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National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

MAY 11 2004

CERTIFIED MAIL-RETURN RECEIPT REQUESTED

Mr. Sandra Martin, Acting Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Rd. East
Building 1
Santa Fe, NM 87505

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Dear Ms. Martin:

On behalf of the Department of Energy (DOE) and Sandia Corporation, DOE is submitting two documents, the Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico (SNL/NM) Technical Area-V (TA-V); and the Corrective Measures Evaluation (CME) Work Plan, Technical Area-V Groundwater Plume. These submittals are required under the final Compliance Order on Consent (Consent Order) for Sandia National Laboratories, New Mexico, EPA ID No. 5890110518.

The Current Conceptual Model report satisfies the requirements of Section IV.C of the Consent Order, which states that site characterization efforts at SNL/NM TA-V must be completed to the satisfaction of the NMED prior to conducting a Corrective Measures Evaluation (CME). The objective of the Current Conceptual Model is to provide a basis for the NMED to determine the adequacy of site characterization performed at TA-V so that SNL/NM can proceed with a CME. Evaluation of remedial alternatives for contaminants of concern in groundwater at TA-V relies on this current conceptual model of groundwater flow and contaminant transport.

The CME Work Plan has also been developed under the direction of Section IV of the Consent Order, which identifies TA-V as an area of groundwater contamination requiring completion of a CME. The CME Work Plan complies with requirements set forth in the Consent Order and with the guidance of the Resource Conservation and Recovery Act Corrective Action Plan

The Corrective Measures Implementation Schedule found in Section 7 of the CME Work Plan shows the steps for completion of a CME Report by September 30, 2005 (the date established by Table XI-2 of the Consent Order). To ensure that the CME Report due date is met, we request that any comments by the NMED on the enclosed documents be provided by June 16, 2004.

SNL 1240

If you have any questions, please contact John Gould [(505) 845-6089] of my staff.

Sincerely,

Patty Wagner
Manager

Enclosures

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CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **Corrective Measures Evaluation Work Plan Technical Area V Groundwater; and**
Current Conceptual Model of Groundwater Flow and Containment Transport at Sandia National Laboratories/New Mexico Technical Area V

Document authors: **Kevin Hall and Brennon Orr, North Wind, Inc.**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature: Peter B. Davies — 4/23/04
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Director
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Date

and

Signature: Patty Wagner — 4-30-04
Patty Wagner
Manager
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office
Owner and Co-Operator

Date

SANDIA REPORT
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Printed April 2004

Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico Technical Area V

Brennon R. Orr
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National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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Printed April 2004

Corrective Measures Evaluation Work Plan Technical Area V Groundwater

Kevin A. Hall
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Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico Technical Area V

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Abstract

The New Mexico Environment Department (NMED) requires a Corrective Measures Evaluation to evaluate potential remedial alternatives for contaminants of concern (COCs) in groundwater at Sandia National Laboratories/New Mexico (SNL/NM) Technical Area (TA)-V. These COCs consist of trichloroethene, tetrachloroethene, and nitrate. This document presents the current conceptual model of groundwater flow and transport at TA-V that will provide the basis for a technically defensible evaluation.

Characterization is defined by nine requirement areas that were identified in the NMED Compliance Order on Consent. These characterization requirement areas consist of geohydrologic characteristics that control the subsurface distribution and transport of contaminants. This conceptual model document summarizes the regional geohydrologic setting of SNL/NM TA-V. The document also presents a summary of site-specific geohydrologic data and integrates these data into the current conceptual model of flow and contaminant transport. This summary includes characterization of the local geologic framework; characterization of hydrologic conditions at TA-V, including recharge, hydraulics of vadose-zone and aquifer flow, and the aquifer field of flow as it pertains to downgradient receptors. The summary also discusses characterization of contaminant transport in the subsurface, including discussion about source term inventory, release, and contaminant distribution and transport in the vadose zone and aquifer.

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Acronyms

AOC	area of concern
ARG	ancestral Rio Grande
bgs	below ground surface
CME	Corrective Measures Evaluation
COA	City of Albuquerque
COC	contaminant of concern
COOC	Compliance Order on Consent
DO	dissolved oxygen
DOE	U.S. Department of Energy
EPA	Environmental Protection Agency
ER	environmental restoration
ft/min	feet per minute
ft/yr	feet per year
gpm	gallons per minute
KAFB	Kirtland Air Force Base
LWDS	Liquid Waste Disposal System
MCL	maximum contaminant level
MDL	method detection limit
NFA	No Further Action
NMED	New Mexico Environment Department
ORP	oxidation reduction potential
PCE	tetrachloroethene
ppbv	parts per billion by volume
ppmv	parts per million by volume
SERF	Sandia Engineering Reactor Facility
SNL/NM	Sandia National Laboratories/New Mexico
SWMU	Solid Waste Management Unit
TA	technical area
TCE	trichloroethene
TOC	total organic carbon
VOC	volatile organic compound

1.0 INTRODUCTION

Sandia National Laboratories/New Mexico (SNL/NM) is located on Kirtland Air Force Base (KAFB), south of Albuquerque, New Mexico (Figure 1-1). SNL/NM operates five Technical Areas (TAs) (i.e., TA-I, TA-II, TA-III, TA-IV, and TA-V). TA-V is a secured research and testing area that covers approximately 35 acres in the central part of KAFB. This area has been operating since the 1960s.

In Section IV.C of the Draft Final Compliance Order on Consent issued to the Department of Energy and Sandia National Laboratories (NMED 2003), the New Mexico Environment Department (NMED) identified TA-V as an area with groundwater contamination:

> TA-V is located in the northeastern corner of TA-III, in the southwestern part of Kirtland Air Force Base. [Trichloroethene] TCE has been detected in water samples from some monitoring wells screened in the regional aquifer in and around TA-V since 1993. Also, nitrate, a contaminant from septic system effluent, has been detected above state drinking water and groundwater standards. TCE levels have ranged as high as 23 µg/L, and nitrate has ranged as high as 16.3 mg/L.

In addition, tetrachloroethene (PCE) has been detected in several water samples from one well at concentrations up to 7.5 µg/L. The U.S. Environmental Protection Agency (EPA) drinking water maximum contaminant level (MCL) is 5 µg/L for both TCE and PCE in groundwater (40 CFR 141.61). The nitrate MCL is 10 mg/L (as nitrogen) (40 CFR 141.62).

Also in Section IV.C of the Draft Final Compliance Order on Consent, NMED requires a Corrective Measures Evaluation (CME) of TA-V groundwater contamination. Evaluation of remedial alternatives for contaminants of concern (COCs) in groundwater at TA-V requires a current conceptual model of groundwater flow and contaminant transport. This conceptual model will provide the basis for a technically defensible evaluation that will be developed and documented in the CME.

1.1 Background

TA-V facilities are designed to test radiation effects on components. These facilities include large electron beam accelerators, three research reactors in two reactor facilities, an intense gamma irradiation facility, and a hot-cell facility. Historically, wastewater containing contaminants derived from these facilities was disposed to drainfields, seepage pits, and unlined ponds at TA-V.

Numerous subsurface investigations have been conducted in conjunction with surface remediation activities at TA-V. These investigations have resulted in a substantial body of information available in a series of publications and other data sources concerning elements of conceptual models of contaminant release and transport through the vadose zone and Santa Fe Group aquifer. These studies are tabulated in Appendix A of this report.

