we do it?

- Update data and simulation model(s) as Hydrogeologic Work Plan and "surface" corrective actions proceed
- Iterate until an end-state (including a groundwater monitoring network) is established to ensure that performance standards are met

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When can we start?

- Now!
  - "Core Team" to establish performance standards
  - Groundwater pathway assessment model ready for screening assessment application
  - Canyon, mesa and regional aquifer models ready for cumulative impacts assessment application
  - Probability model ready to optimize site-wide monitoring well network
  - 3-D geologic data model ready for integrating new R-Well data for simulation model iterations
  - ERDB ready for "quick and easy" source identification

October 16, 2001

Current Geologic Components in Appendix 4 of the Hydrogeologic Workplan: *DQO Process Outputs (Data Needs)*

- Unit hydraulic properties
- Pathways of contaminant transport
- Identification and hydrologic properties of faults (fault zones)
- Identification and hydrologic properties of fracture zones
- Redox potential (Bandelier Tuff)
- K_ds for Sr, Cs, U, Pu, Am, Np (RDX and products? ClO_4?)

(I) Updates for the 3-D Geologic Model: 1) **Structure**

- Incorporation of new mapping (Seismic Hazards, Frijoles Quadrangle; example of Seismic Hazards data in next image).
- Structure beneath the LANL site is still poorly known.
- A new digital elevation model is available for analysis of fine-scale structures.
- Surface geophysical studies may help.

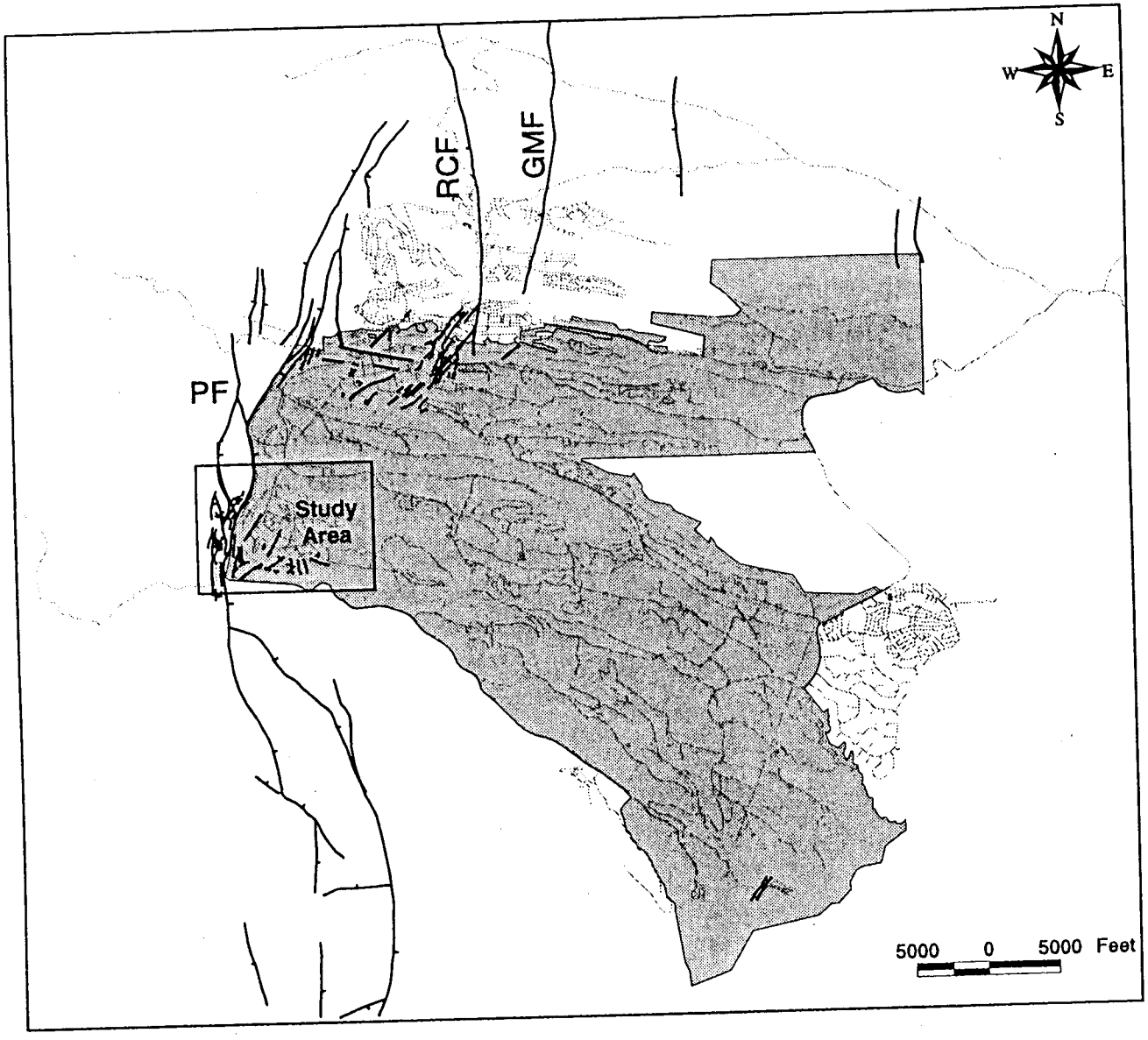
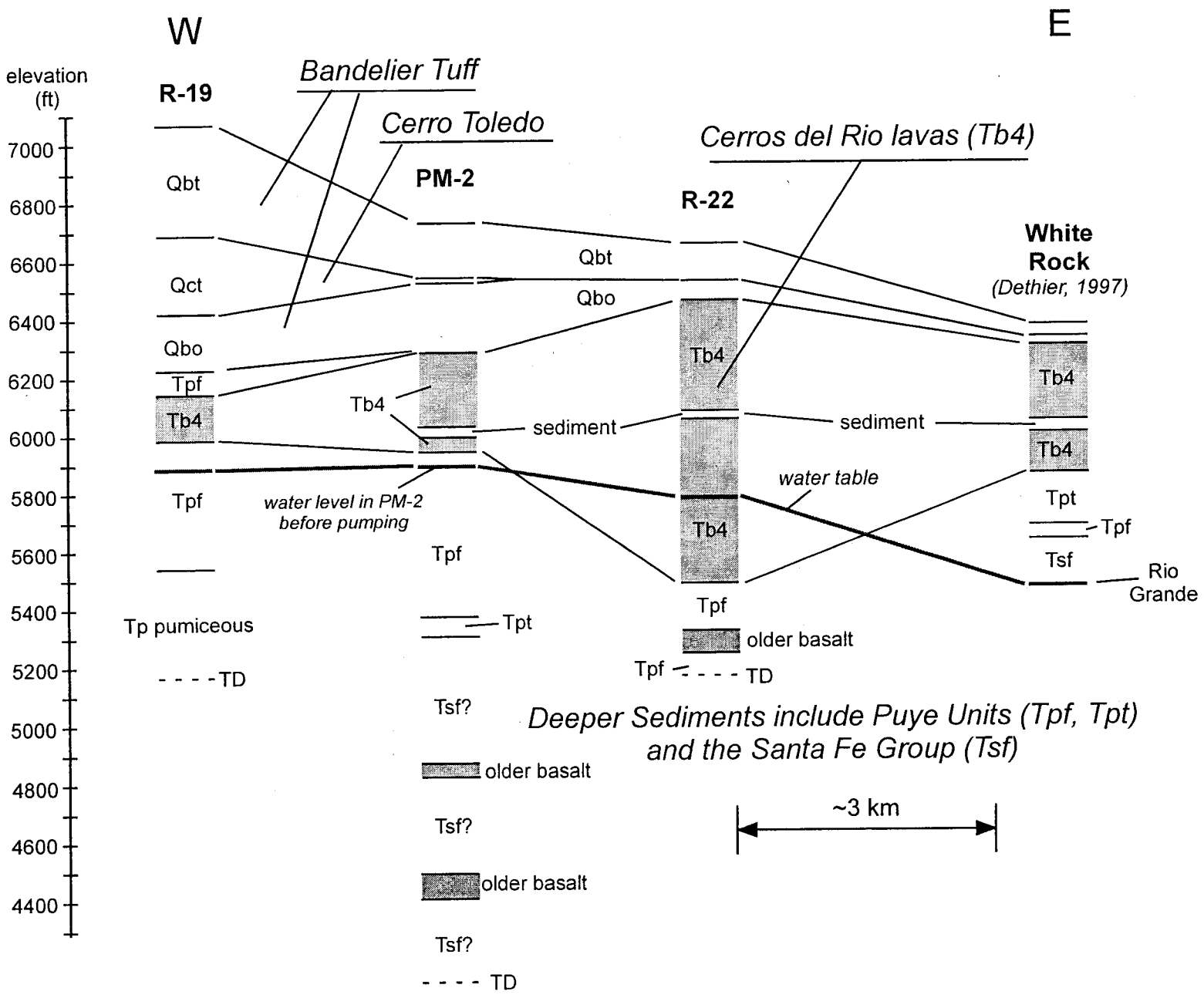


Figure 2. Map showing the study area and the main elements of the Pajarito fault system in the vicinity of Los Alamos National Laboratory. LANL is shaded gray. PF = Pajarito fault; RCF = Rendija Canyon fault; GMF = Guaje Mountain fault. Structure in the northwest portion of LANL from Gardner et al. (1999), and structure in the area between that study and this study is unmapped.

(from Gardner et al., 2001, LA-13831-MS)

(I) Updates for the 3-D Geologic Model: 2) Stratigraphy

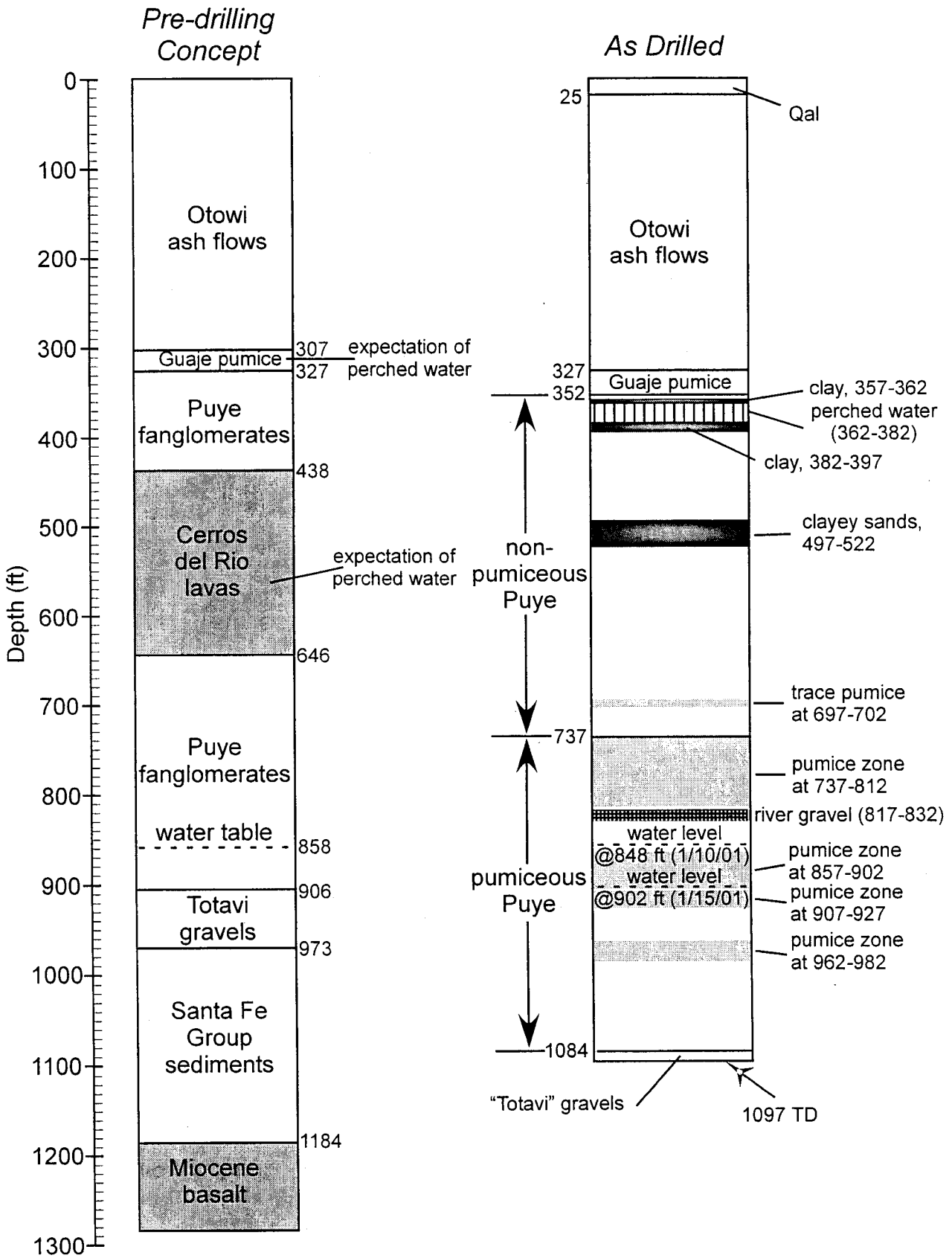
- **Tuff:** The upper Bandelier (Tshirege) is well known; the Cerro Toledo unexpectedly thick in some areas and the Otowi is correspondingly thinner. Alteration in the Otowi, especially beneath canyons, is poorly known.
- **Lavas:** Where does the Cerros del Rio end and the Tschicoma begin? Cerros del Rio unexpectedly thick in some areas, containing more of the regional hydrologic system than anticipated (example cross-section in next image).


W
E
elevation (ft)
7000
6800
6600
6400
6200
6000
5800
5600
5400
5200
5000
4800
4600
4400
R-19
Bandelier Tuff
Cerro Toledo
PM-2
Cerros del Rio lavas (Tb4)
R-22
White Rock
(Dethier, 1997)
Qbt
Qct
Qbo
Tpf
Tb4
Tp pumiceous
- - - - TD
Tb4
water level in PM-2 before pumping
Tpf
Tpt
Tsf?
older basalt
Tsf?
older basalt
Tsf?
- - - - TD
Qbt
Qbo
sediment
Tb4
Tb4
Tpf
older basalt
Tpf - - - - TD
sediment
water table
Tb4
Tb4
Tpt
Tpf
Tsf
Rio Grande
Deeper Sediments include Puye Units (Tpf, Tpt) and the Santa Fe Group (Tsf)
~3 km

(I) Updates for the 3-D Geologic Model:
2) Stratigraphy (cont.)

- **Sediments:** Puye sediments divisible into new subunits (upper section linked to known pumice-poor sources; lower section with yet unknown sources that produced abundant pumice - example from R-7 in next image). Santa Fe Group sediments are less prevalent than previously thought.

R-7: New Views of Puye Stratigraphy

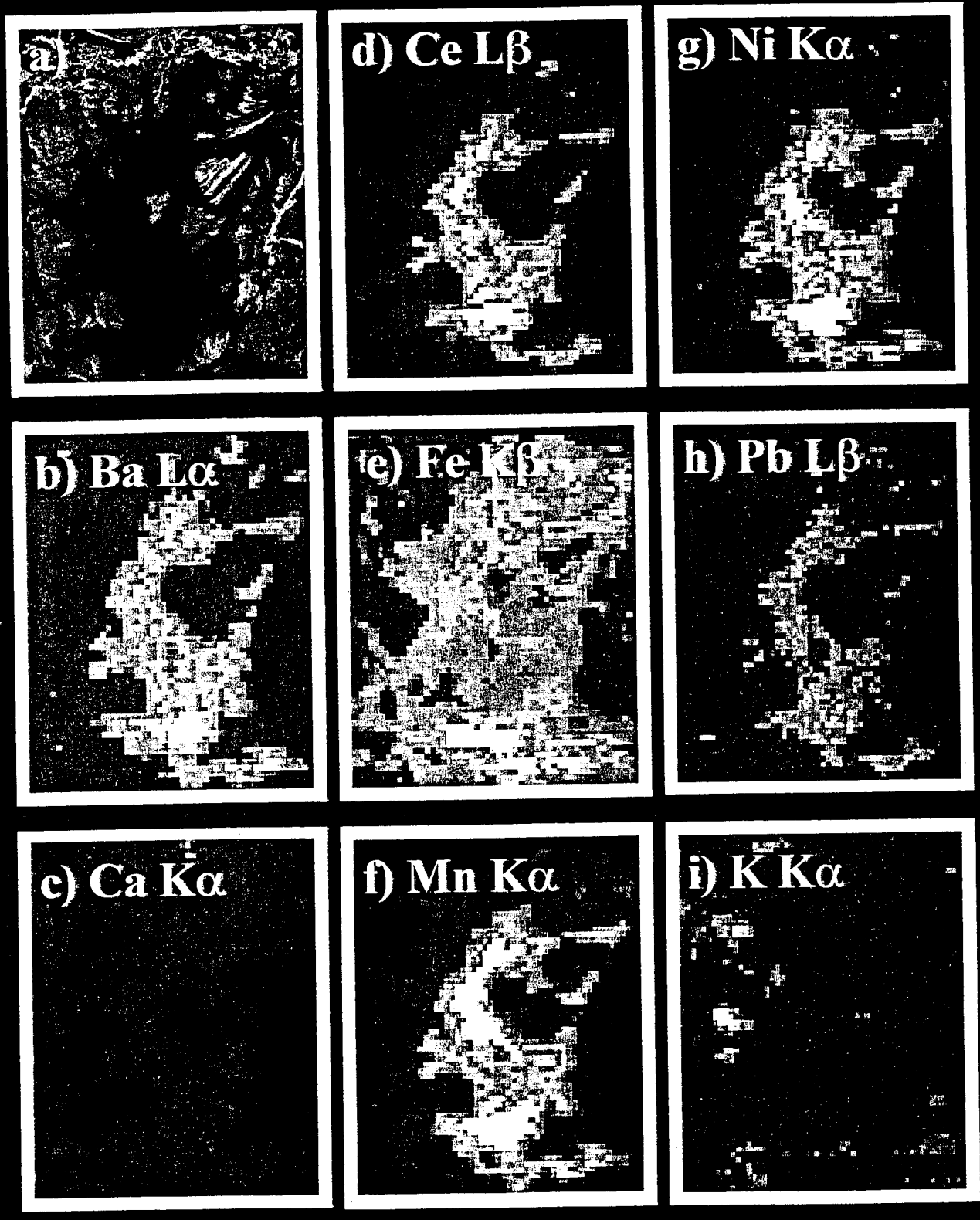


(II) Other Aspects: Alteration and Contaminant Systems

- The northeastern portion of the LANL site is probably underlain by a fossil hydrothermal system with associated clay, carbonate, and zeolite alteration (reassessment of O-1 and preliminary data from R-5).
- This system is still poorly characterized. Possible impacts include (1) nature of reactive transport and (2) anomalous geochemistry that may be reflected in groundwater chemistry (*e.g.*, host rocks of Ba, Mn-rich alteration vs. unaltered siliceous glass).

(III) Other Aspects: Pathways and Mechanisms of Movement

- Reactive translocation of clays (colloid and particulate carrier systems) is observable in the near-surface; does this occur at depth?
- Redox accumulation of heavy metals may be focused at oxide-mineral surfaces, especially Mn-oxides (example of Mn-oxide at Pajarito Mesa in next image).
- How does groundwater chemistry differ between different host rocks? What are the systematic differences and are they significant?


a)
d) Ce Lβ
g) Ni Kα
b) Ba Lα
e) Fe Kβ
h) Pb Lβ
c) Ca Kα
f) Mn Kα
i) K Kα

Previous image: A photomicrograph (a) of a Mn-oxide (dark) in clay from a fracture in the Bandelier Tuff at Pajarito Mesa and coregistered synchrotron micro-XRF elemental images of (b) Ba, (c) Ca, (d) Ce, (e) Fe, (f) Mn, (g) Ni, (h) Pb and (i) K. The dimensions of each image are 500 x 600 μm; analytical points within this area were obtained with an 8 x 13 μm beam.

(IV) Evaluation of Data Needs for the Geologic System

- What has to be done to meet the need to understand "basic geology, hydrogeology, and pathways for contaminant transport" (NMED, 1995)?
- Increase the accuracy and relevance of the 3D Geologic Model in defining structure and lithology.
- What are the relations between lithology and permeability? Does lithology play a role in flow (vadose zone and regional aquifer)?
- What role does lithology play in reactive transport?

(IV) Evaluation of Data Needs for the Geologic System (cont.)

- What role does lithology play in groundwater chemistry (cation composition, phase saturation, Eh, and colloid formation in particular)?
- Fill the holes in the drilling program (surface geophysics, field work).
- Evaluate the geologic accuracy of borehole sampling (examples: compare core and cuttings as at R-8 and compare outcrop data with borehole data).
- Do what needs to be done to avoid surprises (example: alteration systems of anomalous geochemistry superimposed on primary stratigraphy).

DQO Iteration Overview

Geochemistry

P. Longmire

October 16, 2001

DQO Iteration Overview
Vadose Zone Hydrology/Modeling

October 16, 2001

Bruce Robinson

Objectives of Vadose Zone Characterization

- **Pathways:** need to obtain sufficient understanding of the pathways in the vadose zone
- **Percolation:** need to know the spatial distribution of downward water percolation from the mesa tops and alluvial groundwater
- **Travel Times:** need to estimate travel times to regional aquifer
- **Contaminant Fate:** need to predict the fate of key contaminants of concern within the vadose zone

Pathways - What We Know

- **One-dimensional, downward migration under unsaturated conditions**
- **Lateral diversion beneath regions of high infiltration where low-permeability barriers restrict downward percolation**
  - **alluvial groundwater**
  - **within Basalts and Puye formation**
  - **within Tshirege member at TA-16**

Pathways - What We Know

- Rapid lateral transport over kilometer distances
  - tracer test in Mortandad canyon
  - tritium transport in Los Alamos and Mortandad Canyons
- Rapid lateral diversion to canyons within the mesa at TA-16
  - tracer tests, geochemical monitoring
- Transport in intermediate perched zones is uncertain
  - Velocity?
  - Direction?

Pathways - What we don't know

- Velocity in intermediate perched zones
  - Bathtub model (flow delay)
  - lateral diversion model - porous medium flow
  - lateral diversion model - fast-path flow
- Direction is controlled by:
  - Dip of unit on which perching occurs
  - Dip of local permeability features not present in geologic model

* Bottom line: although intermediate perched zones provide an opportunity to collect water samples and thus obtain contaminant concentration values, it will be very difficult to collect enough data to map out the paths and predict transport velocity with precision

Pathways - A Path Forward

- Incorporate perched water representation into vadose zone models, capturing the extremes of behavior
- Perform site-wide analysis of potential flow path directions based on geologic model and simple conceptual models of lateral diversion. Test against available data.
- Determine whether uncertainties in lateral transport significantly affect the prediction of the location of contaminant arrival at the water table
- Bracket the travel times to the water table by:
  - 1D travel times from surface to regional aquifer (largest time)
  - 1D travel time to perched zone only, short-circuit to water table after that (shortest time)

Vadose Zone Travel Times: Conclusion from Sensitivity Analyses

Taking into account uncertainties in the water budget and the hydrologic properties, the available data are consistent with percolation rates ranging of a factor of 3 above and below the base case estimate.

Do we need to do better? Can we do better?

Vadose Zone Travel Time - A Simple Calculation

Matrix flow and transport through 100 m of Bandelier Tuff

Undisturbed, Dry Mesa	Wet Canyon Bottom
Perc. rate: 1 mm/y (0.001 m/y)	Perc. rate: 500 mm/y (0.5 m/y)
Water content = 0.1	Water content = 0.25
transport velocity = 0.001/0.1 = 0.01 m/y	transport velocity = 0.5/0.25 = 2 m/y
travel time = 100/0.01 = 10,000 y	travel time = 100/2 = 50 y
Uncertainty range: 3,000 to 30,000 y	Uncertainty range: 15 to 150 y
Do we need to do better? No (close enough)	Do we need to do better? Yes (decisions may depend on the value)

Reducing Uncertainty in Travel Time

- **Geologic Model Uncertainty**
  - **Estimate uncertainties**
  - **Continue to update geologic model with new data**
  - **Focus on uncertainties that matter to travel time**
- **Uncertainty in Migration Rate**
  - **Water budget studies**
  - **Infiltration monitoring sites**
  - **Shallow boreholes to measure water contents *and* the migration of chemical fronts**

Tritium Transport Model Validation

- Tritium not found in aquifer upstream from LA-DP confluence (R-7)
- Downstream observations (TW-3, R-9, O-1) are due to thinning of Bandelier Tuff and inputs from DP canyon surface water. Pueblo Canyon source contributes also.
  - Prediction: Tritium will be found at the water table in R-8 at levels on the order of 1000 pCi/l
- Model qualitatively reproduces the observed behavior. Quantitative matching of concentrations is not possible for the following reasons:
  - lack of resolution of model and sparse data
  - heterogeneities
  - uncertainty in the mixing process in the regional aquifer

Role of the R-Wells in Vadose Zone Characterization

- Geologic model is more refined
- Moisture content and contaminant front data have been very useful, but
  - There is merit in considering a separate set of shallow holes for moisture and contaminant measurements selected to reduce uncertainty in flux and travel time at specific locations
- Further characterization of the intermediate groundwater to determine flow directions and velocity within the perched zones may not be warranted
- Since chemical samples from the regional aquifer reflect the transport characteristics of the vadose zone, they are an effective means for validating vadose zone models

Conclusions

- Current state of knowledge: moisture content measurements and water budgets can only reduce uncertainty in travel times to about one order of magnitude
- Joint inversion of moisture content and contaminant front data can reduce this uncertainty
- More shallow wells would be better than a few deep wells for estimating percolation rates and travel times
- By focusing on contaminants in the regional aquifer, the R-Well drilling program provides important constraints on vadose zone travel times
- Bounding approaches for handling the intermediate groundwater are needed to overcome the difficulty of characterizing the nature of flow in these water-bearing zones

DQO Iteration

Data needs for regional aquifer hydrology

Hydrology and Modeling Subcommittees

Hydrogeologic Characterization Program
Quarterly Meeting
October 16-18, 2001

Goals:

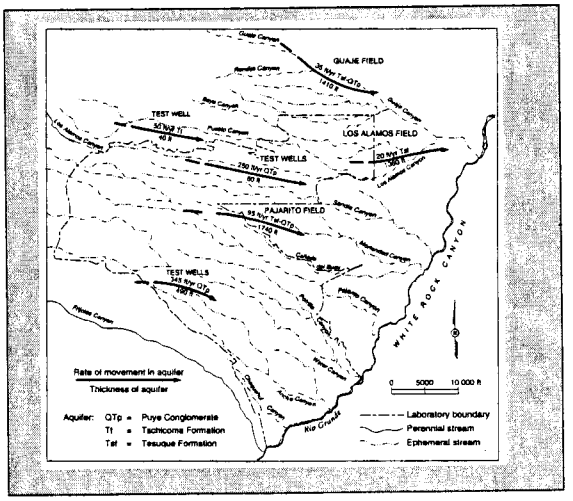
Basic characterization

To design monitoring well network

To provide DOE & stakeholders reasonable predictions of contaminant migration

Groundwater **flow directions** and **velocities**,

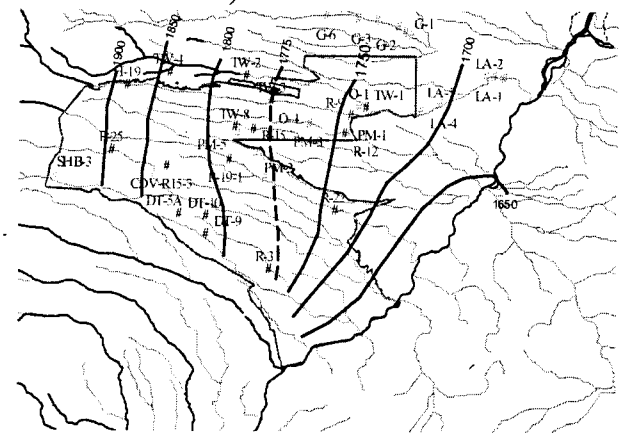
including influence of pumping (present and future)

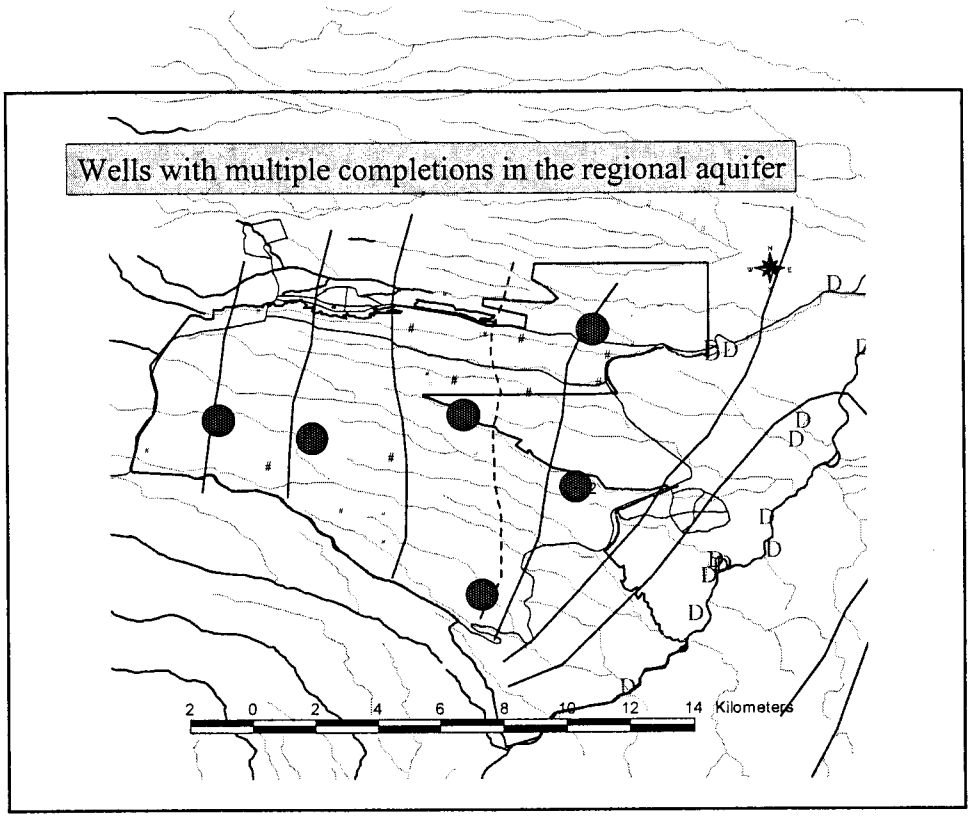


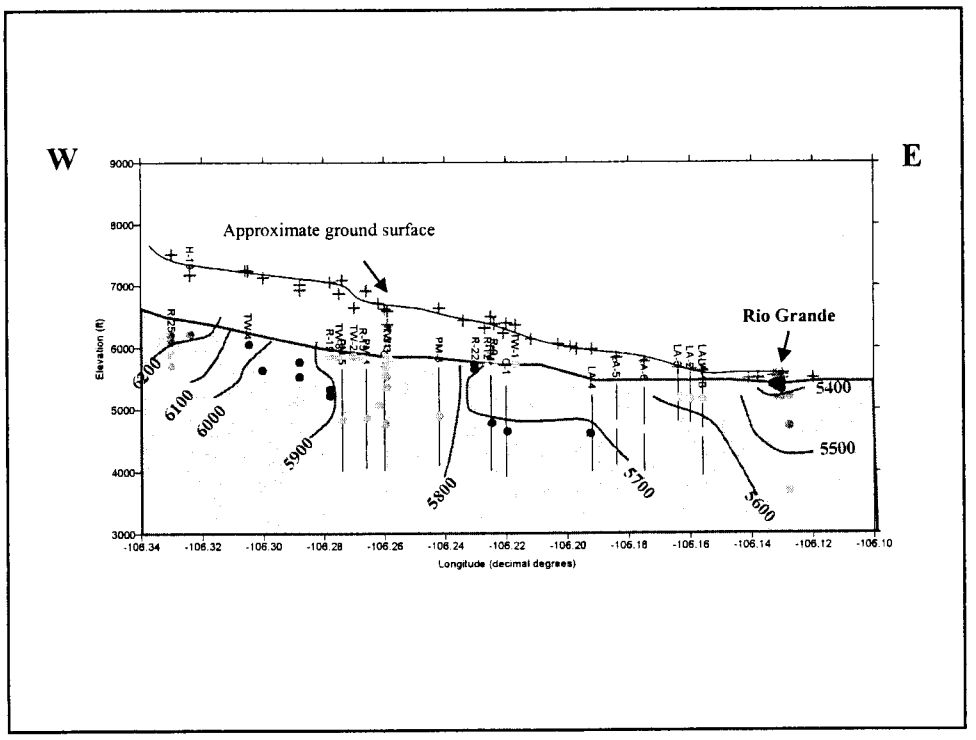
Flow directions

- Head data
- Permeability structure (3-D geologic model)
- Permeability data (hydraulic tests)
- Geochemical tracers

Heads in wells completed in upper portion regional aquifer
(Contour interval = 50m)




Wells with multiple completions in the regional aquifer
2 0 2 4 6 8 10 12 14 Kilometers


W
E
Approximate ground surface
Rio Grande
6200
6100
6000
5900
5800
5700
5600
5500
5400
Elevation (ft)
Longitude (decimal degrees)

Summary, Data Needs

Water levels

1. Vertical gradient information is lacking in northwestern portion of LANL

2. Spatial coverage is reasonable for estimating plateau-scale flow directions

3. *Looking ahead to monitoring:* deeper wells may be necessary to detect contamination upgradient of supply wells; spinner log information could be very useful

Aquifer Permeability

- What is the range of measured permeabilities in the aquifer?

- What permeability values are assumed in the flow and transport models?

- What type of information is necessary to better define

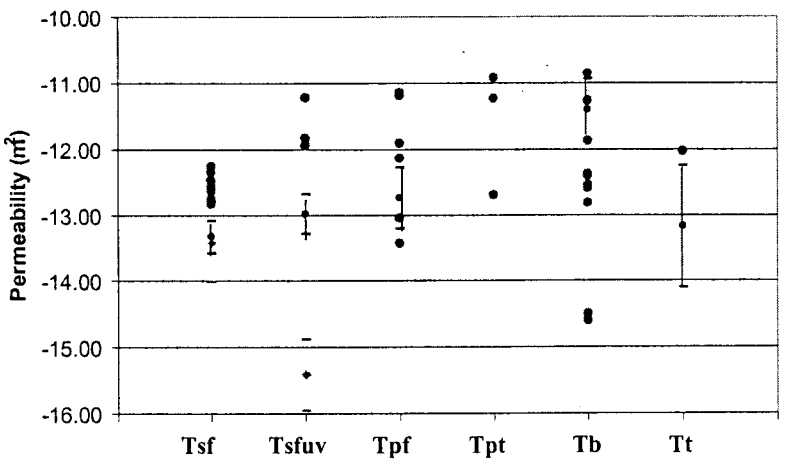
  a) aquifer permeability
  b) how low & high permeability zones are distributed spatially? (geologic controls)

Why do we care?

1. Permeability variations will control flow paths (water seeks higher permeability zones)

2. Travel times are linearly proportional to permeability

Permeability estimates derived from single hole tests



Large-scale permeability
(relation between permeability and stratigraphy)

a) "average" permeability of sedimentary rocks varies only slightly

b) effective permeability of Santa Fe group rocks is lower than single-hole pump tests estimates (faulting?)

Data need:

Larger-scale (multi-hole) pump tests to determine effective permeability of Santa Fe Group rocks

Water level data across Pajarito fault zone

Small-scale permeability

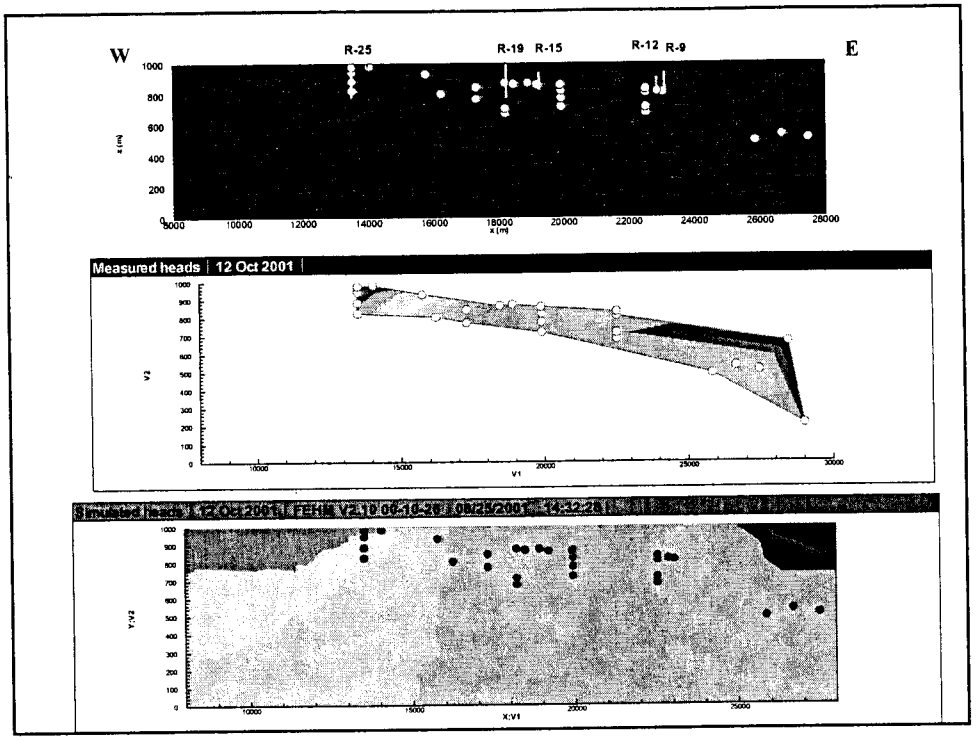
Both water level and permeability data suggest that significant heterogeneity exists within sedimentary rocks

Data needs:

- Continue to conduct single-hole hydraulic tests in R-wells

Analysis activities:

- Re-examine existing geophysical, geologic, and hydrologic data
- Continue to develop conceptual model(s) of how these high and low permeability zones are distributed spatially
- Test alternative conceptual models against water level data



Flow velocity

Head gradients

Permeability

Porosity

Effective Porosity (field scale)

Essentially no site-specific data for saturated zone

Major influence on predicted travel times in the regional aquifer

Existing tracer data inadequate for estimating travel times

Influence of porosity

Table 2. Summary of transport scenarios

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

Methods:

1. Single-well injection-withdrawal (huff-puff) tracer tests
2. Cross-hole forced-gradient tracer test
3. Age dating

Water levels – data need

1. Vertical gradient information is lacking in northeastern portion of LANL
2. Spatial coverage is reasonable for estimating plateau-scale flow directions

Permeability – data & analysis needs

Data needs:

1. Larger-scale (2 hole) hydraulic tests required for

- Better understanding of relation between geology and permeability
- Estimating connectivity of high or low permeability zones
- Determining impact of fault zones

Permeability

Analysis :

1. Re-analyze available geologic information gathered during drilling (textural information, lithology, etc.) and identify those parameters that are best correlated with permeability estimates

2. Test conceptual models about permeability structure using water level data via groundwater flow modeling

Requires more frequent iterations between 3-D geologic model and flow model

Groundwater velocity/transport – Data needs

1. Age dating of waters sampled in wells with short screens

2. Single-well injection-withdrawal (huff-puff) tracer tests

   - Groundwater flux
   - Matrix diffusion

3. Forced-gradient cross-hole tracer tests

   - Effective porosity
   - Longitudinal dispersivity

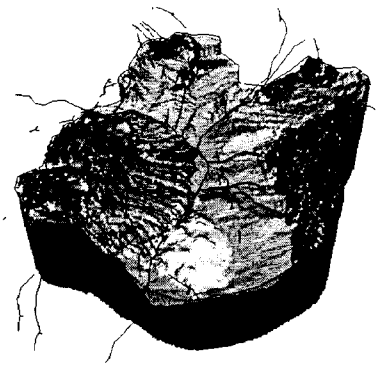
Hydrogeologic Characterization Program DQO Iteration

Charlie Nylander

Background

- Hydrogeologic Workplan primary purpose: gain understanding of hydrogeologic setting adequate to design monitoring network
- Iterative process: adjust data collection based on new data and understanding
- Iteration was conducted over the summer of 2001