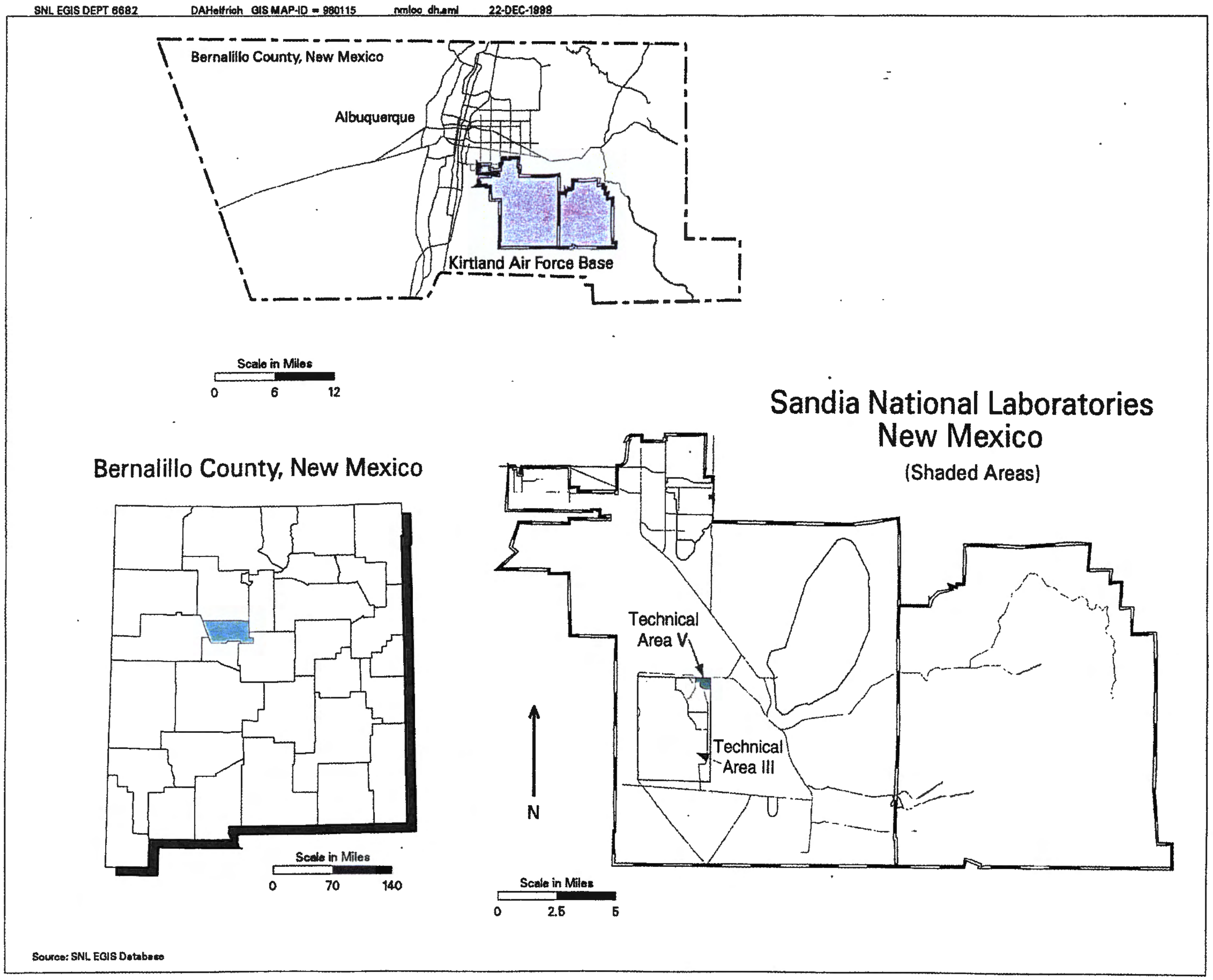


Figure 1-1. Location of SNL/NM and TA-V.

1.2 Objectives

According to Section IV.C of the Draft Final Compliance Order on Consent (NMED 2003), site characterization efforts at SNL/NM TA-V must be completed and documented prior to conducting a CME. The objective of this document is to provide a basis for the NMED to determine that they are sufficiently satisfied with the characterization performed at TA-V and that SNL/NM can proceed with a CME.

This document summarizes geohydrologic data that have been collected at TA-V and presents a current conceptual model of contaminant release and subsequent subsurface transport that characterizes contaminant source terms, the geohydrologic framework, and the distribution of contaminants in the subsurface at SNL/NM TA-V. This conceptual model compiles and integrates available hydrogeologic information that has been gathered from numerous past geohydrologic investigations at TA-V, recent data collection, and discussions with technical experts. This compilation will be used to determine that present information is adequate to develop the current conceptual model within the context of contaminant remediation.

1.3 Organization

Nine requirement areas were identified in the NMED Compliance Order on Consent to satisfactorily characterize contaminant transport in the subsurface at TA-V (NMED 2003). Those nine areas and their correlation to specific sections of this document are presented in Table 1-1. This document, presenting the current conceptual model of groundwater flow and contaminant transport at TA-V, is organized into the following sections:

- Section 1 provides the introduction, background, objectives, and organization of this report.
- Section 2 summarizes regional geohydrologic conditions at SNL/NM TA-V.
- Section 3 presents a summary of geohydrologic data and integrates these data into the current conceptual model of groundwater flow and contaminant transport for TA-V. The conceptual model discussion includes:
    - Characterization of the local geologic framework, including structural and stratigraphic features that are important to flow and transport.
    - Characterization of hydrologic conditions at TA-V, including groundwater recharge, hydraulics of vadose-zone and aquifer flow, and the aquifer field of flow as it pertains to downgradient receptors.
    - Characterization of contaminant transport in the subsurface, including discussions of source term inventory, contaminant release mechanisms, contaminant distribution and transport in the vadose zone and aquifer, and geochemistry.
    - Description of numerical tools that have been developed based on the conceptual model and used to aid in remedial work at TA-V.
- Section 4 summarizes key elements of the conceptual model of contaminant release, transport through the vadose zone, and transport in the Santa Fe Group aquifer at TA-V.

Table 1-1. Characterization requirements established in the Compliance Order on Consent (NMED 2003) and correlation of these requirements to sections within the TA-V Current Conceptual Model.

Characterization Requirements	TA-V Current Conceptual Model (Sections)
1. Nature, rate of transport, and extent of contamination	3.3 Distribution of Contaminants in the Subsurface at TA-V
2. Regional and perched aquifer boundaries	2.0 Regional Geohydrologic Conditions
3. Depth to water, water levels, water table, potentiometric surface, and any seasonal variations	3.2 Hydrologic Conditions at TA-V
4. Flow directions and velocities	3.2 Hydrologic Conditions at TA-V
5. Geologic, hydrostratigraphic, and structural relationships	3.1 Geologic Features of TA-V
6. Water supply well pumping influences, seasonal pumping rates, and annual amounts of water withdrawn	3.2 Hydrologic Conditions at TA-V
7. Saturated hydraulic conductivity, porosity, effective porosity, permeability, transmissivity, particle size, storage coefficients, and estimated fracture/secondary porosity	3.2 Hydrologic Conditions at TA-V
8. Contaminant concentrations in soil, rock, sediment, vapor, and water (as appropriate)	3.3 Distribution of Contaminants in the Subsurface at TA-V
9. General water chemistry	3.3 Distribution of Contaminants in the Subsurface at TA-V

2.0 REGIONAL GEOHYDROLOGIC CONDITIONS

SNL/NM TA-V is located within the Albuquerque Basin of the Rio Grande Rift in north-central New Mexico. The geologic and hydrologic conditions of the Albuquerque Basin form the regional context of local groundwater flow and contaminant migration at TA-V.

2.1 Regional Geologic Conditions

The Rio Grande Rift is a relatively continuous regional structural zone that extends north from Mexico, across New Mexico, and into southern Colorado. Formation of this feature began 25 million years ago in northern Mexico and continued toward the north as tectonic forces began to pull apart the brittle upper crust of the North American Plate.

The Rio Grande Rift is marked by a series of sediment-filled structural basins and adjoining uplifted mountain ranges (Figure 2-1). One of these basins, the Albuquerque Basin (also known as the Middle Rio Grande Basin), covers about 3,000 square miles in central New Mexico and extends from the Cochiti Reservoir on the north to San Acacia, New Mexico on the south. The Albuquerque Basin includes the City of Albuquerque (COA). KAFB and SNL/NM TA-V are located within Bernalillo County (Figure 1-1) on the eastern side of the Albuquerque Basin.