Iteration Process



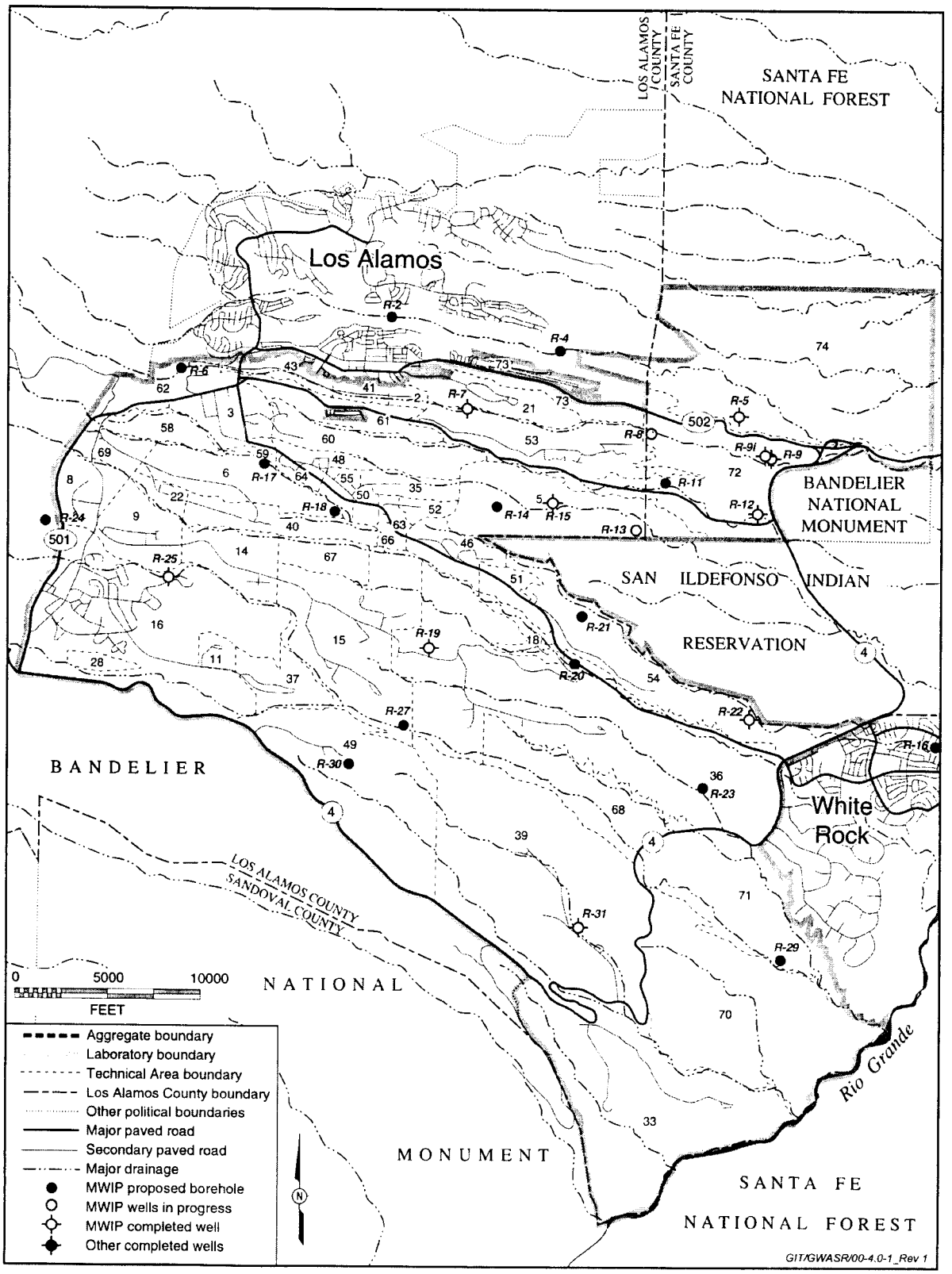
- Comprehensive evaluation
- Compiled data needs and recommended data collection
- Reviewed remaining wells and studies for continued importance
- Developed proposal for revised HWP scope

Next Steps

- Core team made up of DOE, LANL, NMED to reach consensus/approval on the proposed revision of scope
- Continue to provide site-wide monitoring and formulate enhanced comprehensive groundwater monitoring program
- Establish a long-term stewardship program

Proposed Revision to Hydrogeologic Workplan

- Install 15 regional aquifer wells (26 wells versus 32 wells)
- 13 other field-based activities
  - Hydrologic testing, geochemical, geologic mapping and sampling
- 11 analytical activities
  - regional aquifer modeling, geochemical modeling, information management
- 3 Project Management activities


LOS ALAMOS COUNTY
SANTA FE COUNTY
SANTA FE NATIONAL FOREST
Los Alamos
BANDELIER NATIONAL MONUMENT
SAN ILDEFONSO INDIAN RESERVATION
BANDELIER
White Rock
LOS ALAMOS COUNTY
SANDOVAL COUNTY
NATIONAL
MONUMENT
SANTA FE NATIONAL FOREST
Rio Grande
R-2
R-4
R-5
R-6
R-7
R-8
R-9
R-9i
R-11
R-12
R-13
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R-21
R-22
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R-24
R-25
R-27
R-29
R-30
R-31
501
502
4
0 5000 10000
FEET
Aggregate boundary
Laboratory boundary
Technical Area boundary
Los Alamos County boundary
Other political boundaries
Major paved road
Secondary paved road
Major drainage
MWIP proposed borehole
MWIP wells in progress
MWIP completed well
Other completed wells
N
GIT/GWASR/00-4.0-1_Rev 1

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
Other Field (Non-Well) Activities			
OF-1	Spinner logs	Spinner logs, to determine the most productive zones in a well, should be run in water supply wells where a sentry well is planned. High priority wells for spinner logs are PM-3, PM-5, and O-1.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-2	Multiple-Well Hydrologic Testing for Large-Scale Permeability	Multiple well pump test(s) to determine medium-to-large scale permeability & to reconcile model parameters with test data. R-20 and R-11 could be close enough to water supply wells to conduct testing.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-3	Tracer test for Effective Porosity	Conduct cross-hole forced-gradient tracer tests to estimate field scale effective porosity. Requires construction of a test facility with two wells screened in intervals of interest.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-4	In Situ Downhole Velocity Tests	Tests to be conducted in water supply wells if they become available. The test results would provide a check on the modeling.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-5	Airborne Electromagnetic Survey	To map the extent of intermediate perched groundwater. The data collection is about 75% complete.	
OF-6	Percolation Rates	Install a number of approximately 300-feet deep wells in a canyon to look at moisture and contaminant distribution. The shallow wells would be used for estimating percolation rates and travel times.	**Task:** Develop Hydrologic Model **Subtask:** Compile and publish hydraulic characteristic data, 1) Bandelier Tuff
OF-7	Refine Groundwater Age Estimates	Determine age and groundwater travel times in regional aquifer (R wells). Perform this work activity during sampling of R wells. Need to obtain representative calcite samples from core collected at R wells and outcrops to correct $\delta^{13}C$ for	**Task:** Develop Geochemical Model **Subtask:** Geochemical characteristics of key subsurface hydrogeologic units

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
		recalculating C-14 dates.	
OF-8	Sorption Parameters	Perform sorption experiments on uranium, strontium, plutonium, and americium using groundwater and core-cutting samples to determine adsorption constants (distribution coefficients and surface complexation parameters) from the Cerros del Rio basalt (perched groundwater zones) in Los Alamos Canyon and Mortandad Canyon.	**Task:** Develop Geochemical Model **Subtask:** Geochemical characteristics of key subsurface hydrogeologic units
OF-9	Pre-Bandelier Sedimentology	Characterize the components of the Puye Formation and Santa Fe Group to develop a representative description of grain size, shape, sorting, and mineralology. The current descriptions based on drill cuttings are biased toward the larger grain sizes because the fines that wash out while drilling. Collect samples from outcrops of these units to determine the relative proportion of the size components.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3)Hydrologic parameter estimation for Pajarito Plateau
OF-10	Basalt Flow Geometry	Spatial refinement of the geometry of basalt flows, which are potential fast pathways, is uncertain. Use the airborne EM survey and surface mapping of Frijoles and Guaje Mountain (SE corner) quadrangles. Develop and consider multiple alternative geologic models and test them with flow model against water level data.	**Task:** Develop Geologic Model **Subtask:** Develop 3-dimensional database
OF-11	Range of measured permeability - small scale	Conduct pumping hydrologic tests in zones of interest. Slug tests may only test the filter pack materials.	**Task:** Develop Hydrologic Model **Subtask:** Water Quality Data 2) Evaluate water quality variations and vertical stratification
OF-12	Chemical stratification within the regional aquifer	Characterization wells completed with multiple screened intervals and sampling ports within the regional aquifer will be used to evaluate water quality variations and vertical stratification	**Task:** Develop Hydrologic Model **Subtask:** Water Quality Data 2) Evaluate water quality variations and vertical stratification
OF-13	Spring Flow and Quality Monitoring	Flow measurements and water quality analysis for springs in areas impacted by contamination, e.g. TA-16	**Task:** Develop Hydrologic Model **Subtask:** Inventory Springs Onsite
Analytical Activities			
A-1	Regional Aquifer Modeling - Facies Model & Aquifer Permeability	Review logs to see if anything is in logs related to permeability. Develop a method of logging to provide a correlation between textural deposits or depositional facies and permeability estimates.	**Task:** Develop Geologic Model **Subtask:** Develop 3-dimensional database **Task:** Develop Hydrologic Model

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
		Incorporate hypotheses concerning fault zones, facies within sedimentary rocks, alternative realizations about structure of basalt flows, etc. quickly into 3-D geologic model so that they can be tested against water level data using flow modeling.	**Subtask:** Compile Hydraulic Characteristic Data 3)Hydrologic parameter estimation for Pajarito Plateau **Task:** Develop Hydrologic Model **Subtask:** Groundwater flow modeling using FEHM code
A-2	Groundwater Pathway Assessment	Rank contaminants of potential risk-significance to groundwater receptors on a site-wide basis. Synthesize information from contaminant sources and hydrogeologic data to assess transport times and pathways.	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-3	Regional Aquifer Modeling - Local Perturbations of Flow Field	Potential effects of fault zones with data from R-25, R-24, R-2 and R-4; link canyons models to regional aquifer model through the water table boundary condition, examine effects of local recharge	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-4	Regional Aquifer Modeling - Future Water Quality and Quantity	Incorporate new data into model calibration; define capture zones for water supply wells; assess potential future changes in water quality due to pumping; predict future water level declines	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-5	Regional Aquifer Modeling - Support Monitoring Well Network Design	Incorporate all pertinent data into model calibration; calculate final sensitivity analyses to generate confidence intervals for all simulated flow directions and velocities for use in designing the monitoring well network.	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-6	Chloride and Stable Isotope Analysis	Determine recharge rates in core from boreholes in Potrillo Canyon, collected from the area where surface water disappears. Core is available for analysis.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 2)Vadose Zone fluxes in Los Alamos mesas
A-7	Baseline Geochemistry	Finalize publication and make database available.	**Task:** Develop Geochemical Model **Subtask:** Hydrochemical and statistical evaluation of solute distributions
A-8	Geochemical Modeling	Understand the important processes occurring along flow paths using baseline water quality and characterization sampling data	**Task:** Develop Geochemical Model **Subtask:** Geochemical Modeling
A-9	Pajarito Plateau	Refine plateau-wide water balance as part of regional aquifer	**Task:** Develop Hydrologic Model

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
	Water Balance	modeling on an annual basis.	**Subtask:** Long-term water balance
A-10	Information Management	ER/ESH data exchange, system maintenance and administration, and project management to consolidate historical and newly collected water quality-related data	**Task:** Develop Hydrologic Model **Subtask:** Water Quality Data, Consolidate historical water quality database
A-11	Three-Dimensional Geologic Model	Maintain three-dimensional geologic model to produce structure contour, isopach, water table maps and to provide geologic data for hydrologic modeling; update annually with new data	**Task:** Develop Geologic Model **Subtask:** Develop 3-dimensional database **Subtask:** Perform comprehensive review of 3-dimensional stratigraphy
Project Management Activities			
PM-1	GIT Activities	Quarterly meetings, annual meetings, annual groundwater status report	
PM-2	EAG Activities	Semi-annual project reviews, semi-annual reports	
PM-3	Field Support Facility	Maintain field support facility and core facility	

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 1: Los Alamos/ Pueblo	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	Yes		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	Yes		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-2, R-4, R-6, R-24 • A-7, A-8, A-10, A-11
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Distribution and rates of percolation. • Sorption parameters • Range of measured permeability - small scale • Mappable perched zones • Geochemical modeling • Information management • 3-D geologic model	• R-2, R-4, R-6, R-24 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Spinner logs • Pre-Bandelier sedimentology • Effective porosity on a field scale. • Head Data - Horizontal Gradients • Head Data -Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Baseline geochemistry • Geochemical modeling • Information management • 3-D geologic model	• R-2, R-4, R-6, R-24 • OF-1, OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, Of-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 2: Ca™ada del Buey/Pajarito	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?		• Presence of alluvial aquifer water • Quality of alluvial aquifer water • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • A-7, A-9, A-10
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?		• Presence of intermediate perched water • Quality of intermediate perched water • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • OT-5 • A-7, A-9, A-10
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Sorption parameters • Range of measured permeability - small scale • Mappable perched zones • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Spinner logs • Pre-Bandelier sedimentology • Effective porosity on a field scale. • Head Data - Horizontal Gradients • Head Data -Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Baseline geochemistry • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • OF-1, OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 3: TA-49	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?		• Presence of alluvial aquifer water • Quality of alluvial aquifer water • Geochemical modeling • 3-D geologic model	• R-6, R-24,R-30 • A-7, A-9, A-10
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?		• Presence of intermediate perched water • Quality of intermediate perched water • Geochemical modeling • 3-D geologic model	• R-6, R-24, R-30 • OT-5 • A-7, A-9, A-10
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • 3-D geologic model	• R-6, R-24, R-30 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Sorption parameters • Range of measured permeability - small scale • Mappable perched zones • Geochemical modeling • 3-D geologic model • Information management	• R-6, R-24, R-30 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale. • Head Data - Horizontal Gradients • Head Data -Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Geochemical modeling • 3-D geologic model • Information management	• R-6, R-24, R-30 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 4: Ancho/Indio/ Chaquehui	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	No		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	No		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?	No		
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model	• R-6, R-24, R-29, R-30 • OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling Information management • 3-D geologic model • Information management • Baseline geochemistry	• R-6, R-24, R-29, R-30 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 5: Ca™on del Valle	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	Yes		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	Yes		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-24, R-27 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model • Spring flow and quality monitoring	• R-6, R-18, R-24, R-27 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling Information management • 3-D geologic model • Information management • Baseline geochemistry	• R-6, R-18, R-24, R-27 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 6: Water/ Potrillo/Fence	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?		• Presence of alluvial aquifer water • Quality of alluvial aquifer water • Chloride and stable isotope analysis • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-23, R-24, R-27, R-29 • A-5, A-7, A-9, A-10
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?		• Presence of intermediate perched water • Quality of intermediate perched water • Geochemical modeling • Chloride and stable isotope analysis • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-23, R-24, R-27, R-29 • OT-5 • A-5, A-7, A-9, A-10
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-23, R-24, R-27, R-29 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Chloride and stable isotope analysis • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model •	• R-6, R-18, R-23, R-24, R-27, R-29 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-6, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Chemical stratification in regional aquifer • Chloride and stable isotope analysis • Geochemical modeling and baseline geochemistry • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • 3-D geologic model and information management	• R-6, R-18, R-23, R-24, R-27, R-29 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3, A-4, A-5, A-7, A-8, A-9, A-10, A-11 • • PM-1, PM-2, PM-3

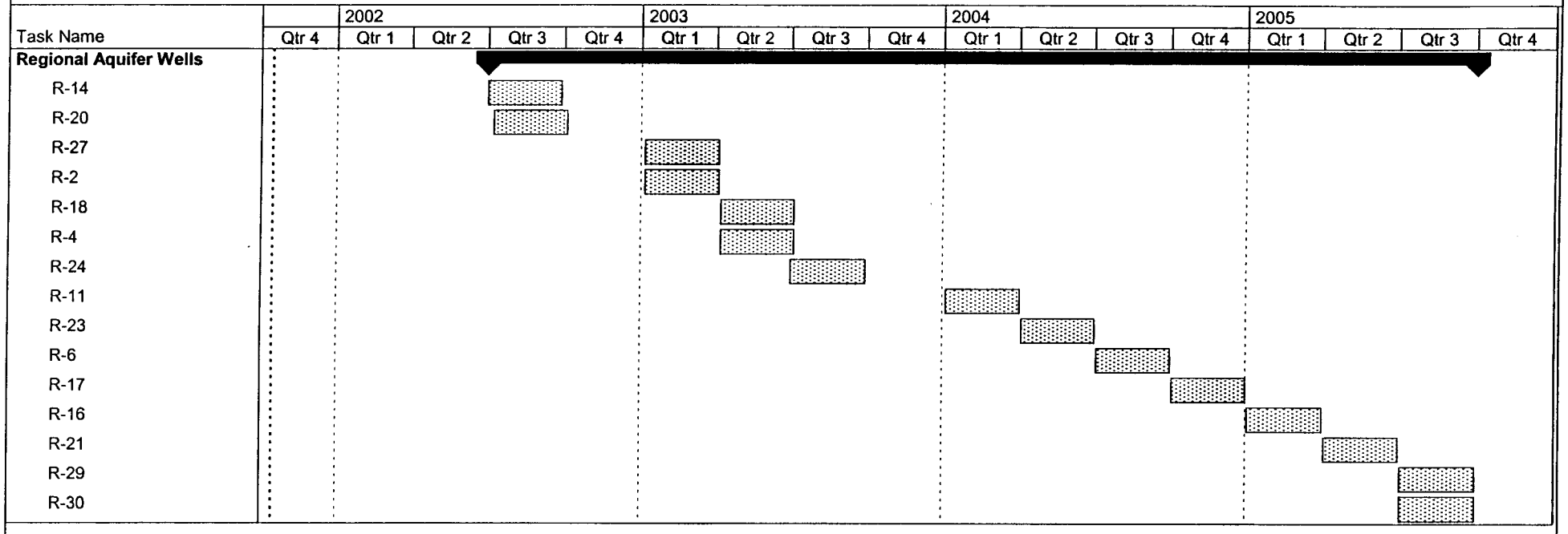
Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 7: Mortandad	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	Yes		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	Yes		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-14, R-16, R-24 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model •	• R-6, R-14, R-16, R-24 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Information management • 3-D geologic model • Information management • Baseline geochemistry	• R-6, R-14, R-16, R-24 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 8: Guaje/Bayo/ Rendija	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	No		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	No		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	No		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?	No		
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?	No		
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?	No		

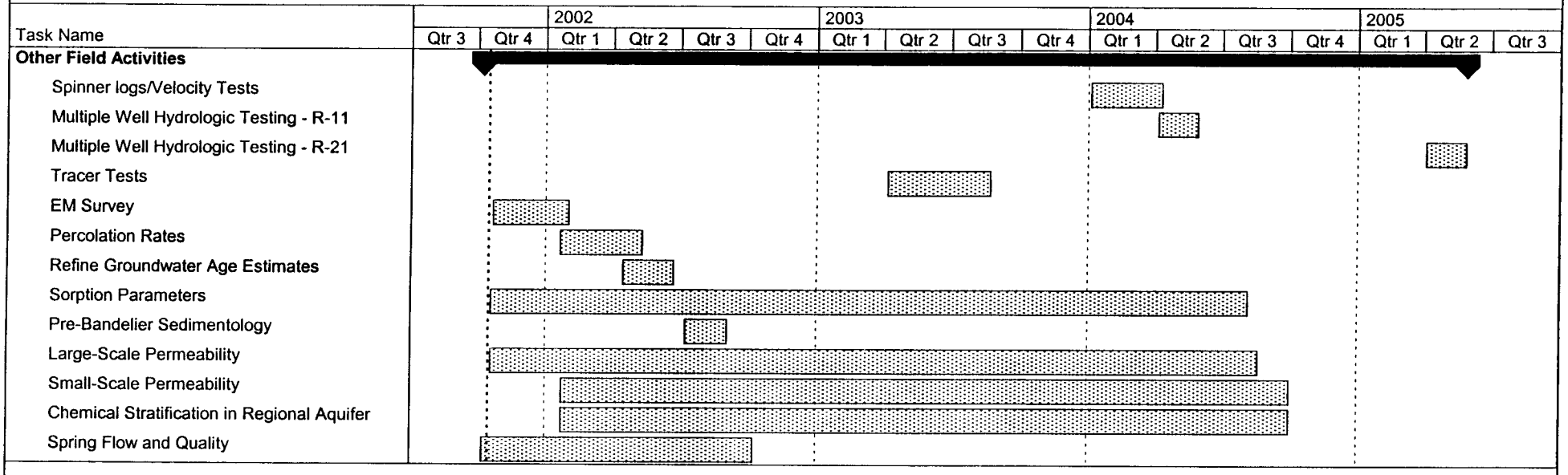
Table 4: Los Alamos National Laboratory Hydrgeologic Workplan
Schedule of Proposed Workplan Activities
October, 2001