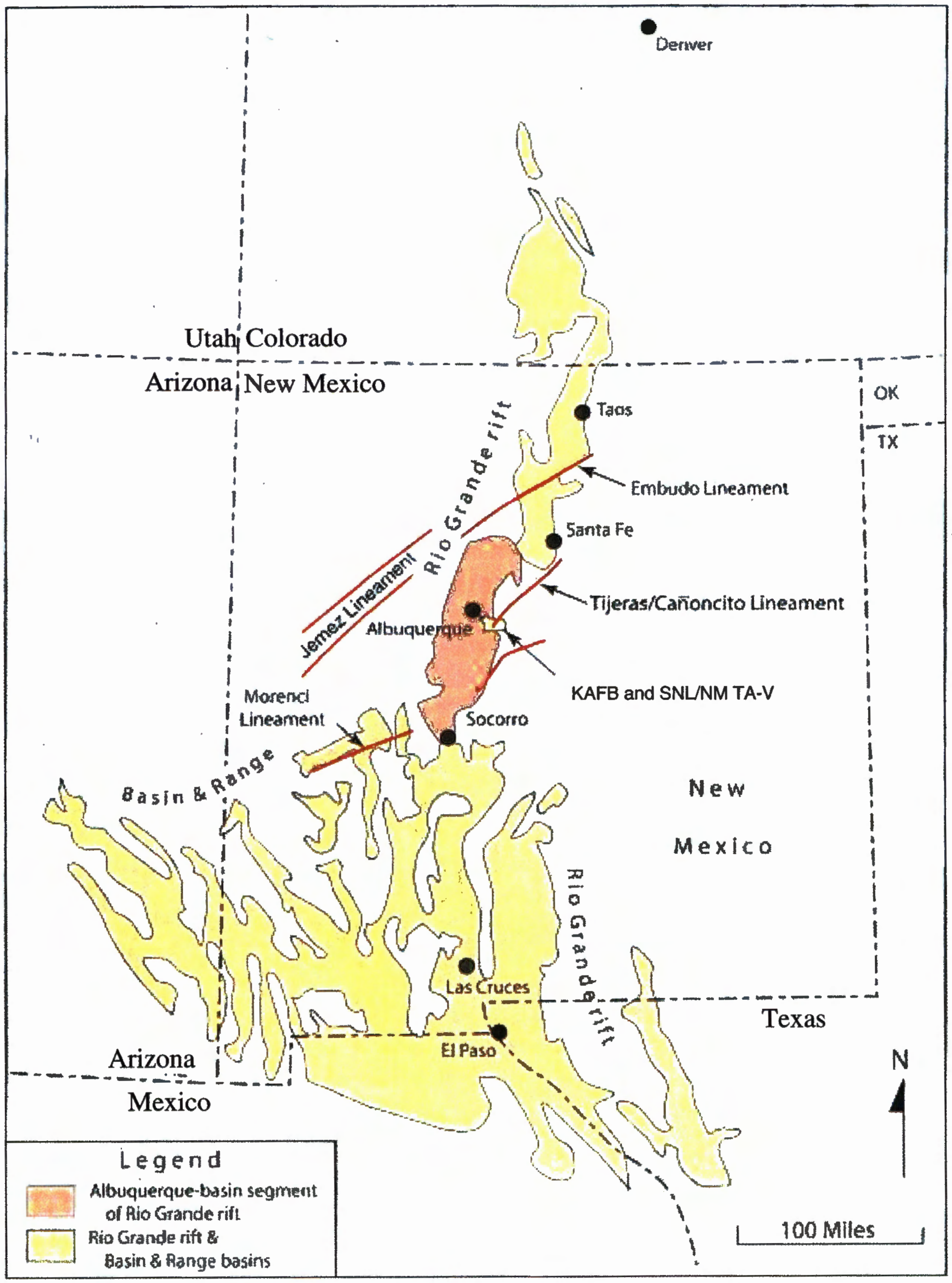
2.1.1 Major Structural Features Associated with the Albuquerque Basin

An extensive system of rift-zone faults and adjacent upfaulted blocks defines the eastern and western boundaries of the Albuquerque Basin. Subsurface bedrock highs have further subdivided the Albuquerque Basin into subbasins. The large-scale system of faults, uplifts, and subbasins has played a major role in the deposition of Santa Fe Group sediments.

The major fault systems that bound the Albuquerque Basin have dominated the development of geologic and hydrologic features within the basin. These fault systems consist of sets of subparallel high-angle large-displacement normal faults that separate the subsided basin from adjoining uplifted mountain blocks. Fault blocks on the inside of the rift zone typically have dropped down relative to uplifted fault blocks on the eastern and western edges of the rift.

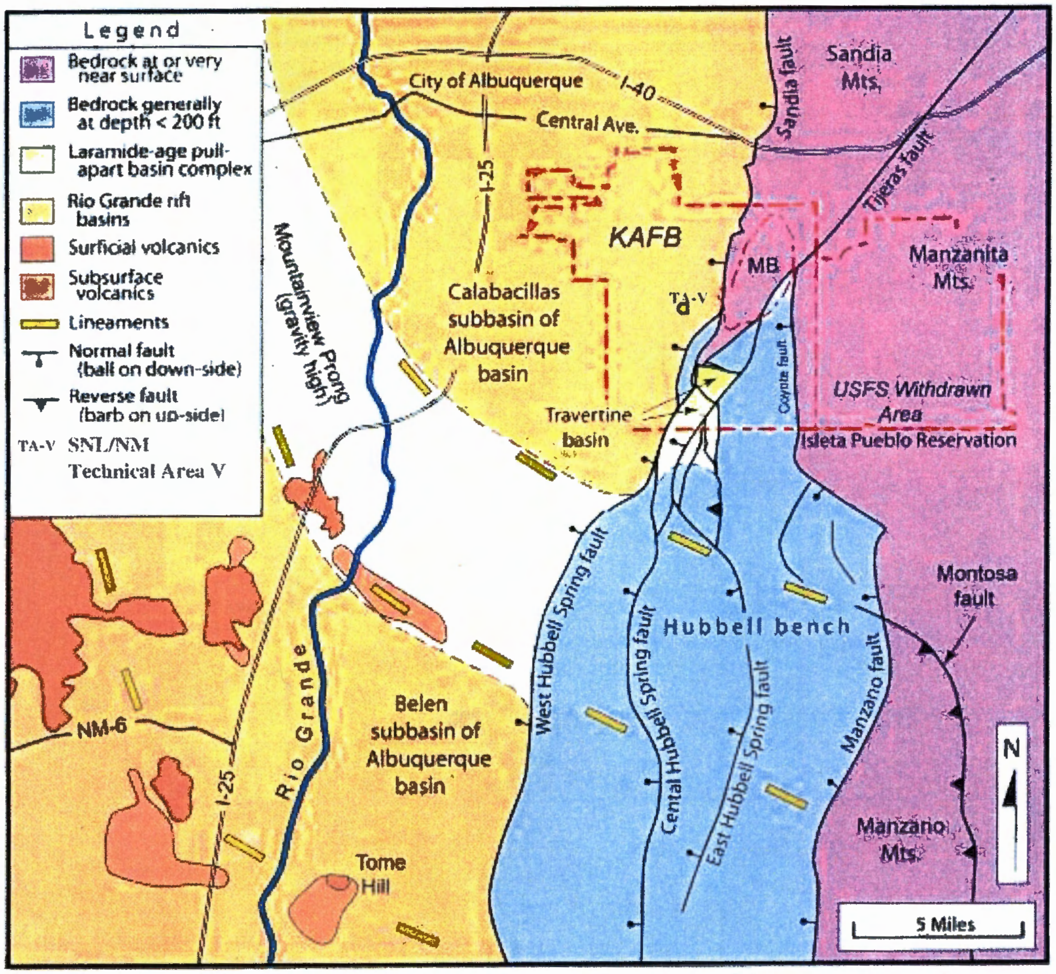
Figure 2-2 illustrates the structural features surrounding KAFB. The Sandia, West Hubbell Spring, Manzano, Tijeras, and associated faults mark the eastern step-faulted boundary of the Albuquerque Basin in the vicinity of Albuquerque and KAFB. This complex network of faults is characterized by as much as 20,000 ft of displacement from the deepest part of the basin eastward to the top of the Sandia Mountains. Rift zone faults remain active today (Bartolino and Cole 2002).

Rift zone faulting has controlled sedimentary deposition within the Albuquerque Basin throughout its history. Continued movement along faults has modified local drainage systems and formed topographically high areas that provided a ready source of newly eroded sediments. Fault offsets brought Santa Fe Group sediments into contact with upfaulted Paleozoic rocks along the basin margins. Because active faulting was occurring at the same time as sedimentary deposition, faults also have offset stratigraphic units within the Santa Fe Group. Fault zones may act as conduits or barriers for vertical groundwater flow and as regional hydrologic boundaries to the Santa Fe Group aquifer.



From Van Hart, 2003; modified from Kalstrom et al. 1999 and Pazzaglia et al. 1999

Figure 2-1. Location of the Rio Grande Rift, Albuquerque Basin, Select Precambrian Lineaments (in red), KAFB, and SNL/NM TA-V.

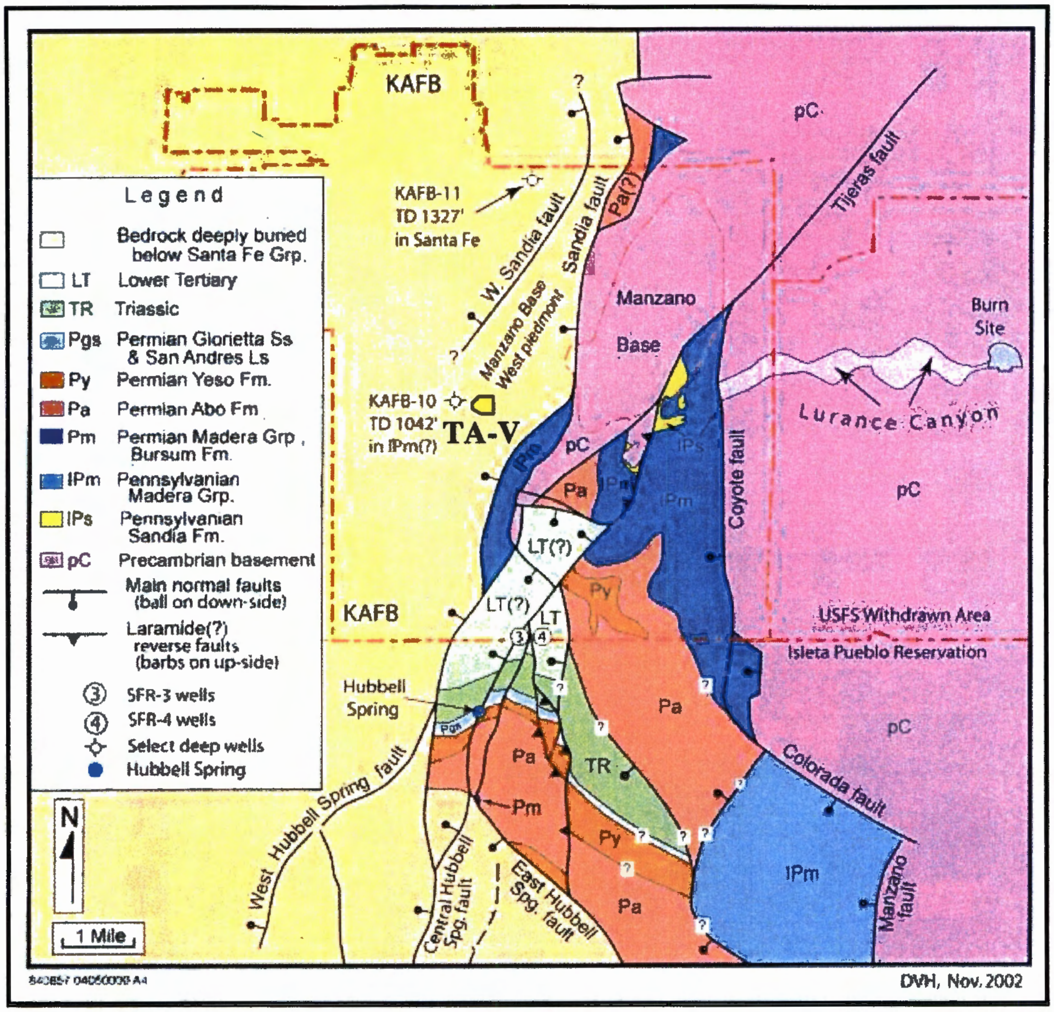


From Van Hart 2003; Modified in part from Grauch et al. 1999, and Maldonado et al. 1999

Figure 2-2. Structural provinces of KAFB and vicinity.

The uplifted mountains to the east of the Albuquerque Basin act as groundwater flow boundaries and provide a source of streamflow and alluvial sediments into the basin from mountain drainages. Streamflow originating from these drainages furnishes a source of surface-water recharge to alluvial-fan sedimentary deposits along the basin margins. Chemical interactions between water and rocks in these drainages affect the chemistry of water recharged to the Santa Fe Group aquifer.

The Sandia Mountains east of Albuquerque consist largely of an uplifted block of Precambrian granitic rocks (Figure 2-3). This block is capped in places by Paleozoic sedimentary rocks. The Tijeras fault is a strike-slip fault that separates this uplifted block from Precambrian metamorphic rocks and Paleozoic sedimentary rocks that comprise the Manzanita Mountains east of KAFB and TA-V. This region of the Manzanita Mountains is a structurally complex uplift formed by the intersection of numerous faults of the Hubbell and Manzano fault zones to the south, Sandia fault zone to the north, and the Tijeras fault (Figure 2-2). Complexities associated with this highly-faulted area have controlled alluvial fan deposition along the margins of the Calabacillas subbasin (Figure 2-2) and have affected the availability and quality of local groundwater recharge.



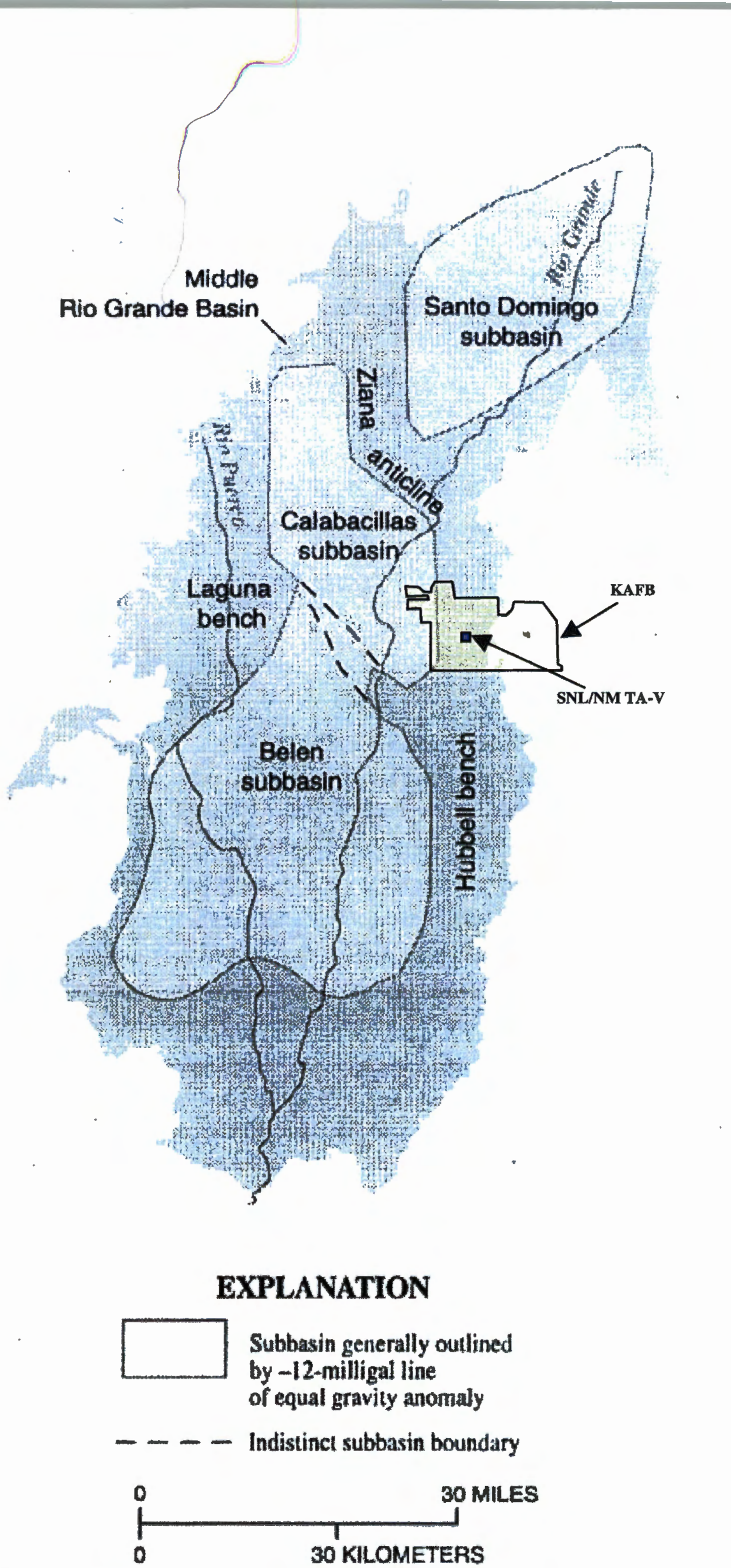
From Van Hart 2003; Modified from Love et al 1996, and Van Hart et al 1999.

Figure 2-3. Fault systems and interpreted bedrock geology of KAFB and vicinity.