Project: iterationschedule
Date: Mon 10/15/01

Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone		Project Summary	
Milestone		Rolled Up Progress		External Milestone	
Summary		Split		Deadline	

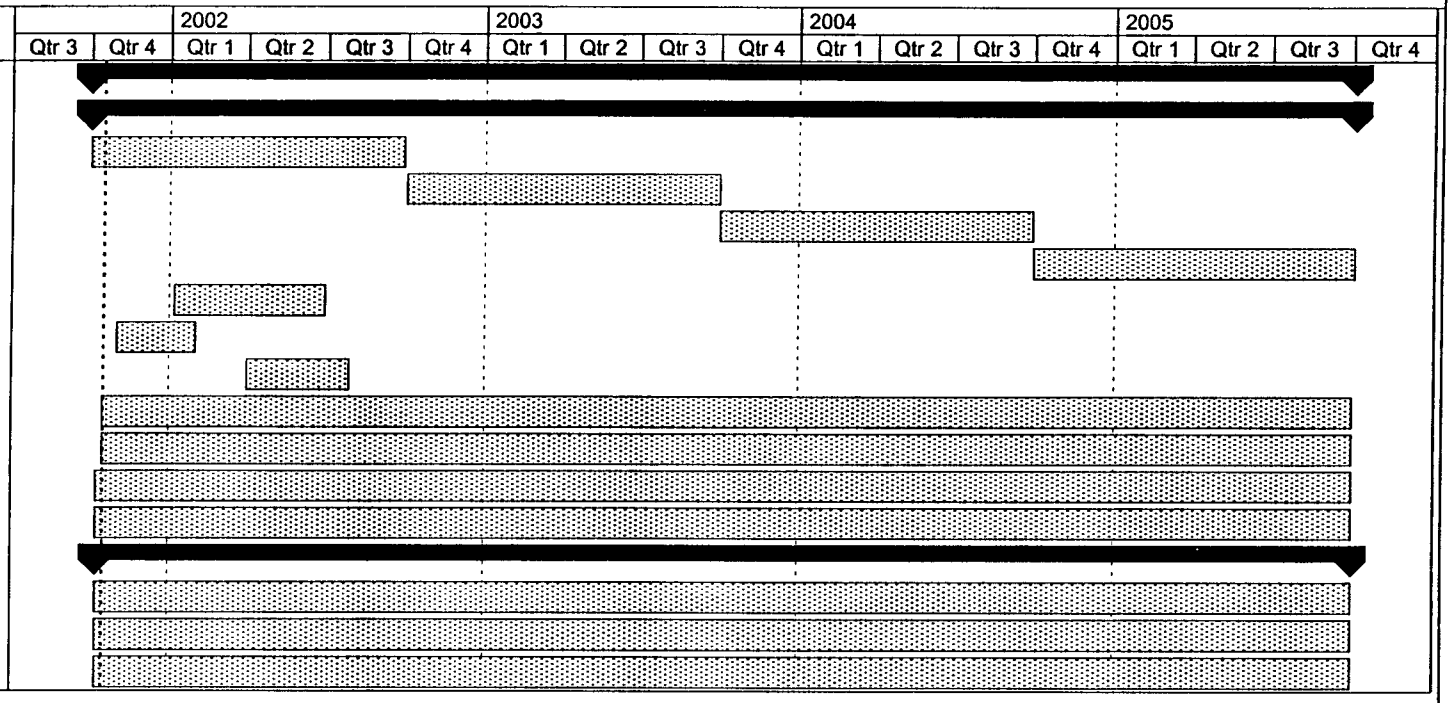
Table 4: Los Alamos National Laboratory Hydrgeologic Workplan
Schedule of Proposed Workplan Activities
October, 2001



Project: iterationschedule
Date: Mon 10/15/01

Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone		Project Summary	
Milestone		Rolled Up Progress		External Milestone	
Summary		Split		Deadline	

Table 4: Los Alamos National Laboratory Hydrgeologic Workplan
Schedule of Proposed Workplan Activities
October, 2001



Project: iterationschedule
Date: Mon 10/15/01

Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone	◇	Project Summary	
Milestone	◆	Rolled Up Progress		External Milestone	◆
Summary		Split		Deadline	⇩

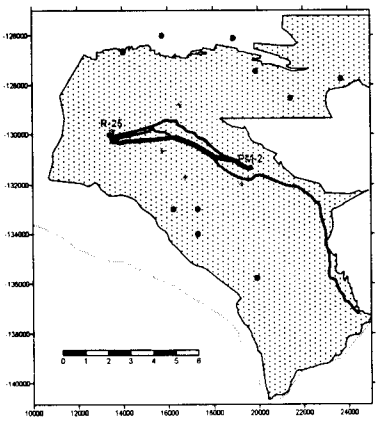
FY02 Proposed Scope

Charlie Nylander

FY02 Field Activities

- Complete R-8 and R-13
- Drill and complete R-14 and R-20
- Characterization sampling and analysis in completed wells
- Well Reports

FY02 Non-Field Activities



- Information Management
- Regional aquifer/vadose zone modeling
- Geologic Model
- Interpretative Work
- Quarterly and Annual Meetings
- Annual Report

10/16/01 HWP Meetings

HSWA LANL G/M/HWP 2001

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Proposed Hydrogeologic Workplan Scope

October 2001

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Proposed Hydrogeologic Workplan Scope
October, 2001

Introduction

The Hydrogeologic Workplan was developed as a response to multiple groundwater characterization needs identified by Los Alamos National Laboratory (LANL), Department of Energy (DOE), and New Mexico Environment Department (NMED). The primary purpose of the Hydrogeologic Workplan is to gain an understanding of the hydrogeologic setting adequate to design a monitoring network capable of detecting water quality threats to the regional aquifer. The Hydrogeologic Workplan provides for an iterative process of learning from each activity, especially wells that are installed, thus guiding the succeeding data quality objectives and the location and data collection of the succeeding wells. The interpretive process is equally as important as the well installation and data collection, although it is a process that is not as visible as data collection. Numerical modeling is a primary tool used to interpret the data collected from drilling and testing in the wells. This document describes the iteration process and resulting proposed revisions in scope to the Hydrogeologic Workplan.

Hydrogeologic Workplan Background

In 1995, pursuant to DOE Order 5400.1, the LANL Groundwater Protection Management Plan (GWPMP) was developed that identified the need for site-wide hydrogeologic characterization. Also in 1995, the NMED denied the LANL groundwater monitoring waiver demonstrations on the basis that LANL did not have adequate understanding of the hydrogeologic system to demonstrate waiver of monitoring requirements. Accordingly, NMED requested site-wide hydrogeologic characterization. In addition, the Laboratory through the Environmental Restoration Project must fulfill the requirements of the1990 EPA/NMED RCRA Operating Permit, which includes a requirement in the HSWA Module VIII, Task III, Section A.1 to evaluate hydrogeologic conditions. Thus, in 1995 LANL began developing the Hydrogeologic Workplan that would collect data on the hydrogeologic setting that would be useful for making decisions regarding monitoring and environmental restoration using the Data Quality Objective (DQO) process. In March 1998, NMED approved the Hydrogeologic Workplan.

The ultimate objective of Hydrogeologic Workplan is to understand the hydrogeologic setting in order to design a monitoring network. The series of decisions established in the Hydrogeologic Workplan (flow diagram and DQO process outputs, Figure 1-3 and Appendix 4, respectively, of the Hydrogeologic Workplan) were intended to focus the data collection activities on information important to monitoring design. Thus, the hydrogeologic data collection is more concentrated in areas with the highest potential for contaminant impacts. The resulting data and analyses are used in recognizing the pathways and rates of contaminant migration. Although one objective of the Hydrogeologic Workplan is to identify areas of groundwater contamination, determining the extent of contamination and the risk posed by that contamination is the responsibility of the LANL Environmental Restoration Project. Investigation of contaminant plumes is

not within the scope of the Hydrogeologic Workplan. The workplan was intended to be the integrated characterization phase necessary for two different programs to carry out their related missions -- institutional environmental monitoring and environmental restoration -- in a coordinated and cost-effective fashion.

Iteration Process

The DQO iteration began with a comprehensive evaluation of all groundwater-related data collected, analyzed, and interpreted to date in the program in order to determine what is known and what data are necessary to complete the Hydrogeologic Workplan. This document is a compilation of the necessary data and analyses which forms the proposed revisions to the Hydrogeologic Workplan. The next step is to establish a small core group of LANL, DOE and NMED decision-makers to review and develop consensus on the proposed revisions.

The comprehensive evaluation took place between June and October 2001. It was intended to familiarize all of the LANL Groundwater Integration Team (GIT) members with the state of groundwater characterization knowledge and to develop a complete and consistent an understanding of the hydrogeologic system with the available information. To accomplish this task, each scientific discipline represented on the GIT (as subcommittees) provided a presentation that reflects an overview of the information collected to date. The presentations incorporated observations and findings in that discipline on a site-wide basis, what is known on an aggregate basis, and provided a status with respect to resolving the decisions in the Hydrogeologic Workplan. The notes from the presentations made during this process are included as Appendix A.

Following the comprehensive evaluation each GIT subcommittee developed a set of data needs and data collection activities to fill the data needs. From the subcommittee inputs, a list of data needs was compiled. The remaining regional aquifer wells and interpretive activities listed in the Hydrogeologic Workplan were reviewed by the GIT with respect to the list of data needs. The GIT as a whole determined which of the remaining wells and other studies were still necessary and added new studies as necessary to provide the data. Table 1 lists the regional aquifer wells, along with the rationale for the wells, which are proposed to complete the scope of the Hydrogeologic Workplan. Figure 1 shows the proposed locations of the wells. Table 2 lists the other field activities, analytical activities, and project management activities that are also necessary to complete the scope of the Hydrogeologic Workplan. Additionally, Table 2 provides a cross-walk of the non-well based activities to the 1998 Hydrogeologic Workplan.

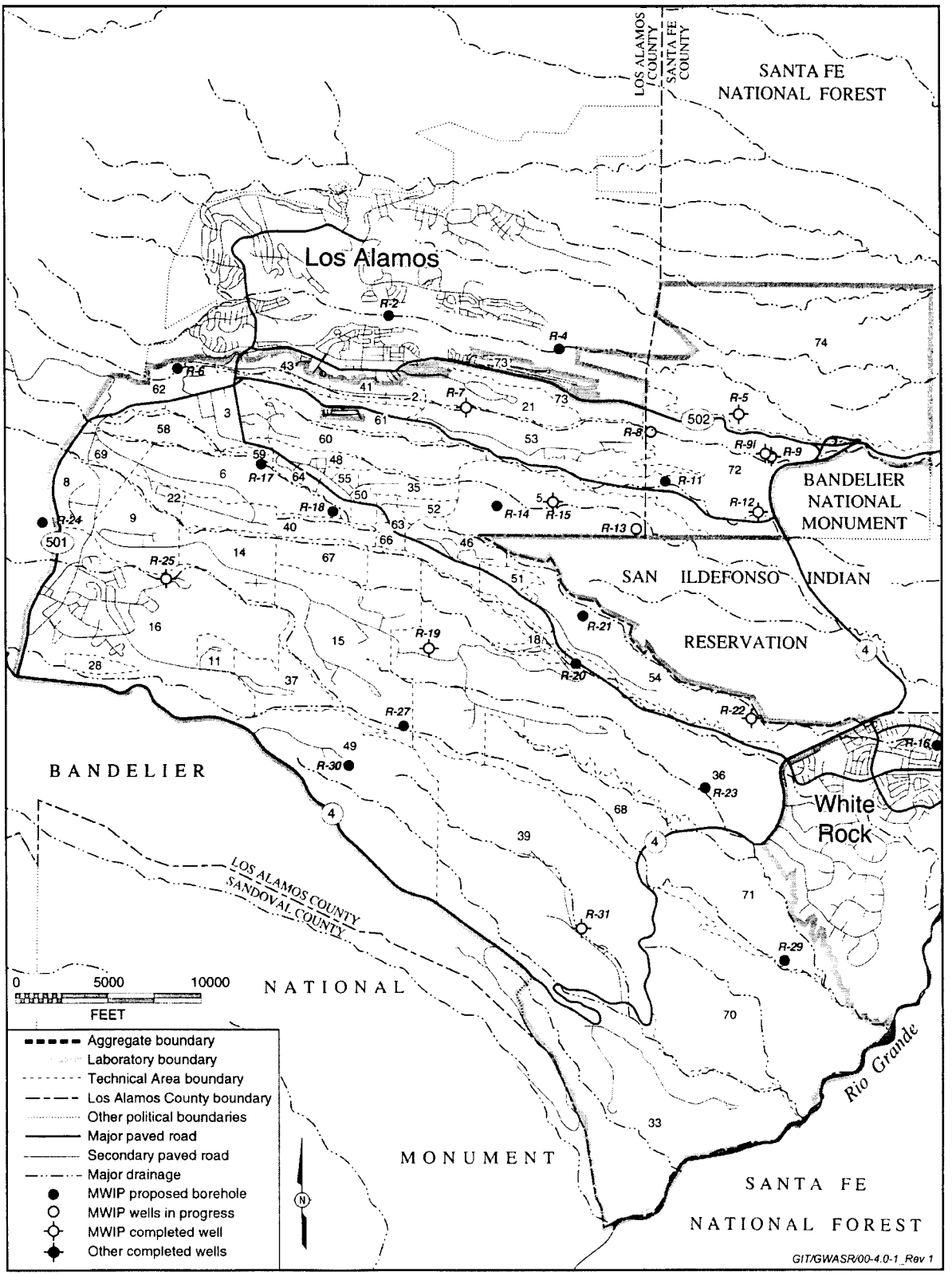


Figure 1 Map of Characterization Wells

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Proposed Hydrogeologic Workplan Scope
October, 2001

Proposed Hydrogeologic Workplan Scope

As an overview, the proposal is to install 15 more regional aquifer wells (Table 1) in the locations shown on Figure 1. The proposed scope also includes 13 other field-based activities, 11 analytical activities, and 3 project management activities (Table 2).

Table 3 summarizes the decisions in the Hydrogeologic Workplan for each aggregate, the data needed to resolve the decisions, and the proposed data collection activities. The combination of Tables 2 and 3 replaces Table 3-1 and Sections 3.2 and 3.3 in the 1998 Hydrogeologic Workplan and the combination of Tables 1 and 3 and Figure 1 replaces Tables 4-1 through 4-10 in the Hydrogeologic Workplan. Table 4 is a proposed schedule for completing the revised scope.

In most aggregates the first four decisions, which involve the presence of contaminants in saturated zones, are largely resolved. As anticipated, contamination of saturated zones has occurred in wet canyon systems (e.g. Los Alamos and Pueblo canyons) and is not seen in dry canyon systems (e.g. Ancho Canyon). The remaining decisions, which involve identification of pathways and prediction of the potential for contamination in the future, are not resolved.

For example, some conservative contaminants (e.g. tritium and perchlorate) are observed in the regional aquifer beneath Pueblo Canyon. It is not clear from these observations whether the contamination is moving through the vadose zone as a point source (intersecting the regional aquifer at a relatively small locus) or as a line source (intersecting the regional aquifer in a line below the length of the canyon). The resultant plume in the regional aquifer would be of substantially different proportions depending on the outline of the source. Similarly, the monitoring network design would be quite different in response to the anticipated shape of a plume. Thus, many of the proposed data collection activities are targeted at identifying the pathways and the factors that affect transport within the saturated zones. These activities are concentrated in wet canyons where contaminants were discharged because those are the areas where contamination of saturated zones is anticipated.

Data collection in dry canyon systems and upgradient of LANL is focused on regional aquifer hydrologic characteristics, particularly boundary conditions, permeability, porosity, vertical and horizontal gradients, and faulting effects on the hydrology. This information is critical for predicting the direction and rate of water flow and contaminant transport from any site at the Laboratory.

Table 1: Regional Aquifer Wells

Borehole	Original Start Date	Current Start Date	Funding Source	Rationale of Proposed Boreholes
R-14	FY02	FY02	NWT	R-14 is planned for installation as a water-supply protection well for PM-5. R-14 will provide information about the radius of influence of pumping from PM-5, and its location will be optimized to detect the migration of contaminants from Mortandad Canyon towards the water supply well. R-14 is part of a southeasterly traverse of reference wells that includes R-6 and R-16 and a north-south traverse that includes R-1 and R-28.
R-20	FY02	FY02	NWT	R-20 is planned for installation in lower Pajarito Canyon near water supply well PM-2. R-20 is expected to have multiple completions in the regional aquifer and be located close enough to PM-2 to allow cross-hole hydrologic testing. Intermediate perched zones may occur within the Bandelier Tuff, based on drilling logs for PM-2, and within basalts.
R-27	FY00	FY03	ER	R-27 is planned for installation in Water Canyon. The location will be further east of the location shown in the original Hydrogeologic Workplan because this well was combined with R-28 and moved to a location approximately half way between the two wells. The well is expected to have multiple completions in the regional aquifer. The purpose of the well is to characterize baseline water quality in intermediate perched zones and in the regional aquifer groundwater beneath this wet canyon. Moisture characteristics of the Bandelier Tuff will be measured to evaluate recharge and transport. R-27 also will provide baseline information on the geology, hydrology, and water quality for the poorly-characterized south-central part of the Laboratory.
R-18	FY99	FY03	ER	R-18 is planned for installation at the confluence of Pajarito and Twomile Canyons to provide information about intermediate perched zone groundwater, depth to the regional aquifer, and water quality of perched zones and the regional aquifer in the poorly-characterized west-central part of the Laboratory. The well is expected to have multiple completions in the regional aquifer. It is located downstream from Laboratory release sites at TA-8, TA-9, TA-14, TA-22, TA-40, and TA-69, but is in an area that has not been characterized for either groundwater or contaminants. The occurrence of surface flow through most of the year indicates perched alluvial groundwater is present in this part of the canyon.
R-2	FY00	FY03	NWT	R-2 is planned for installation in upper Pueblo Canyon within Los Alamos townsite. The location will be further west than shown in the original Hydrogeologic Workplan in order to intercept what is expected to be the maximum contamination. The well is expected to have multiple completions in the regional aquifer. R-2 is sited in Pueblo Canyon and is downgradient of the Rendija Canyon fault. Recharge contaminated from past releases may be reaching intermediate perched zones and the regional aquifer along this fault. Analyses of core and water samples collected from R-2 will be used to evaluate the fault as a preferential groundwater pathway. R-2 could replace TW-4 drilled by cable tool in 1950.
R-4	FY01	FY03	ER	R-4 is planned for installation to provide water-quality and water-level information for potential intermediate perched zones and for the regional aquifer beneath middle Pueblo Canyon. The location will be further east than shown in the original Hydrogeologic Workplan in order to complement the revised location of R-2. R-4 will provide information about the downgradient extent of groundwater contamination from former TA-45 and will place constraints on the lateral extent of the perched zone(s) and identify deeper perched zones within the Puye Formation and basalts in middle Pueblo Canyon near the northern Laboratory boundary. R-4 will also characterize groundwater water quality upgradient of the county's Bayo Sewage Treatment Plant.
R-11	FY03	FY04	NWT	R-11, planned for installation as a water-supply protection well for PM-3, is located in middle Sandia Canyon. R-11 is expected to have multiple completions in the regional aquifer and be located close enough to PM-3 to allow cross-hole hydrologic testing. PM-3 is downgradient from source terms with a long history of releases at TA-53 and TA-21. R-11 will be on the upgradient side of PM-3 to detect contaminants from release sites. R-11 will also provide information about groundwater gradients near PM-3.