The Albuquerque Basin is subdivided into the Santo Domingo, Calabacillas, and Belen subbasins (Figure 2-4). These fault-bounded subbasins each contain substantial deposits of fluvial, lacustrine, and aeolian sediment, with thicknesses locally exceeding 14,000 ft. The subbasins are internally separated by northwest-trending structural bedrock benches that are overlain by less than 3,000 ft of sedimentary deposits. The Calabacillas subbasin encompasses the COA, much of KAFB, and SNL/NM TA-V. The bedrock bench on the southern boundary of the Calabacillas subbasin is located immediately southwest of KAFB.

2.1.2 Basin-Fill Deposits

The interaction between faulting and concurrent sedimentary processes within the structural basins along the Rio Grande Rift resulted in a complex accumulation of interfingering, lenticular units of sand, gravel, silt, and clay (Bartolino and Cole 2002). Sedimentary units in the basin are truncated, commonly displaced by faults, and are hundreds to thousands of feet thick. As adjoining fault blocks were uplifted, eroded detritus was deposited within the basins formed by the subsiding blocks. Uplift and subsidence also shifted internal stream drainages and forced migration of the different depositional environments within subbasins. These basin-fill sediments are unconsolidated to partially cemented and consist primarily of fluvial and alluvial fan deposits.



From Bartolino and Cole 2002

Figure 2-4. Simplified structural features of the Albuquerque Basin.

Fluvial deposits in the Albuquerque Basin were derived from streamflows that transported sediments from source areas. In the early stages of rifting, the subbasins were internally drained and fluvial deposits were locally derived. Uplift of adjacent mountain ranges resulted in erosion and formation of coalescing alluvial-fan and piedmont deposits along mountain fronts. These deposits are lenticular and poorly sorted and highly variable in texture, with coarser cobble size sediments deposited near the mountain front and finer sands, silts, and clays deposited in the distal parts of the fans and piedmonts. A period of increased precipitation, beginning approximately 5 million years ago, resulted in increased streamflows and transport of coarser sediments into the subbasins of the Albuquerque Basin (Bartolino and Cole 2002).

Approximately 2.7 million years ago, regional integration of stream drainage basins developed the through-flowing ancestral Rio Grande (ARG) drainage (Bartolino and Cole 2002). Increases in streamflows and regional integration of the Rio Grande resulted in deposition of fluvial, coarse-grained sands and gravels that were derived from distant source areas to the north and included large quantities of volcanic detritus from the Jemez Mountain region. These medium to coarse sand and gravel deposits formed an irregular sheet-like zone that is locally several hundred feet thick and is distributed in a broad band that follows the modern Rio Grande (Bartolino and Cole 2002). These deposits are identified as the ARG lithofacies and form a hydrostratigraphic unit that is one of the more productive units within the Albuquerque Basin.

Concurrent deposition of locally-derived erosional detritus continued to build alluvial fans and piedmonts to the east of the Rio Grande. Aggradation of the ARG flood plain continued until about 1 million years ago. Subsequently, the modern Rio Grande began to incise the Albuquerque Basin deposits in response to lowering of the stream base level associated with the integration of the Rio Grande to the Gulf of Mexico.

Persistent volcanic eruptions in the Jemez Mountains north of the Albuquerque Basin produced thick deposits of volcanic rocks. These rocks provided a source of transported volcaniclastic debris (i.e., fragments of volcanic rock). Volcanic ash is commonly observed in younger ARG fluvial deposits. Volcanic activity along rift zone faults within the Albuquerque Basin also contributed to the basin-fill process. These volcanic deposits consist largely of locally-derived basalt flows and ash deposits. This volcanic activity modified stream drainages and local sedimentary depositional processes.

Fluvial sediments deposited within active stream channels commonly are coarse-grained and of relatively uniform size (Bartolino and Cole 2002). Areas of overbank floodplain deposition are characterized by fine-grained sediments typically found in a lower-velocity environment. Stratigraphic deposits derived from perennial streamflow are relatively extensive and uniform. Deposits derived from local, ephemeral streamflow are more poorly sorted, lenticular, and variably distributed.

2.2 Regional Hydrologic Conditions

The regional hydrologic conditions within the Albuquerque Basin are defined by the geometry of the Santa Fe Group aquifer, distribution and hydrologic characteristics of hydrostratigraphic units, sources of recharge to the aquifer, regional groundwater flow, and location of discharge from the aquifer.

2.2.1 Aquifer Geometry

The sedimentary deposits of the Santa Fe Group and overlying alluvium that fill the Albuquerque Basin contain the Santa Fe Group aquifer system. This aquifer system provides the primary source of municipal, domestic, and industrial water in the Albuquerque area.

The present-day structure of the aquifer system within the Middle Rio Grande Basin is complex (Bartolino and Cole 2002). The major hydrostratigraphic units in the aquifer are tabular and wedge-shaped bodies that are truncated and displaced by numerous faults. Few of the major units are present continuously throughout all three subbasins and most pinch out against the subsurface basement blocks that separate the subbasins. These major units are hundreds to thousands of feet thick, extend over tens of square miles, and primarily consist of unconsolidated and partially-cemented deposits that interfinger in complex arrangements. The diverse rock types and intricate interbedding relations indicate that the hydrologic characteristics of these units can be defined only in general terms.

2.2.2 Hydrostratigraphic Characteristics

Hydrostratigraphic units within the Santa Fe Group aquifer consist of sedimentary materials that are derived from similar depositional environments and have similar hydraulic properties (Bartolino and Cole 2002). These units consist predominantly of unconsolidated to partially-cemented sand and silt with lesser amounts of clay and gravel. Regional groundwater flow is controlled in part by the distribution and thickness of these hydrostratigraphic units and by their capacity to store and transmit water. The numerous depositional processes, modifications attributed to continued uplift and subsidence, and the varied sources of sediment combine to form a complex, three-dimensional framework of truncated and overlapping sedimentary units exhibiting hydrologic properties that vary both laterally and vertically.

Alluvial fan sediments occur extensively along the eastern boundary of the Albuquerque Basin and include a thick section of older fine-grained piedmont and younger coarser-grained alluvial fan deposits. Older piedmont deposits are characterized by lower hydraulic conductivity because of their fine-grained texture. Younger alluvial fan deposits are coarser and have higher hydraulic conductivity. These deposits locally are thousands of feet thick.

Grain size in the alluvial fan deposits decreases with depth and distance from sediment source areas. Variations in grain size that occur within short lateral distances also are attributed to the lenticular nature of deposits typically found in an alluvial fan. As a result of the highly variable texture, a large range of hydraulic conductivities can be anticipated in the vadose zone and in the aquifer.

The youngest sedimentary deposits of the Santa Fe Group consist of coarser-grained materials than most of the earlier basin fill (Bartolino and Cole 2002). These deposits include locally-derived alluvial fan deposits and deposits laid down by the ARG. Coarse sand and gravel are common in these deposits, indicating a more energetic depositional environment. The transition in grain size is evident on a regional scale and is consistent with global evidence of substantial increase in precipitation. These younger, coarser-grained deposits comprise the productive zones of the aquifer in the Albuquerque Basin. They are not laterally extensive and are only a small percentage of the basin-fill deposits. These deposits are currently being eroded in the Rio Grande drainage.

2.2.3 *Regional Recharge*

Regional recharge occurs from infiltration of streamflow from the Rio Grande and arroyos, from infiltration of areal precipitation, and from underflow originating from mountain-front recharge. On the federal property that includes SNL/NM, Tijeras Arroyo and Arroyo del Coyote provide limited recharge, as does mountain-front recharge when it connects across the fault complexes. Areal precipitation is estimated to provide a negligible contribution, as 95 to 99% or more is estimated to be lost to evapotranspiration (SNL/NM 1998).

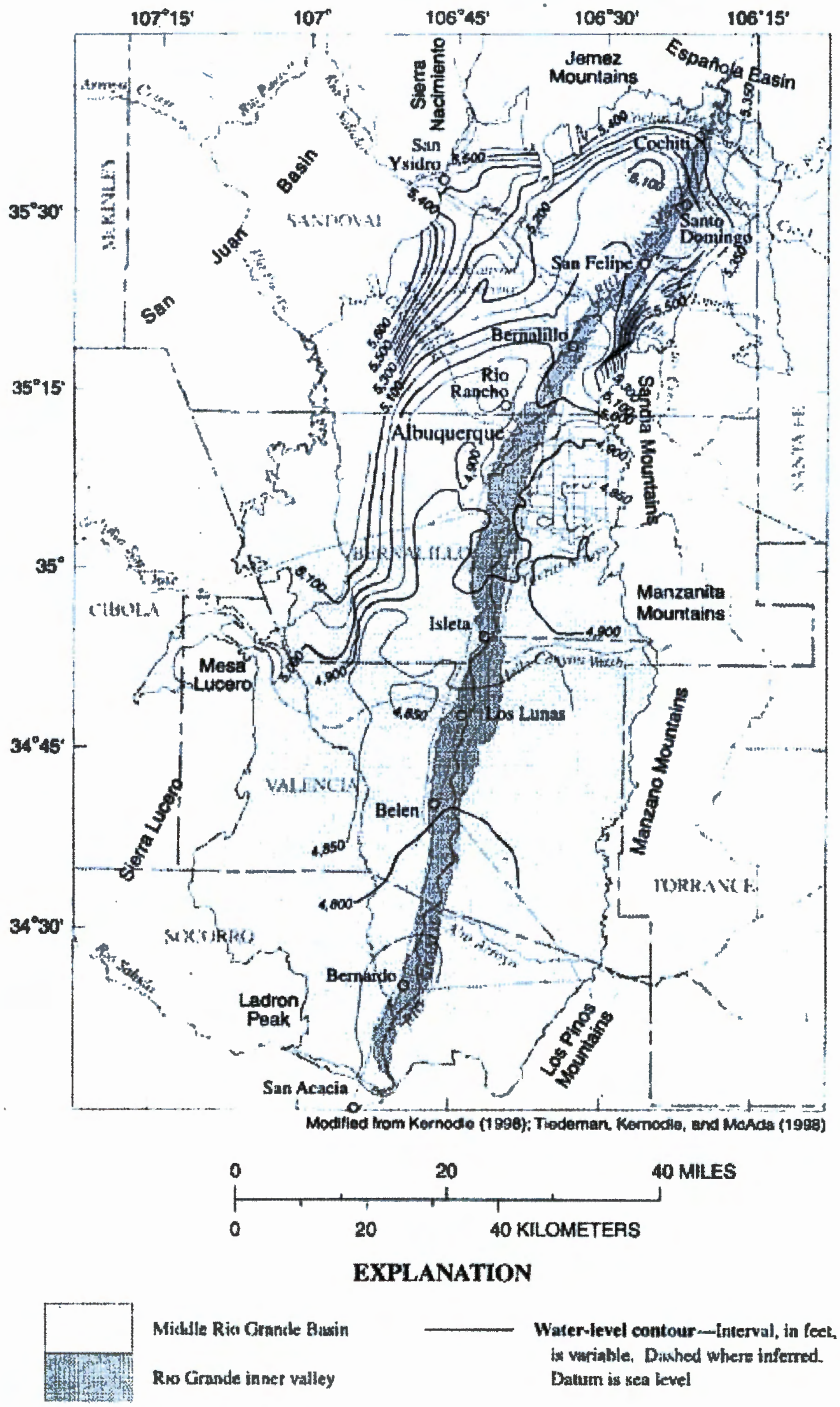
2.2.4 *Regional Groundwater Flow*

Prior to development of water resources in the Albuquerque area, groundwater flow in the Albuquerque Basin was generally from the north to the south, with a westward component of flow from recharge areas along mountain-front boundaries to the east (Bartolino and Cole 2002). As the Santa Fe Group aquifer has been developed as a source for municipal and industrial water supplies, groundwater flow directions have been altered toward pumping centers (Figure 2-5).

On SNL/NM and KAFB property, the predominant groundwater flow was westward prior to water resources development (Bexfield and Anderholm 2000). Recent potentiometric surface maps and numerical modeling studies show the overpowering hydrologic influence of the pumping centers just north of the federal boundaries. The Ridgecrest supply wells in particular are completed less than 1 mile north of the federal boundary and are screened in the north-south trending fluvial deposits. Their capture zones extend south via these deposits onto federal property (SNL/NM 2001a; Plate 3-2). The Air Force owns and operates a lesser influential network of supply wells within the federal boundaries. Together these pumping centers contributed to today's post-development north-northwest groundwater flow direction.

2.2.5 *Regional Discharge*

Regional discharge occurs as groundwater moves out of the Albuquerque Basin into downgradient basins on the Rio Grande Rift as underflow or through discharge to the Rio Grande. Discharge also occurs as pumpage from the COA municipal production well fields. The discharge is greater than recharge and effectively dewaters the aquifer on the federal property. Seasonal fluctuations are apparent only in wells at the north end of the federal property (SNL/NM 1998). The seasonal effect is damped out and becomes insignificant between the pumping centers and TA-V.



From Bartolino and Cole 2002.

Figure 2-5. Configuration of the regional groundwater surface in the Albuquerque Basin, 1994-1995.

3.0 CURRENT CONCEPTUAL MODEL FOR TECHNICAL AREA V

Groundwater flow and contaminant transport at SNL/NM TA-V are controlled by the local geologic features and hydrologic conditions. A current understanding of these features, including discussion about contaminant distribution, transport, and geochemistry, is presented in the following sections.

3.1 Geologic Features of Technical Area V

Contaminant transport at TA-V is constrained by geologic features at TA-V. These features include the local stratigraphic framework and structural features. Discussion of these features in subsequent sections is drawn heavily from the update of subsurface geology at KAFB by Van Hart (2003).

3.1.1 Stratigraphic Framework

The stratigraphy of alluvium and the Santa Fe Group at TA-V is defined using stratigraphic and geophysical information obtained from boreholes and wells at and near the area. The stratigraphic units of hydrologic significance consist of the alluvial fan lithofacies and ARG deposits.

3.1.1.1 Alluvial Fan Lithofacies

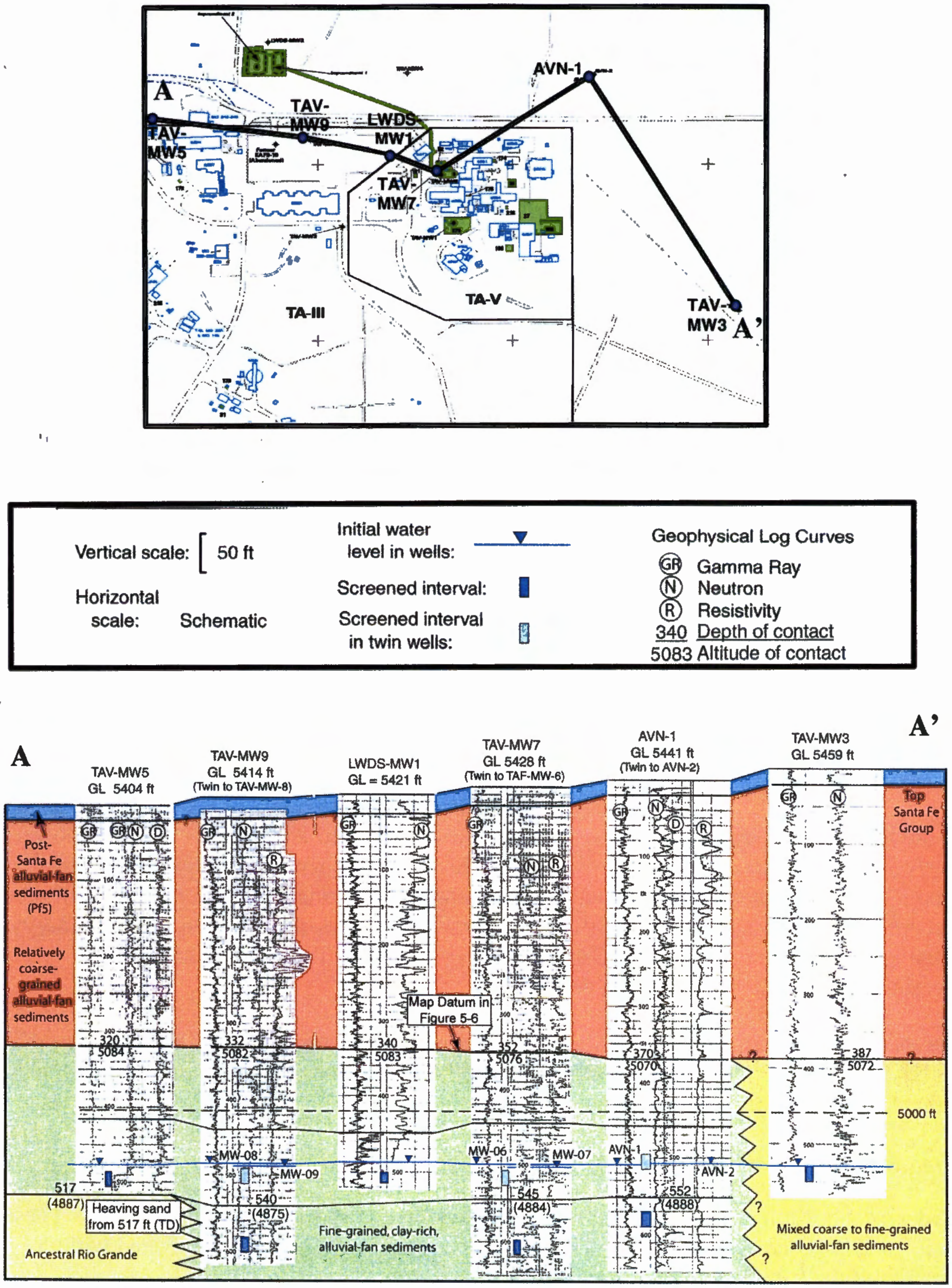
TA-V is largely underlain by a thick section of alluvial fan deposits (Figure 3-1, Section A-A'). These deposits consist of the alluvial fan lithofacies of the Santa Fe Group overlain by post-Santa Fe Group alluvial fan deposits. Well AVN-1 penetrated 650 ft of these deposits. The total thickness at TA-V is unknown.