Table 1: Regional Aquifer Wells

Borehole	Original Start Date	Current Start Date	Funding Source	Rationale of Proposed Boreholes
R-17	FY02	FY04	ER	R-17 is tentatively planned for installation in Twomile Canyon, a major tributary to Pajarito Canyon, to provide information about intermediate perched zones, depth to the regional aquifer, and water quality of intermediate perched zones and the regional aquifer in the poorly-characterized northwest part of the Laboratory. The well is expected to have multiple completions in the regional aquifer. It is located downstream from Laboratory release sites at TA-3, TA-6, TA-58, TA-59, TA-62, and TA-69, but is in an area that has not been characterized for either groundwater or contaminants. R-17 will also provide upgradient water-quality information for Aggregate 7.
R-6	FY03	FY04	NWT	R-6, planned for installation in upper Los Alamos Canyon, is designed to provide baseline information about the geology, hydrology, and water quality for the western boundary of the Laboratory. This borehole will determine background water quality for intermediate perched zones and the regional aquifer upgradient of Aggregate 1. The well is expected to have multiple completions in the regional aquifer. It also will provide information about the depth to the regional aquifer for the western part of the Laboratory, and contribute to the construction of accurate groundwater maps for placing monitoring wells in this part of the Laboratory. R-6 is part of a southeasterly traverse of reference wells that includes R-14 and R-16 and a north-south traverse that includes R-25.
R-23	FY02	FY04	ER	R-23, located near the southeastern Laboratory boundary, is planned for installation to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of active firing sites in Potrillo Canyon. The well is expected to have multiple completions in the regional aquifer. R-23 is sited within a hydrological sink, a broad area of infiltration on the canyon floor that typically marks the easternmost occurrence of surface water flow in this canyon. R-23 will evaluate the hydrological sink as a possible recharge zone for perched groundwater and for the regional aquifer. The final location of R-23 will be determined after chloride and stable isotope analysis of existing core from this area.
R-24	FY02	FY03	NWT	R-24 is planned for installation west of the trace of the Pajarito fault system and west of Aggregate 5. This borehole will provide water-quality and water-level data for intermediate perched zones and the regional aquifer on the upthrown block of a major splay of the Pajarito fault system. The location and occurrence of perched water and water level data for the regional aquifer, when compared with similar data from R-25 on the downthrown block, will be used to evaluate the influence of the Pajarito fault system on the regional piezometric surface and provide information about its role as a recharge zone. Moisture characteristics of the Bandelier Tuff will be measured to evaluate recharge and transport. Water quality data from intermediate perched zone and regional groundwater in R-24 will define background conditions upgradient from the Laboratory, and in particular for Aggregate 5. These background geochemical data will be used to define potential impacts on groundwater from Laboratory facilities and to provide input data for geochemical and hydrological modeling of different groundwater systems.
R-16	FY03	FY05	NWT	R-16, planned for installation in White Rock, will provide baseline information on the geology, hydrology, and water quality for a large uncharacterized area between the eastern boundary of the Laboratory and the Rio Grande. The current regional aquifer water level maps have an unexpected perturbation in this area that can only be resolved by measuring the water level in the vicinity of R-29 and R-16. The well is expected to have multiple completions in the regional aquifer. R-29 and R-16 will provide important information on clay, carbonate, and hydrothermal alteration in the Puye and Santa Fe, which affects contaminant transport. Numerous springs in White Rock Canyon probably represent discharge points for intermediate perched zones and the regional aquifer based on significant differences in major ion chemistry and stable isotopes. R-16 will determine background water quality for intermediate perched zones and the regional aquifer between the Laboratory and the Rio Grande, provide information about the depth to the regional aquifer for the eastern part the Laboratory, and clarify the relationship between springs in White Rock Canyon and various groundwater zones. R-16 is part of a southeasterly traverse of reference wells that includes R-6 and R-14.
R-21	FY02	FY05	ER	R-21 is planned for installation to provide upgradient water quality information for MDAs L and G. It will be located on the mesa above R-20 to examine the continuity of intermediate perched zones beneath the mesa. It is expected to have multiple completions in the regional aquifer.

Table 1: Regional Aquifer Wells

Borehole	Original Start Date	Current Start Date	Funding Source	Rationale of Proposed Boreholes
R-29	FY03	FY05	NWT	R-29 is planned for installation in lower Water Canyon. It will provide information about the depth to the regional aquifer in a poorly-characterized area. The current regional aquifer water level maps have an unexpected perturbation in this area that can only be resolved by measuring the water level in the vicinity of R-29 and R-16. The well is expected to have multiple completions in the regional aquifer. R-29 and R-16 will provide important information on clay, carbonate, and hydrothermal alteration in the Puye and Santa Fe, which affects contaminant transport. Data from this well will be used to understand the discharge boundary conditions in the regional aquifer model and to optimize the placement of downgradient monitoring wells along the eastern Laboratory boundary. Water quality data from perched and regional groundwaters in R-29 will be compared to similar data for springs in White Rock Canyon to identify potential groundwater flow paths near the Rio Grande.
R-30	FY02	FY05	ER	R-30 is planned to determine water quality in intermediate perched zones and in the regional aquifer beneath MDA AB, which was used for underground hydronuclear experiments. The final location of R-30 will be based on unsaturated zone modeling that has been completed for MDA AB.

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
Other Field (Non-Well) Activities			
OF-1	Spinner logs	Spinner logs, to determine the most productive zones in a well, should be run in water supply wells where a sentry well is planned. High priority wells for spinner logs are PM-3, PM-5, and O-1.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-2	Multiple-Well Hydrologic Testing for Large-Scale Permeability	Multiple well pump test(s) to determine medium-to-large scale permeability & to reconcile model parameters with test data. R-20 and R-11 could be close enough to water supply wells to conduct testing.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-3	Tracer test for Effective Porosity	Conduct cross-hole forced-gradient tracer tests to estimate field scale effective porosity. Requires construction of a test facility with two wells screened in intervals of interest.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-4	In Situ Downhole Velocity Tests	Tests to be conducted in water supply wells if they become available. The test results would provide a check on the modeling.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3) Hydrologic parameter estimation for Pajarito Plateau
OF-5	Airborne Electromagnetic Survey	To map the extent of intermediate perched groundwater. The data collection is about 75% complete.	
OF-6	Percolation Rates	Install a number of approximately 300-feet deep wells in a canyon to look at moisture and contaminant distribution. The shallow wells would be used for estimating percolation rates and travel times.	**Task:** Develop Hydrologic Model **Subtask:** Compile and publish hydraulic characteristic data, 1) Bandelier Tuff
OF-7	Refine Groundwater Age Estimates	Determine age and groundwater travel times in regional aquifer (R wells). Perform this work activity during sampling of R wells. Need to obtain representative calcite samples from core collected at R wells and outcrops to correct $\delta^{13}C$ for	**Task:** Develop Geochemical Model **Subtask:** Geochemical characteristics of key subsurface hydrogeologic units

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
		recalculating C-14 dates.	
OF-8	Sorption Parameters	Perform sorption experiments on uranium, strontium, plutonium, and americium using groundwater and core-cutting samples to determine adsorption constants (distribution coefficients and surface complexation parameters) from the Cerros del Rio basalt (perched groundwater zones) in Los Alamos Canyon and Mortandad Canyon.	**Task:** Develop Geochemical Model **Subtask:** Geochemical characteristics of key subsurface hydrogeologic units
OF-9	Pre-Bandelier Sedimentology	Characterize the components of the Puye Formation and Santa Fe Group to develop a representative description of grain size, shape, sorting, and mineralology. The current descriptions based on drill cuttings are biased toward the larger grain sizes because the fines that wash out while drilling. Collect samples from outcrops of these units to determine the relative proportion of the size components.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 3)Hydrologic parameter estimation for Pajarito Plateau
OF-10	Basalt Flow Geometry	Spatial refinement of the geometry of basalt flows, which are potential fast pathways, is uncertain. Use the airborne EM survey and surface mapping of Frijoles and Guaje Mountain (SE corner) quadrangles. Develop and consider multiple alternative geologic models and test them with flow model against water level data.	**Task:** Develop Geologic Model **Subtask:** Develop 3-dimensional database
OF-11	Range of measured permeability - small scale	Conduct pumping hydrologic tests in zones of interest. Slug tests may only test the filter pack materials.	**Task:** Develop Hydrologic Model **Subtask:** Water Quality Data 2) Evaluate water quality variations and vertical stratification
OF-12	Chemical stratification within the regional aquifer	Characterization wells completed with multiple screened intervals and sampling ports within the regional aquifer will be used to evaluate water quality variations and vertical stratification	**Task:** Develop Hydrologic Model **Subtask:** Water Quality Data 2) Evaluate water quality variations and vertical stratification
OF-13	Spring Flow and Quality Monitoring	Flow measurements and water quality analysis for springs in areas impacted by contamination, e.g. TA-16	**Task:** Develop Hydrologic Model **Subtask:** Inventory Springs Onsite
Analytical Activities			
A-1	Regional Aquifer Modeling - Facies Model & Aquifer Permeability	Review logs to see if anything is in logs related to permeability. Develop a method of logging to provide a correlation between textural deposits or depositional facies and permeability estimates.	**Task:** Develop Geologic Model **Subtask:** Develop 3-dimensional database **Task:** Develop Hydrologic Model

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
		Incorporate hypotheses concerning fault zones, facies within sedimentary rocks, alternative realizations about structure of basalt flows, etc. quickly into 3-D geologic model so that they can be tested against water level data using flow modeling.	**Subtask:** Compile Hydraulic Characteristic Data 3)Hydrologic parameter estimation for Pajarito Plateau **Task:** Develop Hydrologic Model **Subtask:** Groundwater flow modeling using FEHM code
A-2	Groundwater Pathway Assessment	Rank contaminants of potential risk-significance to groundwater receptors on a site-wide basis. Synthesize information from contaminant sources and hydrogeologic data to assess transport times and pathways.	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-3	Regional Aquifer Modeling - Local Perturbations of Flow Field	Potential effects of fault zones with data from R-25, R-24, R-2 and R-4; link canyons models to regional aquifer model through the water table boundary condition, examine effects of local recharge	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-4	Regional Aquifer Modeling - Future Water Quality and Quantity	Incorporate new data into model calibration; define capture zones for water supply wells; assess potential future changes in water quality due to pumping; predict future water level declines	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-5	Regional Aquifer Modeling - Support Monitoring Well Network Design	Incorporate all pertinent data into model calibration; calculate final sensitivity analyses to generate confidence intervals for all simulated flow directions and velocities for use in designing the monitoring well network.	**Task:** Develop Hydrologic Model **Subtask:** Groundwater modeling using FEHM code
A-6	Chloride and Stable Isotope Analysis	Determine recharge rates in core from boreholes in Potrillo Canyon, collected from the area where surface water disappears. Core is available for analysis.	**Task:** Develop Hydrologic Model **Subtask:** Compile Hydraulic Characteristic Data 2)Vadose Zone fluxes in Los Alamos mesas
A-7	Baseline Geochemistry	Finalize publication and make database available.	**Task:** Develop Geochemical Model **Subtask:** Hydrochemical and statistical evaluation of solute distributions
A-8	Geochemical Modeling	Understand the important processes occurring along flow paths using baseline water quality and characterization sampling data	**Task:** Develop Geochemical Model **Subtask:** Geochemical Modeling
A-9	Pajarito Plateau	Refine plateau-wide water balance as part of regional aquifer	**Task:** Develop Hydrologic Model

Table 2: List of Other (Non-Well) Activities to Complete the Hydrogeologic Workplan

Task ID Number	Task Name	Task Description	Cross-Walk to Hydrogeologic Workplan (Table 3-1)
	Water Balance	modeling on an annual basis.	**Subtask:** Long-term water balance
A-10	Information Management	ER/ESH data exchange, system maintenance and administration, and project management to consolidate historical and newly collected water quality-related data	**Task:** Develop Hydrologic Model **Subtask:** Water Quality Data, Consolidate historical water quality database
A-11	Three-Dimensional Geologic Model	Maintain three-dimensional geologic model to produce structure contour, isopach, water table maps and to provide geologic data for hydrologic modeling; update annually with new data	**Task:** Develop Geologic Model **Subtask:** Develop 3-dimensional database **Subtask:** Perform comprehensive review of 3-dimensional stratigraphy
Project Management Activities			
PM-1	GIT Activities	Quarterly meetings, annual meetings, annual groundwater status report	
PM-2	EAG Activities	Semi-annual project reviews, semi-annual reports	
PM-3	Field Support Facility	Maintain field support facility and core facility	

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 1: Los Alamos/ Pueblo	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	Yes		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	Yes		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-2, R-4, R-6, R-24 • A-7, A-8, A-10, A-11
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Distribution and rates of percolation. • Sorption parameters • Range of measured permeability - small scale • Mappable perched zones • Geochemical modeling • Information management • 3-D geologic model	• R-2, R-4, R-6, R-24 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Spinner logs • Pre-Bandelier sedimentology • Effective porosity on a field scale. • Head Data - Horizontal Gradients • Head Data -Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Baseline geochemistry • Geochemical modeling • Information management • 3-D geologic model	• R-2, R-4, R-6, R-24 • OF-1, OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, Of-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 2: Ca™ada del Buey/Pajarito	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?		• Presence of alluvial aquifer water • Quality of alluvial aquifer water • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • A-7, A-9, A-10
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?		• Presence of intermediate perched water • Quality of intermediate perched water • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • OT-5 • A-7, A-9, A-10
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Sorption parameters • Range of measured permeability - small scale • Mappable perched zones • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Spinner logs • Pre-Bandelier sedimentology • Effective porosity on a field scale. • Head Data - Horizontal Gradients • Head Data -Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Baseline geochemistry • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-16, R-18, R-24, R-27 • OF-1, OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 3: TA-49	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?		• Presence of alluvial aquifer water • Quality of alluvial aquifer water • Geochemical modeling • 3-D geologic model	• R-6, R-24,R-30 • A-7, A-9, A-10
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?		• Presence of intermediate perched water • Quality of intermediate perched water • Geochemical modeling • 3-D geologic model	• R-6, R-24, R-30 • OT-5 • A-7, A-9, A-10
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • 3-D geologic model	• R-6, R-24, R-30 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Sorption parameters • Range of measured permeability - small scale • Mappable perched zones • Geochemical modeling • 3-D geologic model • Information management	• R-6, R-24, R-30 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale. • Head Data - Horizontal Gradients • Head Data -Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Geochemical modeling • 3-D geologic model • Information management	• R-6, R-24, R-30 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 4: Ancho/Indio/ Chaquehui	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	No		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	No		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?	No		
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model	• R-6, R-24, R-29, R-30 • OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling Information management • 3-D geologic model • Information management • Baseline geochemistry	• R-6, R-24, R-29, R-30 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 5: Ca™on del Valle	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	Yes		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	Yes		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-24, R-27 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model • Spring flow and quality monitoring	• R-6, R-18, R-24, R-27 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Chemical stratification in regional aquifer • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling Information management • 3-D geologic model • Information management • Baseline geochemistry	• R-6, R-18, R-24, R-27 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 6: Water/ Potrillo/Fence	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?		• Presence of alluvial aquifer water • Quality of alluvial aquifer water • Chloride and stable isotope analysis • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-23, R-24, R-27, R-29 • A-5, A-7, A-9, A-10
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?		• Presence of intermediate perched water • Quality of intermediate perched water • Geochemical modeling • Chloride and stable isotope analysis • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-23, R-24, R-27, R-29 • OT-5 • A-5, A-7, A-9, A-10
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-18, R-23, R-24, R-27, R-29 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Chloride and stable isotope analysis • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model •	• R-6, R-18, R-23, R-24, R-27, R-29 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-6, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Chemical stratification in regional aquifer • Chloride and stable isotope analysis • Geochemical modeling and baseline geochemistry • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • 3-D geologic model and information management	• R-6, R-18, R-23, R-24, R-27, R-29 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11, OF-12 • A-1, A-2, A-3, A-4, A-5, A-7, A-8, A-9, A-10, A-11 • • PM-1, PM-2, PM-3

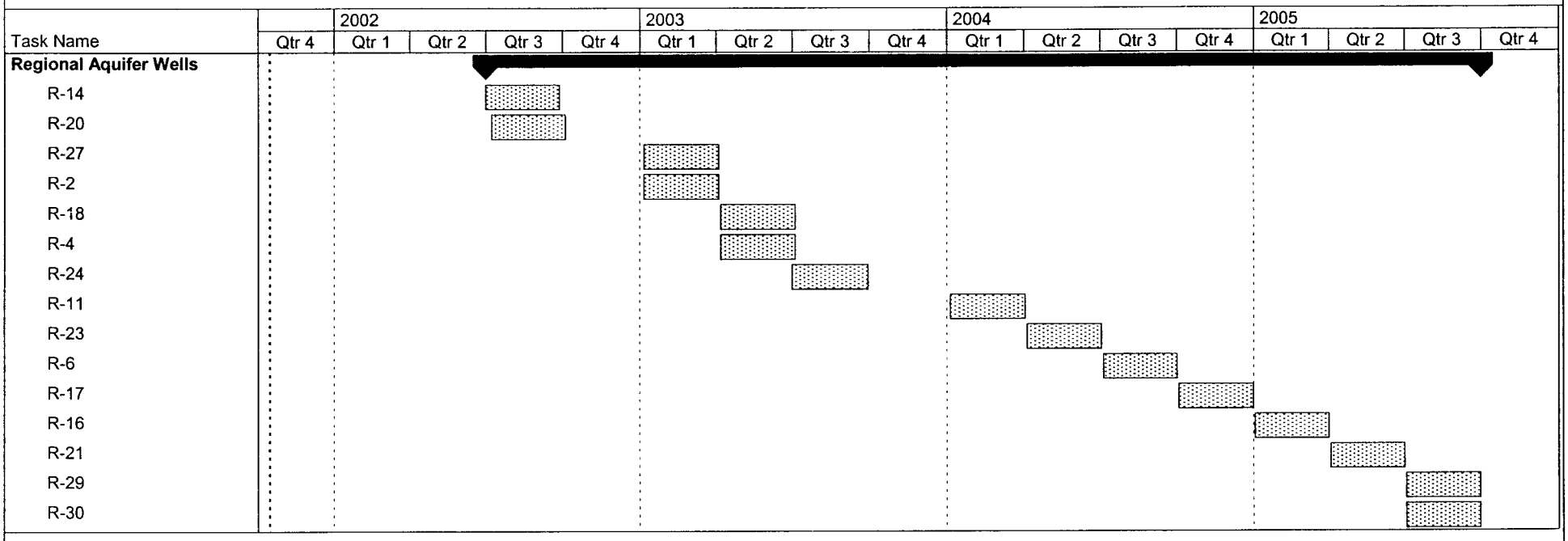
Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 7: Mortandad	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	Yes		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	Yes		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	Yes		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?		• Regional aquifer water quality • Geochemical modeling • Information management • 3-D geologic model	• R-6, R-14, R-16, R-24 • A-7, A-9, A-10
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?		• Mappable perched zones • Geochemical modeling • Pre-Bandelier sedimentology • Information management • 3-D geologic model •	• R-6, R-14, R-16, R-24 • OF-5, OF-6, OF-8, OF-10, OF-11 • A-2, A-7, A-8, A-10, A-11 • PM-1, PM-2, PM-3
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?		• Range of measured permeability - large scale • Pre-Bandelier sedimentology • Effective porosity on a field scale • Head Data - Horizontal Gradients & Vertical Gradients • Determine age and groundwater travel times in regional aquifer • Regional aquifer modeling • Information management • 3-D geologic model • Information management • Baseline geochemistry	• R-6, R-14, R-16, R-24 • OF-2, OF-3, OF-4, OF-7, OF-9, OF-10, OF-11 • A-1, A-2, A-3,A-4, A-5, A-7, A-8, A-9, A-10, A-11 • PM-1, PM-2, PM-3

Table 3: Summary of Hydrogeologic Workplan Decision Status, Data Needs, and Planned Data Collection Activities

Decision	Aggregate 8: Guaje/Bayo/ Rendija	Data Needs	Planned Data Collection (Tables 1 and 2)
Are there sources of sufficient magnitude to cause contamination of groundwater?	No		
Are the alluvial sediments and uppermost subsurface water at contaminant concentrations > regulatory risk limit or risk level?	No		
Is the intermediate perched groundwater at contaminant concentrations > regulatory limit or risk level?	No		
Is the regional aquifer as affected by the canyon systems by contaminant concentrations > regulatory limit or risk limit?	No		
What are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?	No		
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?	No		

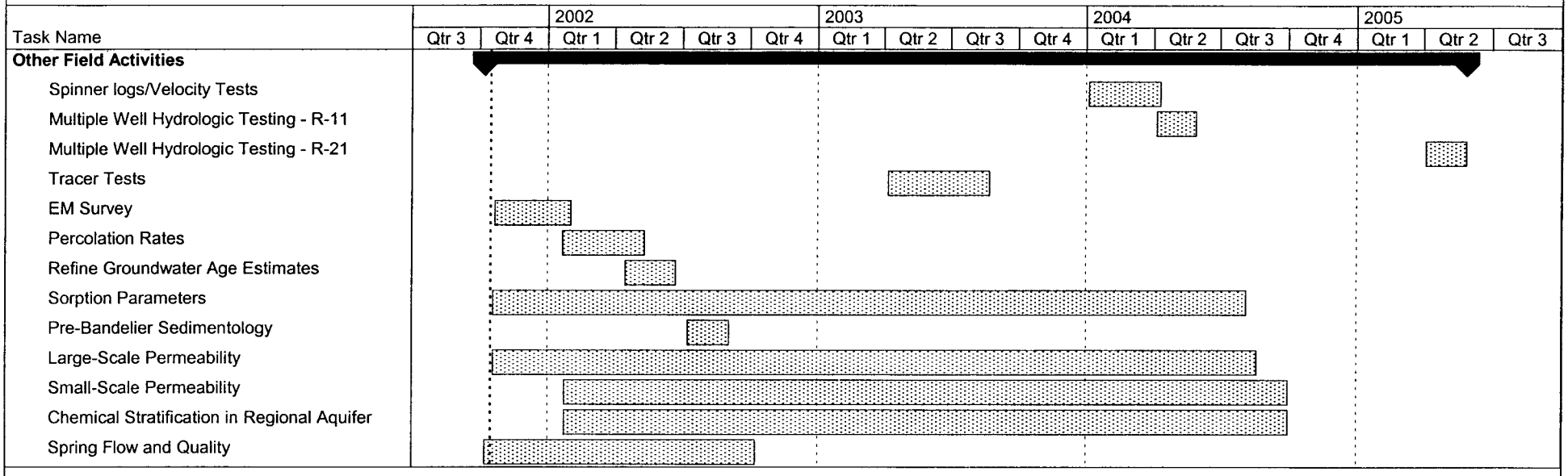
Table 4: Los Alamos National Laboratory Hydrgeologic Workplan
Schedule of Proposed Workplan Activities
October, 2001



Project: iterationschedule
Date: Mon 10/15/01

Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone		Project Summary	
Milestone		Rolled Up Progress		External Milestone	
Summary		Split		Deadline	

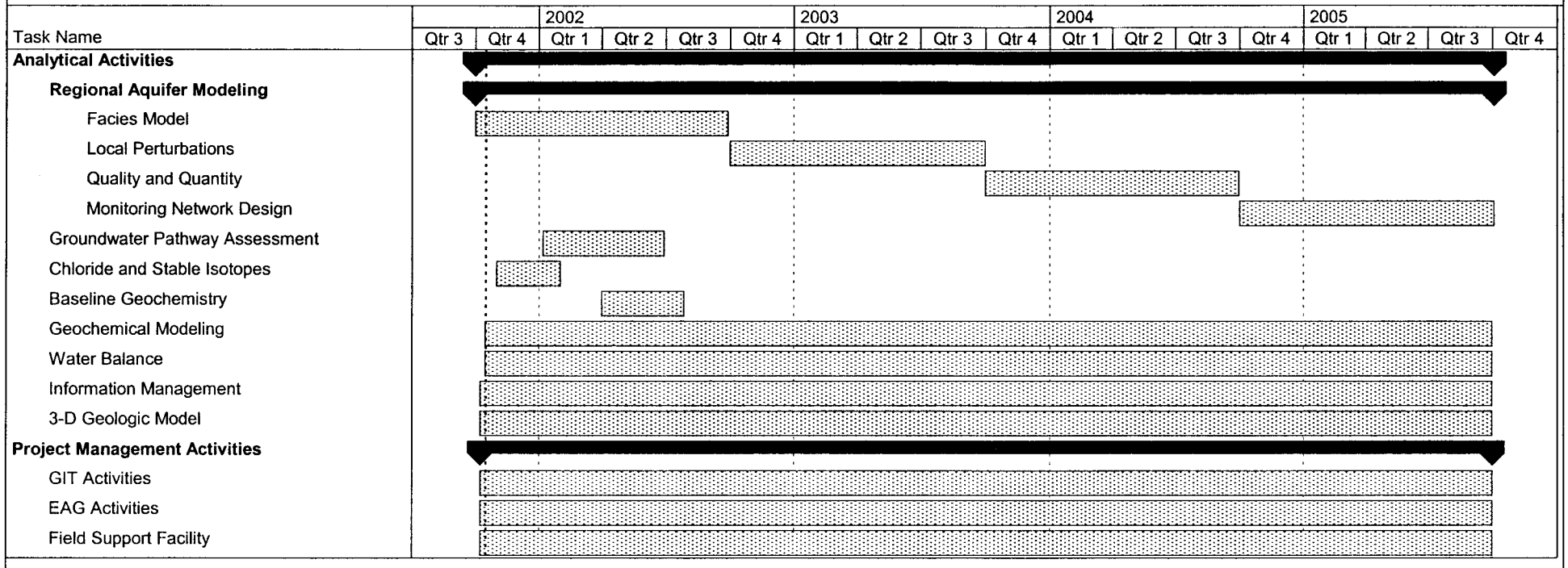
Table 4: Los Alamos National Laboratory Hydrgeologic Workplan
Schedule of Proposed Workplan Activities
October, 2001



Project: iterationschedule
Date: Mon 10/15/01

Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone		Project Summary	
Milestone		Rolled Up Progress		External Milestone	
Summary		Split		Deadline	

Table 4: Los Alamos National Laboratory Hydrgeologic Workplan
Schedule of Proposed Workplan Activities
October, 2001



Project: iterationschedule
Date: Mon 10/15/01

Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone		Project Summary	
Milestone		Rolled Up Progress		External Milestone	
Summary		Split		Deadline	

10/16/01 HWP Meeting

HSWA LANL G/M/HWP 2001

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Proposed Hydrogeologic Workplan Scope
Appendix A
October, 2001

Los Alamos National Laboratory
Hydrogeologic Characterization Program
Proposed Hydrogeologic Workplan Scope
Appendix A
October, 2001

A.1 Introduction

This appendix records the overview portion of the DQO iteration comprehensive evaluation. The following sections are notes taken during presentations made to the LANL Groundwater Integration Team (GIT) between June and October 2001. The presentations were intended to familiarize all of the GIT members with the state of groundwater characterization knowledge and to develop a complete and consistent an understanding of the hydrogeologic system with the available information. The sections in this appendix are:

- Geologic Overview (Greg Cole and David Vaniman)
- Geochemical Overview (Pat Longmire)
- Vadose Zone Hydrology and Modeling (David Rogers and Bruce Robinson)
- Regional Aquifer Hydrology and Modeling (Elizabeth Keating)

A.2 Geological Overview of the Pajarito Plateau

(I) STATUS OF THE 3-D GEOLOGIC MODEL

The site-wide 3-D Geologic Model has been updated and refined several times. Early in FY01, the geology group held a series of meetings to evaluate our understanding of the LANL Site geology, especially with regards to hydrogeology. These meetings identified those data most needed to support conceptual and spatial models and adequate for risk-assessment activities. Some of the data deficiencies have been met by new data from the characterization wells, by reassessment of data and samples from earlier drill holes, by new geologic maps of the Puye and Frijoles Quadrangles, and by Seismic Hazards Program studies.

a) Structure

The current Hydrogeologic Workplan places special emphasis on faults and fractures. There are faults to the north and south of the Laboratory, known from surface mapping, but structure beneath the Laboratory is poorly known. North-south trending faults and other fault sets near the rift margin bound basins and present structures that affect paleogeorgaphy, sedimentation (alluvial, volcanic), and possibly the locations of basaltic volcanic centers and of fossil hydrothermal systems.

Information on faults comes from surface mapping and from the Seismic Hazards boreholes. Two faults were identified in core from SHB-1 (near TA-55), one in a

lava (Cerros del Rio?) and one in Bandelier Tuff. Both faults had abundant sheared clay. Faults along the western boundary of the Laboratory (the Pajarito Fault and splays) are best known, where the Seismic Hazards Program has focused its efforts. These western faults are often filled with clay but have secondary fractures that are transmissive. Clay-filled fault zones may impact flow paths. However, as hydrogeologic entities faults may be most important as pathways in the vadose zone, linking canyons and perched horizons with the regional aquifer. For future work, the new digital elevation model is accurate within ± 0.5 feet and inflections in the surface may be examined to infer buried structure.

b) Stratigraphy

New data from FY00 and FY01 have not yet been incorporated in the current model, and will significantly change both our understanding of the conceptual model and of spatial realization as modeled by the enhanced set of geologic contact information.

Bandelier Tuff

The Bandelier Tuff is reasonably well represented in the 3-D Geologic Model, but thickness and nature of the Otowi remains the least well known part of the Bandelier system. Model thicknesses under canyon bottoms remain suspect (*e.g.*, misprediction of Otowi thickness at R-31). Data from Los Alamos Canyon (LAOI-1.1) show that the Otowi may be extensively altered under some canyon reaches; this alteration may be provide mappable evidence of groundwater incursion into the Bandelier Tuff beneath canyon bottoms. The structure contour map of the base of the Bandelier Tuff suggests possible flow in the Guaje Pumice Bed toward a low in the south-central part of the Laboratory, stratigraphically higher than but coincident with the Purtymun high-yield aquifer. This low crosses between canyons, but it is unknown whether flow can be diverted between canyons at this horizon.

Cerros del Rio

Cerros del Rio lavas and cinder deposits in R-22 were over 1000 feet thick, twice as thick as predicted by the current geologic model. When these new data for the Cerros del Rio are evaluated within the existing set of observations, the impact of paleotopography of ancestral river channels on the deeper spatial distribution of these units will become clearer. These units are important hydrogeologically, as fractures within these basalts can provide laterally extensive zones of high hydraulic conductivity. In addition, preliminary

groundwater chemistry data suggest differences between Cerros-hosted and Puye-hosted groundwater hydrochemistry.

In Cerros del Rio time (principally 2.3 to2.8 million years ago), volcanic flows and cinder deposits extended out over the Puye fanglomerates. Erosional surfaces on the fanglomerates probably led to significant topographic variability entombed at the base of the Cerros del Rio volcanic deposits. River gravels are present beneath the thicker basalts at R-31 but not at R-22; channels beneath the basalt appear to include both local and through-going stream systems. On a broader site-wide basis, contours for the base of the Cerros del Rio define a paleosurface that generally slopes toward the south. In the vicinity of Mortandad Canyon, flow of perched water in the Cerros del Rio basalt may be to the south, following the dip of the unit. Cerros del Rio flows can produce confined/perched aquifers and may provide tabular zones of enhanced flow beneath the water table. Volcanic deposits of the Cerros del Rio have varied hydrogeologic impact because they can occur above, at, and below the water table.

Puye

The Puye Formation is poorly defined beneath the Laboratory. Interplay between fanglomerates shed from the west and the ancestral Rio Grande is not well understood and could be a significant factor in determining groundwater flow transitions between different lithologies. The deeper Puye Formation is vitric to the south and clay-rich to the northeast; clay-altered zones could affect the flow of groundwater. The sources of sediment in the "traditional" Puye Formation show a distinct progression from north to west through time; newly-recognized older (pre-Tschicoma) Puye deposits complicate this picture. The ratio of Rb to Sr is useful in tracking Puye source areas. The transition to deeper pumiceous material in the Puye Formation drops in elevation to the south, consistent with the presence of a major basinal structure under the central-southern Laboratory.

There is a continuum of Keres/Polvadera volcanic activity that provided volcanics and volcanogenic sediments and fanglomerates from the west, mixing with axial gravels from the north and plutonic/metamorphic detritus from the east. Axial river gravels may or may not provide a contiguous hydrostratigraphic unit. If the gravel units maintain continuity through significant portions of the lab area, they could provide buried channels of focused groundwater flow.

Deeper Units

The nature of the Puye/Santa Fe contact is poorly defined stratigraphically. Much of the deeper sedimentary material previously classified as Santa Fe is in fact earlier Puye-type volcanogenic material provided by sources that were closer

and depositionally more energetic than the Santa Fe system. Spatial and compositional anisotropy where the Santa Fe depositional system abuts the Puye may be more properly represented as interfingering, provenance-distinct wedges that can be mapped into the 3-D Geologic Model.

(II) ALTERATION AND CONTAMINANT SYSTEMS

a) Alteration and Contaminant Identification

Hydrothermal alteration is suspected in the lower Puye beneath the northeastern portion of the Laboratory, where clay-rich Puye sediments from R-9 and R-12 are alkali-depleted when compared with comparable unaltered pumiceous Puye sediments from R-19. Equivalent clay zones in the Totavi type locality include zeolites and complex manganese-oxides. These alteration features are associated with enrichments of some elements (*e.g.*, Ba and Sr) that can also occur as contaminants and could be misinterpreted as such. Understanding of alteration zones with perturbed chemical signatures is vital if confusion is to be avoided.

Generally, rocks that make up the Pajarito Plateau (Bandelier Tuff, Cerros del Rio lavas, Puye Formation, Santa Fe Group) have a strong coherence in U/Th ratios. A sample from R-9 at 283 feet depth has 39% clay and abnormally high uranium content, suggesting that deviations from regional geochemical trends might be used to determine mechanisms, locations, and amounts of contaminant accumulation in the natural system (a test of natural retardation).

b) How the Hydrogeologic System Behaves Geochemically

There are clay zones in R-9, R-12, O-1, and R-5 where extensive alteration has occurred, but such alteration is missing at R-19, CdV-R-15-3, R-22, and R-31. The newly-recognized lower pumiceous subunit of the Puye is completely clay altered at R-9 and R-12, but apparently not to the west and south, though the depths and extents of these clay zones are not yet known. The spatial restriction of alteration is an important component of site geology that is poorly understood. Preservation of glass in the pumiceous Puye well below the current water table contrasts with significant alteration of glass above the water table in the Otowi beneath some canyons (*e.g.*, LAOI-1.1). The pumiceous Puye above the current water table to the east in Los Alamos Canyon (*e.g.*, R-9) is also altered, but the type and extent of alteration differs from that in the Otowi. Preservation or loss of glass, and the alteration products formed from glass, are hydrogeologic parameters that provide information about reactive transport pathways that is yet to be interpreted.

c) Pathways and Mechanisms of Movement

The translocation of clays in Cerros del Rio basalts can be seen in the clay content in intermediate boreholes MCOBT-4.5 and MCOBT-8.5. In MCOBT-4.5 clay has accumulated near the top of Cerros del Rio basalt. In MCOBT-8.5, there is not much clay near the top, but there is a peak in clay content in the lower part of the Cerros del Rio. This may be the result of translocation of clay through fractures, but this has yet to be demonstrated. Lanthanide-element signatures and other geochemical parameters could be used to assess whether the clay formed in situ or was translocated. Generally the lanthanides behave as a family, but Ce can be segregated where oxidizing groundwater or mineral-surface oxidation occurs (especially on Mn-oxide mineral surfaces). Flow directions and redox reaction rates can be determined from studies of clay, Mn-oxide, and other secondary mineral systems. Most importantly, clays are likely to be the predominant colloid formers in the flow system.

Near-surface (to 20 m depth) clays studied at Pajarito Mesa show that heavy metals that are redox-sensitive are strongly held by Mn oxides. This phenomenon was studied at Yucca Mountain by examining what happens to Ce (a Pu analog) in the presence of Mn oxides. These studies show that Ce is removed from groundwater by manganese oxides along all vadose-zone pathways within flow distances of a few tens of meters. Positive Ce anomalies can be used to identify those portions of the hydrogeologic system where redox-sensitive heavy metals (particularly PU may accumulate.

(III) Evaluation of Data Needs (Geologic System): Some New Directions

Some key components of the geological system to be considered in DQO reassessment are:

(1) What are the relations between lithology and permeability and does lithology play a role in flow (this question needs to be addressed in both the vadose zone and in the regional aquifer)?

(2) What role does lithology play in transport (reactive transport)?

(3) What role does lithology play in groundwater chemistry (cation composition, phase saturation, Eh, and colloid formation in particular)?

(4) What do we need to provide to show that we have addressed the need to understand "basic geology, hydrogeology, and pathways for contaminant transport" (NMED, 1995)?

A.3 Geochemical Overview of the Pajarito Plateau

Purpose and Scope

The purpose of this presentation is to provide a detailed discussion on data quality objectives (DQOs) relevant to geochemical investigations conducted by the Geochemistry Subcommittee of the Groundwater Integration Team (GIT). To date (FY2001), the Laboratory has drilled 15 characterization wells (R wells) to address technical and regulatory issues presented in the Hydrogeologic Workplan, the Hazardous and Solid Waste Amendments (HSWA) permit, and ER Project Workplans for canyons. These DQOs provide input to well drilling, well design, well development, analytical methods, data validation, characterization and monitoring parameters, monitored natural attenuation (MNA), potential groundwater remediation strategies, and pathway analysis for contaminant transport. During the evolution of well drilling, the type and quality of geochemical data have changed depending on well-specific DQOs. It is very appropriate to reevaluate geochemical data needs and to define future data needs for the remaining characterization wells.

Overview

Groundwater occurs in three zones beneath the Pajarito Plateau: alluvium, perched intermediate, and the regional aquifer. Due to geochemical processes (precipitation/dissolution and adsorption/desorption) and residence time, the natural composition of groundwater can vary between and within these zones.

Groundwater Flow and Contaminant Distributions

Alluvial groundwater flows down canyons, generally to the east-southeast, including Los Alamos Canyon, Water Canyon, Cañon de Valle, and Pajarito Canyon. Alluvial groundwater also occurs within canyons that were dry but have received long-term discharges from the Laboratory. These include Mortandad Canyon and Sandia Canyon. Alluvial aquifer materials provide the largest reservoir for effluent-derived constituents such as strontium-90, cesium-137, plutonium-238, plutonium-239,240, and americium-241. These constituents adsorb onto clay- and silt-sized materials resulting in decreased mobility. Non- and semi-sorbing constituents can migrate from alluvial groundwater to perched intermediate zones eventually reaching the regional aquifer. These constituents include perchlorate, tritium, nitrate, and high explosive compounds and associated degradation products.

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Adsorption processes dominate over mineral precipitation for removing metals and radionuclides from groundwater, based on field investigations and geochemical modeling. However, in isolated cases where effluent discharges have changed the alkalinity, solute concentrations, and pH elements such as strontium and barium may precipitate as $SrCO_3$, $BaCO_3$, and coprecipitate as $(Sr\text{-}Ba)SO_4$ in alluvial groundwater. Strontium-90 is influenced by both processes due to the moderately low solubility ($10^{-9.27}$ moles/liter) of $SrCO_3$.

Impacts from the Cerro Grande Fire

The Cerro Grande fire (May 2000) is example of a process that has significantly perturbed surface water and alluvial groundwater chemistry. Ash produced from the fire has been transported within canyons reacting with rain and surface water. Increasing concentrations of dissolved organic carbon, carbonate alkalinity, calcium, potassium, iron, manganese, and other solutes occur in surface water and alluvial groundwater since the Cerro Grande fire. Oxidation and reduction reactions between organic-rich ash and metals and radionuclides, in addition to carbonate complexation, influence aqueous speciation of solutes. Alkalinity affects the mobility (increases desorption) of radionuclides such as uranium, plutonium, and americium. In most canyons, carbonate alkalinity in surface water has increased by a factor of 5-6 since the fire. Surface water and alluvial groundwater have shown increases in turbidity due to the ash and enhanced erosion. Colloid transport in the subsurface is possible under these conditions depending on particle size, surface chemistry of the particles, and aquifer porosity.

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Los Alamos National Laboratory
Hydrogeologic Characterization Program
Proposed Hydrogeologic Workplan Scope
Appendix A
October, 2001

Perched Saturated Zones, Flow Paths, and Residence Time (Age)

Perched intermediate zones of saturation occur beneath several canyons, including Pueblo Canyon, Los Alamos Canyon, Sandia Canyon, Mortandad Canyon, and Cañon de Valle. Perched zones possibly occur beneath Pajarito Canyon, however, there are no wells at present to verify this. Based on hydrostratigraphy, hydraulic gradient, hydraulic conductivity, and porosity, shallow groundwater infiltrates below the alluvium/bedrock contact. This provides a line source of recharge to underlying saturated zones within canyons.