The alluvial fan lithofacies is further subdivided into a lower and an upper section. The lower section consists of a fine-grained clay-rich unit. This unit has been identified as low-energy piedmont deposits derived from upland soils that developed during a pre-glacial humid climate. The upper section consists of relatively coarse-grained sediments deposited in a higher-energy environment. The water table of the Santa Fe Group aquifer at TA-V is located in the fine-grained lower unit of alluvial fan deposits.

The post-Santa Fe Group alluvial fan deposits blanket the area around TA-V and compose the upper few tens of feet of the vadose zone. These deposits were derived primarily from alluvial fans that originated from Coyote Canyon to the east.

3.1.1.2 Ancestral Rio Grande Deposits

ARG deposits interfinger with alluvial fan deposits at depth west of TA-V (Figure 3-1). These deposits consist predominantly of well-sorted sands and gravels that were deposited with the integration of the Rio Grande drainage system.



From Van Hart 2003

Figure 3-1. Geophysical-log correlation Section A-A', extending across SNL/NM TA-V.

3.1.2 Structural Features

The stratigraphic units at TA-V have been modified by structural features. These features include rift-zone faults and subsurface bedrock highs separating subbasins within the Albuquerque Basin.

3.1.2.1 Faults

TA-V is located in proximity of numerous rift-zone faults (Figure 2-3). The Sandia Fault is located approximately 1 mile east of TA-V. The eastern upthrown block of this fault consists of Paleozoic rocks at the land surface. The relatively low hydraulic conductivity of the Paleozoic rocks on the eastern side of the Sandia Fault effectively bounds groundwater flow.

The buried West Sandia Fault is tentatively located west of TA-V based on seismic data (Figure 2-3). This fault may increase the thickness of the aquifer to the west and may vertically offset some Santa Fe Group deposits. Offsets may locally affect groundwater flow by bringing transmissive sediments into contact with less transmissive sediments. These offsets may result in hydraulic gradient changes across the fault.

3.1.2.2 Subbasinal Bedrock Boundary

TA-V is located in the southeastern part of the Calabacillas subbasin. A bedrock high, located several miles to the southwest of TA-V, separates the Calabacillas and Belen subbasins (Figure 2-4). The thinning of the Santa Fe Group aquifer over this bedrock high may reduce the overall transmissivity of the aquifer and locally increase the hydraulic gradient. The effect of this boundary on groundwater flow and contaminant migration at TA-V is minimal.

3.2 Hydrologic Conditions at Technical Area V

Contaminant migration in the subsurface at TA-V is controlled by local recharge to the Santa Fe Group aquifer and by the capability of sedimentary units in the vadose zone and aquifer to store and transmit water and solutes.

3.2.1 Recharge

Aqueous transport of contaminants from contaminant source areas is dependent on the local availability of water that moves from the land surface to the water table. The infiltration of wastewater disposed at TA-V provided the predominant source of local recharge. Precipitation and streamflow are two other potential recharge sources.

3.2.1.1 Wastewater Disposal

Local recharge at TA-V is attributed mainly to wastewater disposal to the Liquid Waste Disposal System (LWDS) drainfield (SWMU 5), LWDS surface impoundments (SWMU 4), and to the TA-V seepage pits (SWMU 275) (Figure 3-2). Table 3-1 identifies the dates of disposals and estimated disposal volume. Figure 3-3 shows cumulative wastewater discharges over time. Yearly discharge information for the drainfield and impoundments (from 1963 and 1971) was previously documented (SNL/NM 1993) and used in this figure. The range of yearly seepage pit discharges shown on figure 3-3 is derived from the overall estimated discharge. After 1992, wastewater was disposed to the COA sewage system. Other potential releases may have included leakage from wastewater transfer piping (SNL/NM 1993).

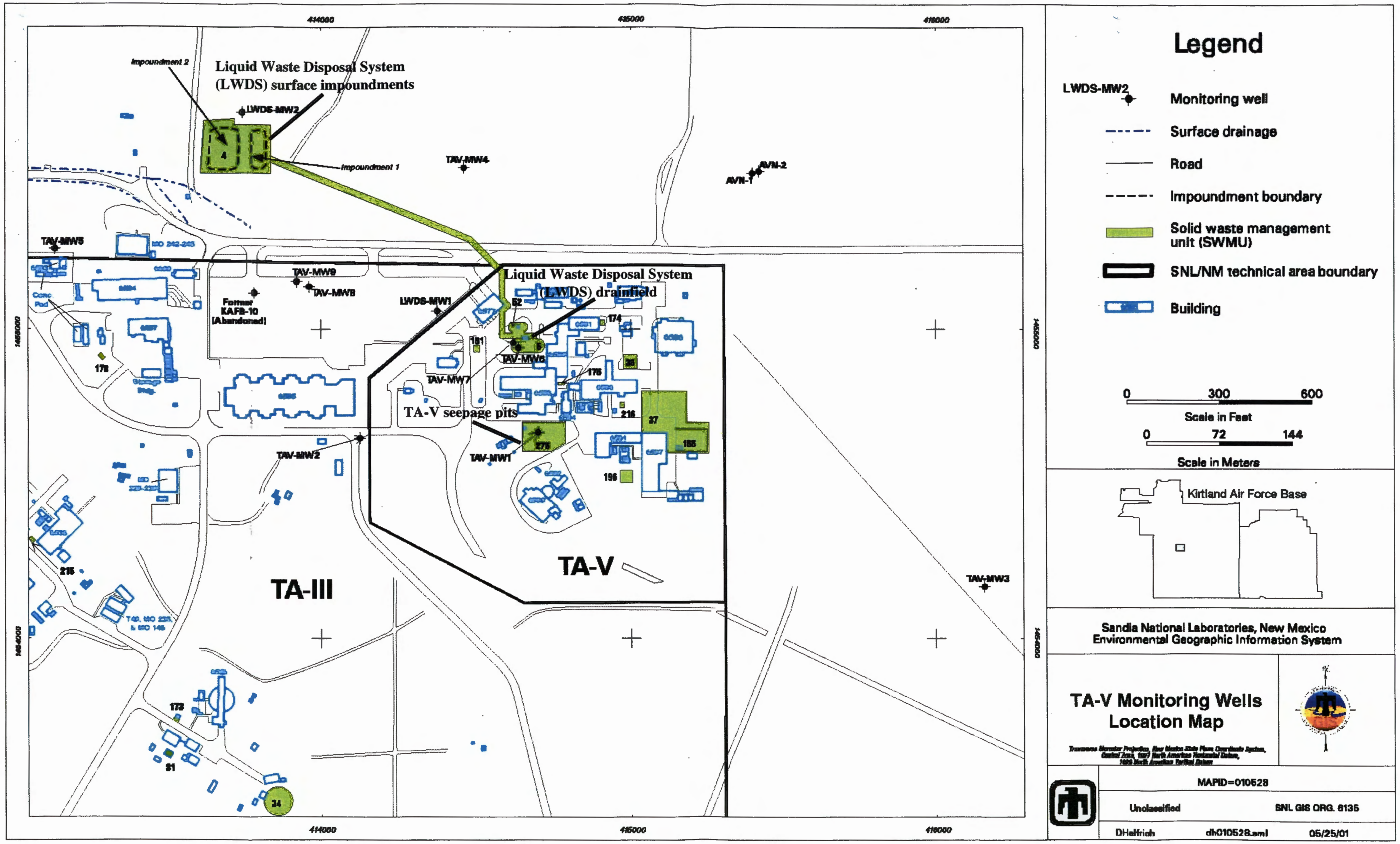


Figure 3-2. Location of waste disposal sites and groundwater monitoring wells in the vicinity of SNL/NM TA-V.