A component of groundwater within perched intermediate zones and the regional aquifer (at and near the regional water table) is less than 60 years old, based on measurable tritium activities that are considerably above the cosmogenic baseline of 1 pCi/L. The Laboratory began operations in 1941 and aqueous effluents were associated with the Manhattan Project. Other chemicals such as perchlorate and nitrate provide additional information on recent recharge to perched zones and the regional aquifer. Portions of the regional aquifer also contain groundwater in excess of 10,000 years based on preliminary ^{14}C dating. Portions of the regional aquifer are dead with respect to tritium (<0.5 pCi/L).

Flow path(s) for alluvial groundwater, which recharge underlying aquifers can be represented by a stepwise function based on permeability contrasts due to the presence of clay minerals and fine-grained material (silt). These materials serve as perching layers and aquitards. Clay minerals can adsorb contaminants (cations) and need to be included in evaluation of monitored natural attenuation (MNA).

The aqueous chemistry of the regional aquifer changes with depth and position along the flow path(s). Groundwater varies from calcium-sodium bicarbonate to sodium-calcium bicarbonate compositions with pH values typically between 6.5 and 8.5. Concentrations of calcium, sodium, and bicarbonate contribute to increasing TDS within perched zones and the regional aquifer. Residence times of groundwater and chemical solutes (mass of water or solute/flux of water or solute) increase with depth and from west to east across the Pajarito Plateau. The TDS increase with depth is remarkably consistent. The TDS also increases from west, near recharge zones within the Sierra de los Valles, to east along the groundwater flow paths. Discharge zones for perched systems and the regional aquifer occur along cliff faces above and at the Rio Grande, respectively, within White Rock Canyon. Concentrations of trace elements including arsenic, barium, boron, bromide, and strontium increase with depth.

Summary of Borehole and R Well Chemistry (FY2001)

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To date, 15 R-wells have been drilled, developed, and sampled. Thirteen of the

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data obtained from characterization samples, including borehole and well samples, is provided in Table A-1.

Table A-1: Summary of Selected Constituents Measured at Boreholes and R Wells (Screening Samples)

Well	Zone	Sample	Contaminant	Concentration
R-9	perched	borehole	uranium	48 µg/L
R-9I	perched	well	uranium	0.64 and 0.07 µg/L
R-9	perched	borehole	tritium	106 and 347 pCi/L
R-9I	perched	well	tritium	246 and 167 pCi/L
R-9	regional	borehole	tritium	14.43 pCi/L
R-9	regional	well	tritium	4.84 pCi/L
R-12	perched	borehole	nitrate (N)	4.93 and 5.50 mg/L
R-12	perched	well	nitrate (N)	<0.10 and 0.13 mg/L
R-12	perched	borehole	tritium	255, 208, and 249 pCi/L
R-12	perched	well	tritium	189 and 111 pCi/L
R-12	regional	borehole	tritium	46.9 pCi/L
R-12	regional	well	tritium	64 pCi/L
R-15	perched	borehole	perchlorate	12 µg/L
R-15	perched	borehole	tritium	3770 pCi/L
R-15	regional	borehole	tritium	1.12 pCi/L
R-15	regional	well	tritium	0.77 pCi/L
R-15	regional	borehole	nitrate	<0.01 mg/L
R-15	regional	well	perchlorate	4.19 µg/L
R-15	regional	well	nitrate	2.30 mg/L
R-19	perched	borehole/well	none	
R-19	regional	borehole/well	none	
R-22	regional	borehole	tritium	109 pCi/L
R-22	regional	well	tritium	2.0 pCi/L
R-22	regional	well	uranium	16.9 µg/L
R-22	regional	well	technicium-99	4.9 pCi/L
R-25	perched	borehole	HMX, RDX, TNT	12, 84, and 19 µg/L
R-25	perched	borehole	tritium	77.2, 81.4, 44.7 pCi/L
R-25	perched	well	tritium	16.5, 43.5, 21.1, 13.1 pCi/L
R-25	perched	well	HMX, RDX, TNT	4.9, 65, 0.36 µg/L
R-25	perched	well	PCE, TCE, toluene	1.3, 1.8, 15 µg/L
R-25	regional?	borehole	HMX, RDX, TNT	9.7, 62, 7.1 µg/L
R-25	regional?	well	HMX, RDX, TNT	4.1, 28, 2.2 µg/L
R-25	regional?	well	TCE, Toluene	1.2, 2.5 µg/L
R-25	regional?	well	tritium	8.4, 8.1 11, 11.7 pCi/L
CdV-15-3	perched	borehole/well	none	
CdV-15-3	regional	borehole/well	none	
R-31	perched	borehole/well	none	
R-31	regional	borehole/well	none	
MCO-	perched	borehole	perchlorate, tritium,	120 ppb, 2020 pCi/L,

BT-4.4			nitrate (N)	7-10 mg/L

Uranium, tritium, high explosive compounds, perchlorate, nitrate, and chlorinated solvents have been detected in R wells completed either in perched zones and/or the regional aquifer. These chemicals are mobile in the subsurface and are not completely removed from groundwater by dispersion, mixing, and biodegradation.

Sources of tritium discharged into Los Alamos Canyon include TA-2 and TA-21. At R-9, activities of tritium range from 100 to 300 pCi/L, which confirms that the regional aquifer has been recharged by surface water since the early 1940s. Elevated concentrations of nitrate (R-12) and high explosive compounds (R-25) also provide evidence of surface water infiltrating to perched groundwater and, in some cases, to the regional aquifer.

In 1999, elevated activities of tritium occur in alluvial (80-29,300 pCi/L) and perched groundwater (2,020 and 3,770 pCi/L) in Mortandad Canyon. Tritium activities, however, are much lower in the regional aquifer at R-15 (< 3 pCi/L) due to its short half life (12.43 yr) and travel times through the vadose zone. Although activities of tritium are less than 3 pCi/L, concentrations of nitrate (N) are elevated above baseline (0.5 mg/L). This suggests that nitrate, in the form of dissociated nitric acid and possibly urine from bioassay analyses, was discharged to Mortandad Canyon prior to tritium releases (TA-50). Nitrate (N) concentrations in R-15 increased from the borehole sample (<0.02 mg/L) to 2.30 mg/L in the well. It is possible that the aquifer testing which involved pumping the well (R-15) enhanced migration of a nitrate plume in the regional aquifer.

Water Quality Impacts from Drilling Fluids

Groundwater borehole and well samples are a proxy to pre-drilling groundwater conditions. The drilling process significantly affects the composition of groundwater, especially if drilling fluids are used. Oxidation-reduction reactions occur when EZ-MUD is used during well drilling for lubricity. EZ-MUD eventually biodegrades and oxidizes to inorganic carbon (alkalinity) and solutes such as sulfate, nitrate, and dissolved oxygen and oxide and hydroxide minerals containing iron(III) and manganese(III, IV) are reduced. These minerals have increased solubilities under reducing conditions where Fe(II) and Mn(II) are soluble solutes.

Examples of drilling fluids including EZ-MUD and QUIK-FOAM impacting water chemistry are presented below. When R-9 was drilled in late 1997 and early 1998, perched groundwater collected from the borehole at a depth of approximately 275 ft contained 48 μg/L dissolved uranium. Based on this

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analytical result and upgradient source terms containing uranium, R9I was drilled to further characterize the two perched zones (175 and 275 ft) within the Cerros del Rio basalt. R-9I was drilled with fluids (EZ-Mud and QUIK FOAM), and concentrations of uranium in the upper and lower perched zones are 0.64 and 0.07 μg/L. The apparent decrease in uranium concentration could be the result of changes in the oxidation-reduction conditions with the introduction of drilling fluids. These reducing conditions enhance adsorption and precipitation of uranium. Another possibility is that during initial drilling, fresh mineral surfaces were exposed and uranium desorbed from mineral surfaces resulting in a temporary increase in uranium concentrations. If this process accounts for the elevated uranium, then this analyte should be observed in similar concentrations at R-12, R-15, R-19, and R-31 that penetrated the Cerros del Rio basalt. Anomalous uranium to thorium ratios (approximately 3) for clay minerals at R-9, however, suggests that additional uranium has been introduced to the system. Typical uranium to thorium ratios are approximately 0.25 or less for the Bandelier Tuff and Cerros del Rio Basalt.

EZ-MUD consists of a copolymer (polyacrylamide ($(-CH_2CHCONH_2-)_n$)-polyacrylate ($(H_2C=CH-COO^-)_n$)) containing nitrogen, carbon, and hydrogen. Analyses of groundwater collected from R-7, R-9I, R-19, R-22, R-31, and CDV-15 resulted in false positives for RDX, TNT, 2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene, and 3-nitrotoluene due to residual EZ-MUD. These false positives are based on similar chemical structures between RDX, including $C-N-NO_2$ functional group, and the copolymers comprising EZ-MUD.

During drilling of R-7 and R-22, acetone was apparently detected at the regional water table. Presence of this organic compound may be due to oxidation of QUIK-FOAM used during drilling, which contains isopropyl alcohol. Isopropyl alcohol has the same retention time and mass units very similar to acetone. The overall oxidation-reduction reaction leading to the formation of acetone is:

$$CH_3CHOHCH_3 + 0.5O_2 = (CH_3C)_2CO + H_2O.$$

The Groundwater Focus Area suspects that the results reported for acetone from the analytical laboratory are false positives from the isopropyl alcohol, which is supported by the mass spectral data. Acetone is being misidentified because the secondary ion for isopropyl alcohol is 43, which is the primary ion for acetone. The analysis of the QUIK-FOAM confirms this suspicion.

Migration of Contaminants

Other contaminants including actinides, metals, and fission products are found within alluvial groundwater (Los Alamos Canyon and Mortanadad Canyon) that adsorb onto sediments and migrate at different rates through the subsurface. It is important to evaluate the transport of these constituents

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because of their potential rusk over 1,000 years.

With regard to interconnection between alluvial groundwater, perched zones, and the regional water table, contaminant source terms correlate reasonably well with the downgradient characterization wells. Non-adsorbing contaminants (perchlorate, nitrate, RDX, and TNT) are the most mobile and travel the furthest distances along groundwater-flow paths. **Perchlorate, RDX, and TNT are the present day risk drivers for groundwater at the Laboratory because their action and/or health advisory levels are less than 20 μg/L.** We observe concentrations of these chemicals in groundwater above recommended health and action levels in several wells (MCOBT-4.4, R-25, and alluvial wells). They are persistent chemicals in the environment.

A.4 Overview of Pajarito Plateau Vadose Zone Hydrology and Modeling

Definitions:
Infiltration - water flowing into a material at its atmospheric interface
Percolation - flow through porous media
Recharge - addition of water to a saturated zone
Vadose - the geologic media between the land surface to regional aquifer, including unsaturated materials, water in capillary fringes, and perched zones.

Infiltration of surface water flow (caused by effluent discharges, spring discharge, or stormwater runoff) maintains shallow groundwater in the alluvium of some canyons. Alluvial groundwater is unconfined and is perched on underlying Bandelier Tuff, Cerros del Rio basalts, or Puye Formation. Evapotranspiration and percolation into the underlying rocks deplete alluvial groundwater as it moves down the canyons. Alluvial groundwater is a source of recharge to underlying intermediate perched zones and to the regional aquifer, usually by unsaturated flow.

Dry canyons have little surface water flow. In these canyons groundwater may occur seasonally in the alluvium. Dry canyons are generally those that head in the eastern portion of the Pajarito Plateau.

In wet canyon bottoms, infiltration of surface water maintains shallow groundwater in the alluvium. Wet canyons generally have large surface water flow, head in the Jemez Mountains, or receive effluent discharges. Groundwater levels are typically highest in the late spring due to snowmelt runoff and in mid-to-late summer due to thunderstorms. Groundwater levels and extent of

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saturation decrease during the winter and early summer when runoff is at a minimum.

Water quality of the alluvial groundwater reflects the composition of storm runoff, snowmelt, and effluent discharges where present. In canyons affected by effluents, the alluvial groundwater and sediments contain the majority of adsorbing contaminants (such as plutonium). Mobile solutes (such as tritium, high explosive compounds, and anions) migrate with moving groundwater, and are present in recharge.

Recharge from alluvial groundwater by unsaturated flow accounts for an important source of contaminants in recharge and relatively rapid rates of groundwater flow (reaching the regional aquifer in decades or less). In some cases recharge might occur by saturated flow. Faults, fractures, joints, surge beds, and higher permeability geologic units that underlie saturated alluvium (such as the Guaje Pumice Bed, Cerro Toledo Interval, Cerros del Rio basalts, and Puye Formation) could provide pathways for downward movement of water and contaminants.

Intermediate perched zones occur beneath major canyons and in the western portion of the Laboratory. Intermediate perched zones are found particularly beneath wet canyons that receive effluent discharges, have large surface water flow, or head in the Jemez Mountains. These intermediate perched zones occur in the Guaje Pumice Bed at the base of the Bandelier Tuff, the underlying Cerros del Rio basalts, and the Puye Formation. The location of intermediate perched zones is determined by presence of sufficient recharge, permeability variations of the rocks (reflecting lithologic variations), and geologic structure. Intermediate perched zones may be confined or unconfined. Discharge at springs and percolation into the underlying rocks (resulting in recharge to the underlying regional aquifer) deplete intermediate perched groundwater.

Intermediate perched zones beneath canyons do not generally extend laterally beneath the mesas. Neither are the intermediate perched zones continuous along the length of the canyon. Variations in stratigraphy and in both recharge and percolation losses along the canyon cause changes in thickness or presence of the intermediate perched zones. Lateral movement of intermediate perched groundwater away from the canyon axis may occur if the dip of the perching horizon and the canyon orientation do not coincide.

In the western portion of the Laboratory, groundwater has been observed to occur as a large (300 ft-thick in well R-25) intermediate perched zone within the

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lower Bandelier Tuff and the Puye Formation, approximately 700 ft below the mesa top. Most recharge for this zone originates as underflow of groundwater from the Jemez Mountains, with some contribution from recharge through mesas and canyon bottoms. Percolation losses from this intermediate perched zone result in recharge to the underlying regional aquifer.

If discharges from the Lab cease, the changes in vadose zone moisture content would vary on a canyon-by-canyon basis. For example, Mortandad Canyon has significant water input from the TA-50 treatment plant. Water in vadose zone moves downward due to gravity, but with a decrease in percolation rate it will move more slowly

Percolation rates are different beneath the canyons and within the mesas. Percolation rates beneath mesas are less than 1 mm/yr or less but vary across the lab due to the variability in precipitation and vegetation with elevation. Beneath canyons, percolation rates range from about 10 to 1000 mm/yr. Based on model results, uncertainty in the percolation rates beneath Los Alamos Canyon is +/- a factor of 3. A question that the GIT must consider is "Do we need to know this better?". One outcome might be that it's not cost effective or possible to know it better. However, another outcome is that is important to reduce the uncertainty. In a few units (for example, the Otowi member) the range in values of hydrologic properties is due to variability in texture. More measurements will not reduce that range of values. The range is the result of variability, not uncertainty. Moisture content measurements and water budgets can only reduce uncertainty in travel times to about one order of magnitude. Joint inversion of moisture content and contamination front data can reduce this uncertainty.

Water flow under unsaturated conditions is principally 1-dimensional and downward. There is lateral diversion beneath regions of high infiltration where low permeability barriers restrict downward percolation; examples: alluvial water, Bandelier tuff perched water, and Puye formation perched water. There has been rapid lateral transport over some distance along canyons. Examples in the alluvial groundwater include a tracer test in Mortandad Canyon and movement of tritium in Los Alamos Canyon. There has also been rapid lateral diversion to canyons from mesas, with travel times of months; examples: within mesa at TA-16; tracer tests and geochemical monitoring (Newman).

Velocity and direction of flow in intermediate zones is uncertain. Velocity in perched zones can be conceptualized with a bathtub model as a trough with water piled up inside and slow percolation out, resulting in a delay in flow time. Another conceptual model is of lateral diversion and flow through porous media. Modeling done so far has been based on the lateral diversion porous flow and it

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does reproduce the perched zones. Even if you could map a perched zone, it would be difficult to know what it means for transport to the regional aquifer. A third conceptual model of flow in the perched zones is lateral diversion model with fast-path flow. It is difficult to distinguish between the two lateral diversion models. Flow direction is controlled by the dip of the unit on which perching occurs and/or the dip of local permeability features not represented in the geologic model.

Although current modeling (such as for Los Alamos Canyon) uses perched intermediate zones, it is difficult to have enough data to fully map, define flow paths, and predict transport velocity. For example, the Los Alamos Canyon weir wells are close enough to begin looking at the perched zones, but we still have not figured them out. Three wells in Mortandad Canyon drilled a short distance apart to the perched zones found very different stratigraphy and saturation. If the aerial geophysics are successful in locating intermediate perched zones, there are still questions of saturated thickness, flow direction, and velocity. Is it realistic to try to map out pathways from the perched zones? Should resources be put into continued investigations in the perched zones?

In summary, what we've found so far is that the intermediate perched zones (except for the one under TA-16) are very thin and discontinuous. They seem not to hold a large volume of water or to have very large extent. Because of their small size and discontinuity, it is likely that the intermediate perched zones' role in contaminant transport isn't that great in terms of water volume. Also because of their small size and discontinuity, it is difficult to obtain sufficient detailed information (in a cost effective fashion) to adequately portray these intermediate perched zones in a model. Small variations in geology such as the presence or thickness of a soil zone or an ash layer within a basalt sequence will cause a local perched zone to form, but these stratigraphic variations cannot be reasonably predicted in the subsurface. The characterization effort should pursue relatively inexpensive methods such as the geophysical techniques to "image" the intermediate groundwater without making false promises about our ability to figure out the details. The reason for the geophysics, combined with ground truth from the well drilling program, is to make a best effort at characterizing the perched water, while at the same time pursuing the bounding analyses are proposed. This would provide confidence that we made a good faith attempt to figure out the intermediate groundwater (and in fact learned something about them, though not everything there is to know) but also honestly acknowledged the inherent limitations and came up with a rational alternative to a rigorous characterization of this groundwater.

Water quality within intermediate perched zones reflects that of the recharge water including precipitation and runoff, effluent discharges, and native

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groundwater. Flow within intermediate perched zones could transport contaminants some distance away from their surface source.

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Summary of Available Information on Vadose Zone Hydrology & Modeling

Sources/ Pathways	Aggregate 1: Los Alamos/ Pueblo	Aggregate 2: Cañada del Buey/ Pajarito	Aggregate 3: TA-49	Aggregate 4: Ancho/ Indio/ Chaquehui	Aggregate 5: Cañon de Valle	Aggregate 6: Water/ Potrillo/ Fence	Aggregate 7: Mortandad	Aggregate 8: Guaje/ Bayo/ Rendija
Sources	Liquid waste discharges, MDAs, reactors	MDA G, L	Underground testing debris	Firing sites, tritium production, landfills	Liquid waste discharges (HE)	Firing sites	Liquid waste discharges	Firing sites, liquid discharges
Pathways/ transport modes	Percolation of alluvial groundwater	Vadose zone percolation	Vadose zone percolation	Percolation of alluvial groundwater?	Percolation of alluvial groundwater, underflow from Jemez Mtns.	Percolation of alluvial groundwater	Percolation of alluvial groundwater	Vadose zone percolation?
Data Needs								
Presence of intermediate perched groundwater	Limited extent and continuity beneath canyons?	No perched/ limited extent beneath Pajarito Canyon?	No perched?	No perched?	Extensive thick zone recharged from Jemez Mtns.?	No perched?	Limited extent and continuity beneath canyons?	No perched?
Subsurface contaminant distribution	Perchlorate beneath Pueblo, tritium, strontium-90	Organic solvents, radionuclides ?			Extent of HE and solvents in perched zone		Extent of radionuclides, nitrate, and perchlorate in vadose zone	
Geologic Information		Structure of basalt controls vapor movement, regional aquifer and		Geology of near-Rio Grande faults, basalts could control regional aquifer and			Structure of basalt controls perched zone flow?	

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Sources/ Pathways	Aggregate 1: Los Alamos/ Pueblo	Aggregate 2: Cañada del Buey/ Pajarito	Aggregate 3: TA-49	Aggregate 4: Ancho/ Indio/ Chaquehui	Aggregate 5: Cañon de Valle	Aggregate 6: Water/ Potrillo/ Fence	Aggregate 7: Mortandad	Aggregate 8: Guaje/ Bayo/ Rendija
		vadose zone flow?		perched flow systems				
Recharge distribution	Percolation of alluvial groundwater				Percolation of alluvial groundwater, perched zone recharge		Percolation of alluvial groundwater	
Percolation processes		Percolation beneath dry mesa?						
Hydrologic data					Extent of perched zone			

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A question that isn't being adequately addressed is the distribution and rates of percolation. A way to collect this type of data is to drill a few shallow wells in a canyon to look at moisture and contaminant distribution. The deeper wells shouldn't be used for this purpose because they need to be focused on presence of water at greater depths. The shallow wells would be used for estimating percolation rates and travel times. R-well drilling program may be over-emphasizing intermediate groundwater investigation at the expense of less data from the regional aquifer. Bounding approaches for handling the intermediate groundwater are needed.

A Path Forward:

The issue of how to treat intermediate perched zones hinges on several considerations: how do the perched zones affect contaminant pathways and travel times?

Pathways - incorporate perched water representation into vadose zone models, capturing the extremes of behavior - bathtub versus lateral flow fast path. Perform site-wide analysis of potential flow path directions based on geologic model and simple conceptual models of lateral diversion. Test against available data. Determine whether uncertainties in lateral transport significantly affect the prediction of the location of contaminant arrival at the water table. Bracket travel times to the water table by:

- 1-D travel times and directions, from surface to regional aquifer (longest time)
- 1-D travel time to perched zone only, short circuit to water table after that (shortest time)

Travel time - Using a back-of-an-envelope calculation it is clear we need to know the wet canyon travel times better. Hydrostratigraphy of vadose zone is important. Estimates of uncertainty of thickness in units such as Bandelier tuff. Infiltration indices for canyon drainages from 1 (driest) to 5 (wettest) net infiltration.

Reduce uncertainty -

- geologic model needs to estimate uncertainties (e.g. in unit thicknesses) but focus on uncertainties that matter to travel time and continue to update geologic model with new data
- migration rate using water budget studies, infiltration monitoring sites, shallow boreholes to measure water contents and migration fronts of contaminants, e.g. nitrate profile in R-15

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A.5 Overview of Regional Aquifer Hydrology and Modeling

This summary attempts to provide an overview of our current knowledge and determine outstanding data needs regarding 1) groundwater flow directions and velocities, and 2) contaminant transport in the regional aquifer; however, we emphasizes data needs regarding (1). This emphasis is reasonable since it addresses basic characterization requirements and also gives us the necessary information to predict migration of highly mobile contaminants which could pose the greatest threat to water quality. Characterization of aquifer properties that control retardation of contaminant migration (essential to (2), for some contaminants) is best addressed on a site- and contaminant-specific basis and is outside the scope of this document.

Flow Directions

Flow directions in the regional aquifer are determined by hydraulic gradients and permeability variations within the aquifer. Variations in both gradients and permeability are expected to be scale-dependent. Characterizing large-scale flow directions (at the scale of the LANL site: kilometers to tens-of-kilometers) is the highest priority; followed by medium-scale flow (hundreds to thousands of meters). The importance of quantifying small-scale variations (tens to hundreds of meters) should be evaluated on a case-by-case basis according to site-specific monitoring and/or environmental restoration issues.

Permeability characterization

The regional aquifer beneath the Pajarito Plateau occurs in rocks of the Puye Formation, the Cerros del Rio basalts, the Tschicoma Formation, and the Santa Fe Group. The hydraulic conductivity of aquifer rocks is heterogeneous and averages approximately 140 m/yr. The aquifer is unconfined in the west and confined or partially confined in some locations near the Rio Grande.

<u>Large-scale permeability variations</u>

The best indicators of large-scale permeability variations (over 100's to 1000's of meters) are water level responses to long-term pumping, spatial variation in water levels across the plateau, and multi-hole pump tests. No multi-hole pump tests have been conducted to date.
If the total flux of water through the aquifer is reasonably well-known, water level data can be analyzed using a numerical flow model to estimate large-scale permeability of hydrostratigraphic units within the aquifer. Analysis of historical streamflow data along the Rio Grande has provided both an estimate of mean flux and associated uncertainty. Combining this flux information and water level

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data (both present and historical) with our flow model for the aquifer, we have estimated large-scale permeability of the major aquifer units. For the sedimentary rocks, there are relatively small differences between units (less than one order of magnitude). There are insufficient water level data available to estimate permeability of other units (basalts, dacite flows) using this method.

Unit	Estimated permeability (m^2)	95% Confidence Limits
Santa Fe Group (lower)	-13.33	+/- 0.25
Santa Fe Group ("Los Alamos aquifer")	-12.99	+/- 0.30
Puye Formation	-12.74	+/- 0.46

Medium-scale permeability variations

Our estimates of medium-scale permeability are derived from single-hole pump tests in water supply wells screened over ~2000'. These estimates are representative of the rock within within tens of meters to a few hundreds of meters of the boreholes. Estimates are only available for the Santa Fe Group (both lower and "Los Alamos Aquifer" facies). Other units such as basalts and Puye were present in many of these boreholes; the effect of these units on test results is unknown.

Unit	Mean permeability (m^2)	Max/Min	Number of te
Santa Fe Group (lower)	-12.5	-12.26/ -12.84	12
Santa Fe Group ("Los Alamos aquifer")	-11.2	-11.94/ -11.67	3

These estimates are noticeably higher than the large-scale estimates (described above). Possible reasons for this discrepancy are 1) large-scale features that single-well pump tests cannot detect, such as low-permeability faults (trending N-S), 2) the fact that pump test data are entirely derived from water supply wells, which may have been purposely sited in relatively high-permeability zones within the Santa Fe Group, and flow model errors such as 3) underestimation of total flux through the aquifer, and/or 4) overestimation of the total thickness of the aquifer. We are using sensitivity analyses to evaluate the plausibility of (3) and (4); preliminary results indicate that neither of these factors can explain the discrepancy. Additional pump test data, particularly 2 or 3-hole pump tests, are needed to evaluate (1) and (2).

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These data clearly suggest that there are relatively high-permeability zones within the Santa Fe Group. At present, we do not have a geologically-based conceptual model of the structure of these high-permeability zones.

Small-scale permeability variations

Hydraulic test data from wells screened over relatively short intervals (e.g. R-wells) demonstrates variability over 4 orders of magnitude exists within the Puye Formation and the basalt flows. Although no such data exist for the Santa Fe group, it is reasonable to assume that similar variability exists within these rocks.

Conclusions

At large-scales, our estimates of the permeability of sedimentary units are very well constrained. However, there are small and medium-scale variations within these units that we do not understand. There are two important aspects to addressing this problem. First, we need larger-scale hydraulic tests (multi-hole tests) that can help us understand the discrepancy between permeability estimates derived from water level data and those derived from single hole tests. Second, we need to continue our efforts to develop a conceptual model and eventually a numerical model of permeability variation within sedimentary rocks. This model will be critical to our ability to accurately simulate water level gradients in the aquifer and to our ability to accurately determine flow directions at medium and local scales. Although more medium and small-scale permeability data may be helpful in this regard, we recommend emphasizing more detailed analysis of *existing* data (water level, geophysical and geologic logs, mineralogy data, hydraulic testing data) to develop a conceptual model relating our geologic understanding to permeability variation at small and medium scales. This analysis is critical to ensure that we are collecting the appropriate types of data in the remaining R-wells.

Permeability data for the basalt units clearly shows a very large variability, presumably due to various lithologies lumped into the "basalt" category such as fractured and unfractured lava, inter-flow breccia, and inter-flow paleosols. It is unclear how important it will be to gather more detailed knowledge of the spatial distribution of these various lithologies.

Hydraulic gradients

At the western edge of the plateau the water table is located approximately 300 to 400 m below ground surface. The hydraulic gradient in the western portion of the aquifer is generally downwards. The flow of groundwater is east/southeast, towards the Rio Grande. The hydraulic gradient in the eastern portion of the aquifer near the Rio Grande is generally upwards.

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In plan view, the spatial distribution of wells on the plateau is sufficient to determine that flow is generally east (although a slight southerly component is present in some areas) in the uppermost portion of the aquifer. Although deeper head data is more sparse and (in some wells) ambiguous (e.g. some heads are composite measurements over long screened-intervals and some heads are heavily influenced by nearby pumping), deeper head data also suggests easterly flow. This result is consistent with regional hydraulic gradient data, which suggests that flow is generally east-west, towards the Rio Grande, despite the well-documented fact that considerable geologic complexity exists within aquifer rocks.

The radiocarbon ages of water from deep wells beneath the Pajarito Plateau increase from west to east, supporting this conceptual model of easterly flow indicated by water level data.

Although all the available data suggests easterly flow, departures from this trend may occur at scales smaller than typical well spacing. There is no reason to expect this, however, unless either 1) new water level data are collected that demonstrate departures from regional gradients, or 2) geologic features are identified *with measured influence on permeability* that would cause either local perturbations in hydraulic gradients and/or cause flow directions to be oblique to water level iso-potentials.

Groundwater velocity

Simple calculations of flow velocity using measured head gradients and assumed values of porosity suggest velocities are tens of meters per year. We are currently using flow and transport modeling, in combination with radiocarbon age dates, to provide a more rigorous analysis of velocities. Unfortuantely, contaminants that have been detected in the regional aquifer, such as ^{3}H, Sr90, HE, cannot be used to calculate velocities because we do not know whether they have been transported from the source primarily in alluvial, vadose zone (including perched aquifers) or primarily in the regional aquifer. Either cross-hole tracer tests or single-hole "huff-puff" tests could provide valuable information about groundwater velocity.

Recharge/discharge

The Rio Grande is the main discharge area for the regional aquifer. Estimates of discharge are based on springflow data (although it is unclear whether springs in White Rock Canyon discharge perched aquifer(s) or the regional system) and streamflow gain along the Rio Grande. These data suggest that the regional system discharges approximately 15 cfs between Otowi Bridge and Cochiti Reservoir. Statistical analysis of streamflow data suggest that this estimate is associated with a standard error of 4.3 cfs.

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The largest component of recharge occurs as underflow of groundwater from the Sierra de los Valles, to the west of the Pajarito Plateau. Recharge also occurs by leakage from mesas and from alluvial groundwater in canyon bottoms on the Pajarito Plateau. While it may be insignificant volumetrically, local recharge on the Pajarito Plateau is important because it provides pathways for contaminants that originate from effluent discharges. The exact volume of recharge occurring on the plateau is *impossible* to measure; however, using the regional aquifer discharge estimate (described above) to place bounds on the total amount of recharge that can possibly occur on the plateau we use sensitivity analyses and flow and transport modeling to evaluate the effect of various plausible recharge scenarios. For example, to predict a "worst-case" scenario, we can simulate aquifer quality assuming all recharge occurs within those canyons that are most contaminated. Water budget, chloride-mass balance estimates, and vadose-zone flow model calibration can also be used to place bounds on recharge rates.

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A.6 Data Needs Compiled from Comprehensive Evaluation Presentations

Data Needed	Recommendations: Field Data	Recommendations: Analysis
Head Data -Vertical Gradients	• **Spinner logs in water supply wells.** Water supply wells are much deeper than R wells. If contamination enters the aquifer in areas with strong downward gradients (such as the vicinity of R25), shallow R wells downgradient may not intercept contamination. Conducting spinner log tests in existing water supply wells would help identify locations where this could be a problem. • **Multiple screen well(s) in northwestern portion of LANL, transducers in all in existing wells.** No data is available east of R-22; lack of vertical gradient information to the east will affect our ability to predict potential impacts to wells on San Ildefonso land.	
Head Data - Horizontal Gradients	▪ Current spatial distribution is adequate to determine large-scale flow directions; **closer well spacing may be necessary to determine local variations in flow.** ▪ **Well(s)s west of the Pajarito Fault zone** will be necessary to evaluate the impact of the fault zone on flow.	
Range of measured permeability - large scale	▪ **Multi-hole pump test(s)** to determine medium-to-large scale permeability & to reconcile model parameters with test data ▪ **Pump tests across fault zones.**	• Geometry of basalt flows, which are potential fast pathways, is uncertain. We should develop and consider **multiple alternative geologic models.** • Do large-scale facies with distinct hydraulic properties exist? Conceptual models need to be incorporated into geologic model and tested (with flow model) against water level data.

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Range of measured permeability - small scale	▪ **Evaluate existing methods** and (if necessary) develop new methods for hydraulic testing to ensure that we're testing the formation and not simply the filter pack	▪ For sedimentary rocks, we need a conceptual model relating depositional or textural facies to permeability variations ▪ **Further analysis of existing geologic, geophysical, and hydrologic data** may provide additional information
Permeability - Geologic influences	▪	▪ Review logs to see if anything is in logs related to permeability. Develop a method of logging to provide a correlation between textural deposits or depositional facies and permeability estimates. ▪ Incorporate hypothesis concerning fault zones, facies within sedimentary rocks, alternative realizations about structure of basalt flows, etc. quickly into 3-D geologic model so that they can be tested against water level data using flow modeling.
Effective porosity on a field scale.	▪ No site-specific data from saturated zones. This will help with travel times in regional aquifer. ▪ Existing tracer data is inadequate to estimate travel times.	
Bracket porosity using some contaminants	Could use 1) single-well injection-withdrawal tracer tests, 2) age dating, or 3) cross-hole forced-gradient tracer tests.	
Presence of intermediate perched groundwater	▪ Aggregates 1 & 7: Limited extent and continuity beneath canyons? ▪ No perched/ limited extent beneath Pajarito Canyon? Need an intermediate well(s) in Pajarito Canyon east of TA-18, based on R-22 analytical results. ▪ Aggregates 3, 4, 6, 8: No perched? West of R-31, however, there are source terms of depleted U and Be. Possibly **delete R-32 based on R-31.** ▪ Aggregate 5: Extensive thick zone recharged from Jemez Mtns.?	▪ Incorporate perched water representation into vadose zone models, capturing the extremes of behavior - bathtub versus lateral flow fast path. ▪ Perform site-wide analysis of potential flow path directions based on geologic model and simple conceptual models of lateral diversion. ▪ Test against available data. ▪ Determine whether uncertainties in lateral transport significantly affect the prediction of the location of contaminant arrival at the water table.

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		Bracket travel times to the water table by: ▪ 1-D travel times and directions, from surface to regional aquifer (longest time) ▪ 1-D travel time to perched zone only, short circuit to water table after that (shortest time)
Subsurface contaminant distribution	▪ Perchlorate beneath Pueblo, tritium, strontium-90. Still need R-4 and R-8 to be drilled. ▪ Aggregate 2: Organic solvents, radionuclides? ▪ Aggregate 5: Extent of HE and solvents in perched zone ▪ Aggregate 7: Extent of radionuclides, nitrate, and perchlorate in vadose zone	
Geologic Controls on contaminant transport	▪ Aggregate 2: Structure of basalt controls vapor movement, regional aquifer and vadose zone flow? ▪ Aggregate 4: Geology of near-Rio Grande faults, basalts could control regional aquifer and perched flow systems; R-17 should be relocated east of TA-18 based on complex hydrogeologic conditions. ▪ **Focus on upper saturated zone, recharge from mountain front, and line source of recharge for locating CDV-37 and additional wells.** ▪ Aggregate 7: Structure of basalt controls perched zone flow?	
Distribution and rates of percolation.	Drill a few shallow wells in a canyon to look at moisture and contaminant distribution. The shallow wells would be used for estimating percolation rates and travel times.	
Vadose Zone Reduce travel time uncertainty	migration rate using water budget studies, infiltration monitoring sites, shallow boreholes to measure water contents and migration fronts of contaminants, e.g. nitrate profile in R-15	▪ geologic model needs to estimate uncertainties (e.g. in unit thicknesses) but focus on uncertainties that matter to travel time and continue to update geologic model with new data ▪ Infiltration indices for canyon drainages from 1 (driest) to 5 (wettest) net infiltration
Pathway Analysis		Form a specialized team that focuses on pathway analysis, consisting of hydrology, modeling, geology,

		and geochemistry. Integrate better with computational efforts.
Groundwater Geochemistry	Single screen wells help to minimize redox reactions produced by drilling fluids and false positives with HE compounds and solvents. R-4, R-8, R-10, R-11, R-13, R-14, and R-17 are in contaminated canyons and should be single completion wells, based on geochemical DQOs.	
Characterization of Reactive Minerals	Mineral distributions are needed for input to adsorption-transport modeling, quantifying natural attenuation, and validating geochemical modeling. Perform this work activity during geologic characterization. Perform simple leaching procedures to determine iron and manganese distributions (major adsorbents).	
Kds for Sr, U, Pu, and other chemicals	Adsorption data are needed for Cerros del Rio basalt and Puye Formation, because they have different chemistries from the Bandelier Tuff.	
C-14, $\delta^{13}C$	Determine age and groundwater travel times in regional aquifer (R wells). Perform this work activity during sampling of R wells. Need to obtain representative calcite samples from core collected at R wells and outcrops to correct $\delta^{13}C$ for recalculating C-14 dates.	
LANL Baseline Groundwater Geochemistry		Finalize publication and make database available.
Information on bentonite annular fill materials	Associated salts, redox properties, K_d	
Flow within perched zones	Can contaminants cross between canyons?	
Mappable perched zones	Alluvium, Guaje/Puye, Cerros del Rio	
	Connect well test data with lithology	
What is (are) the Los Alamos aquifers		
The eastern margin:		

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facies and structure		
Western edge	Recharge, geologic unknowns, complex micrograbens and breathing fractures. Drill R-1, R-2, R-6, R-17, R-14, R-18, R-24, R-26	
Water Canyon (near R27/R28)	Axis of major topographic low in Bandelier time and in the Purtymun trough. Perhaps a change in flow within perched zones to the south.	
Potrillo Canyon (near R-23)	Difference between R-31 and R-22 is great; need to know what is going on there.	
Lower Mortandad Canyon	Could look at surface geology along the river.	
Pajarito Canyon (near R-21)		
Rio Grande	Surface exposures that could provide significant geologic control.	
Pathways	Focus on canyon reaches (e.g. MCOBT, R-15 data sets); canyon to canyon pathways? (*e.g.* dip within perched zones); eastern margin (ancestral Rio Grande paleochannels, eastern faults and changes in basin facies; how does flow get to springs and the present Rio Grande); influence of Puye and Santa Fe clay zones (clay, zeolites, and complex Mn-oxides)	
The sorption problem	Take advantage of contamination: Unlike uncontaminated sites, the dispersion of contaminants at LANL can be used to assess in situ processes, including contaminant tracking.	Literature data will be important, particularly for "conservative" contaminants.

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10/16/01 HWP Meeting

HSWA LANL G/M/HWP 2001

Water Quality Database

Kendra Henning
Sue Kinkead

WQDB Project Overview

WHAT: A centralized data repository for water quality data

WHEN: The Water Quality Database came online in 2000

WHERE: The Internet: http://wqdbworld.lanl.gov

WHY:
- -Improved access to data
- -Streamlined research and reporting capabilities
- -Enhanced data quality

HOW: Collaborative effort between ESH-IM, ESH-18, ER Project and others

WQDB System Evolution

PAST: **Program Resource**

PRESENT: **Group Resource**

FUTURE: **Division & Institutional Resource**

WQDB Data Statistics

Data In Production

Sampling Station Data	900+ records
Analytical Chemistry Data	340,000+ records (1942 – 2001)
Stream Flow Data	700,000+ records (1994 – 2000)
Lookup Table Data	3,000+ records

Current Uses for WQDB

Data Access/Reports
- Data entry or import
- Data assessment
- Standardized and special reports

Collaborations
- Sharing of database design and tools
- Sharing of Electronic Data Deliverable
- Exchange of data

Reports

- ~~Environmental Surveillance~~ Report
- RAC
  - Correlating flow data with chemistry
- Kay Birdsell
  - Contaminant data
- ArcView Station Maps
- Data Screening

Collaborations

- Data Exchange
  - ER
  - NMED
  - USGS
- Database Design and EDD
  - NMED
  - Jemez Pueblo

Plans

Work In Progress

Well Construction, Water Levels

Future Work Planned

Hydrologic Properties, Geophysical Logs