Table 3-1. Wastewater disposal history at TA-V.

Disposal Facility	Dates of Disposal	Estimated Volume (gal)
TA-V seepage pits (SWMU 275)	1960s-1992	30 to 50 million
LWDS drainfield (SWMU 5)	1963-1967	6.5 million
LWDS surface impoundments (SWMU 4)	1967-1971*	12 million
* Used intermittently for unmonitored discharge of local runoff and disposals to sinks and floor drains until 1992.		

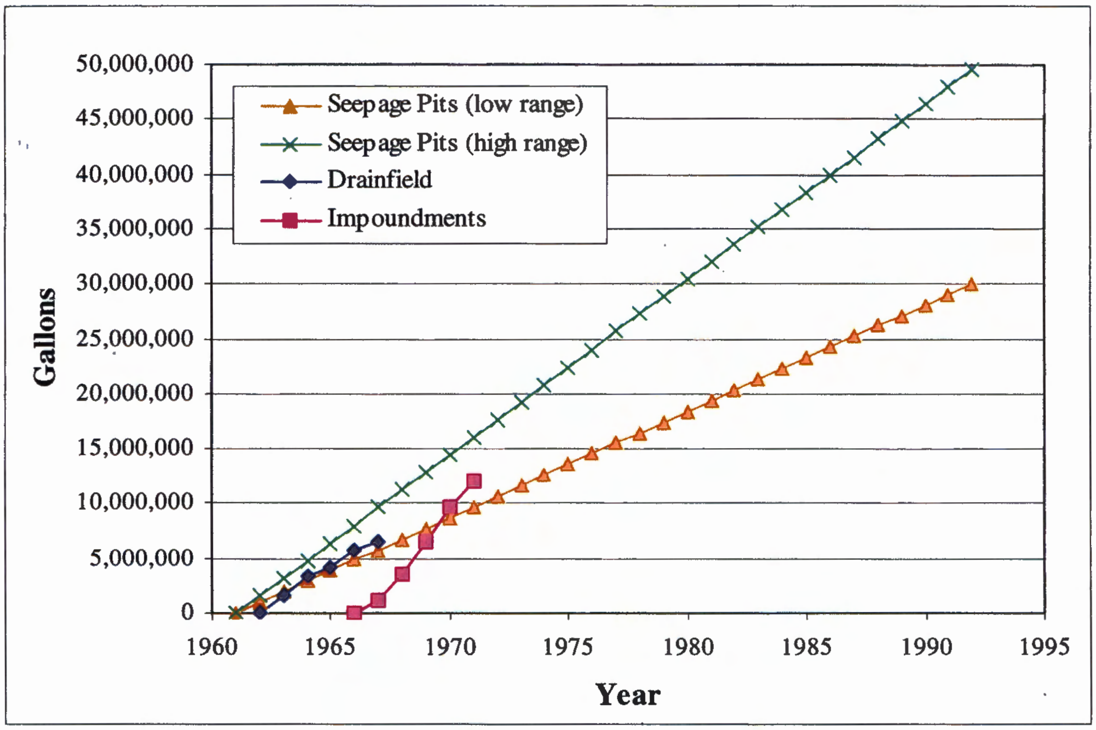


Figure 3-3. Cumulative wastewater discharges at TA-V.

The LWDS was used for disposal of reactor cooling process water from the Sandia Engineering Reactor Facility (SERF) and liquid wastes from the reactor support facilities. The LWDS consists of a set of three holding tanks (designated as SWMU 52) and an associated pumping system, LWDS drainfield, and the two LWDS surface impoundments (SNL/NM 1999).

The LWDS drainfield operated from 1963 until it reportedly collapsed in 1967. The total volume of wastewater discharged from the SERF to the drainfield was about 6.5 million gal. The drainfield is buried approximately 30 ft deep and is located approximately 30 ft south of the LWDS holding tanks. Details regarding the construction of the drainfield are uncertain, but according to the LWDS Work Plan (SNL/NM 1993), a 36-ft-deep trench was constructed with a gravel-filled base and a 3-ft-diameter, open-jointed concrete pipe was placed along the base of the drainfield. The drainfield was backfilled with a mixture of gravel and soil. A 3-in.-diameter drainpipe connects the holding tanks to the concrete pipe at the base of the drainfield (SNL/NM 1999).

The LWDS holding tanks consist of a series of two concrete tanks (Tank 1 and 2) and one steel tank (Tank 4). These tanks served as holding tanks for the liquid waste from the SERF to allow time for short-lived radionuclides to decay before discharge to the drainfield or surface impoundments. Historically, the LWDS drainfield was referred to as Tank 3. Before each discharge to the drainfield, the liquid was thoroughly mixed and monitored for total radioactivity and fission products (SNL/NM 1999). Following decommissioning of the SERF in 1971, the LWDS holding tanks (Tanks 1, 2, and 4) received water from nonreactor facilities. This water was sampled and analyzed for radionuclides and suspended solids prior to release to the sanitary sewer system. On April 15, 2002, sludge and liquid fraction samples were collected from the tanks to perform chemical and radiological analyses. Although TCE had been detected in the past, it was not detected in any of the samples. 1,2-DCE, a degradation product of TCE, was detected in liquid samples from Tanks 1 (1.1 μg/L) and 2 (2.8 μg/L) and in a sludge sample from Tank 2 (7.2 μg/L) (Haggerty 2002).

The LWDS surface impoundments were constructed after collapse of the drainfield. They consisted of two unlined surface impoundments: Impoundment 1 was constructed in 1967 and Impoundment 2 was completed in 1970. The impoundments were used for the disposal of primary coolant water from the SERF and for the disposal of potentially-contaminated water from experiments and operations in the SERF buildings. In addition, waste oil and resin beads were disposed to the surface impoundments on at least one occasion.

The volume and radionuclide activity of the discharges to the impoundments were monitored and recorded during 1967-1971. About 12 million gal of wastewater were discharged during this period; disposed water contained approximately 14 Ci of measured radioactivity. The last discharge of radioactive wastewater from reactor operations occurred in April 1970. The impoundments continued to be used for unmonitored, intermittent wastewater discharges reportedly consisting of uncontaminated process chill water and waste fluids discharged to the LWDS through sinks and floor drains. The U.S. Department of Energy (DOE) ordered the termination of the discharges in September 1992 (SNL/NM 1999). The impoundments are now inactive.

The TA-V seepage pits consist of two septic tanks connected by distribution boxes to six seepage pits. Sewer lines from the seepage pit system were connected to at least six buildings. The two septic tanks have storage capabilities of 5,000 and 4,200 gal, respectively, and are constructed approximately 8 ft below ground surface (bgs). The seepage pits are concrete/cinder block construction and form open-bottomed cylinders approximately 11 ft high with a diameter of 6.5 ft. The bottoms of the seepage pits are approximately 19 to 20 ft bgs and contain a 3-ft-thick layer of 1- to 1.5-in.-diameter gravel. Most of the industrial process water from TA-V was disposed in these seepage pits from the early 1960s until 1992, at which time the seepage pits were abandoned. During this time, an estimated 3,000 to 5,000 gal of water were disposed to the seepage pits on a daily basis (SNL/NM 1999). Use of the seepage pits for disposal was discontinued when the COA sanitary sewer system was extended into the TA-III/V area in 1992 (SNL/NM 1999).

Based on the distribution of contaminants in groundwater, the drainfield and seepage pits were the two probable sources of organic contaminants in the aquifer at TA-V. Disposal of volatile organic compounds (VOCs) to the surface impoundments may have increased volatization in the open air. Evaporative losses also were enhanced through surface disposal, which may have decreased the recharge from infiltrating impoundment water.

3.2.1.2 Precipitation

Average annual precipitation at TA-V is approximately 8 in. (SNL/NM 2001a). Much of this precipitation is derived from thundershowers during July through October. No measurable correlation is seen between precipitation and water levels in TA-V wells. Because the rate of evapotranspiration in the Albuquerque area greatly exceeds precipitation, this source of areal recharge is considered to be minimal as a mechanism for transporting contaminants through the thick vadose zone at TA-V.

3.2.1.3 Infiltration from Streamflow

Arroyo del Coyote, approximately 0.5 miles to the northeast of TA-V, transports sporadic, short, ephemeral streamflows from mountainous drainages to the east. Part of the recharge derived from infiltration of these flows is returned to the atmosphere through evapotranspiration. Some water that infiltrates the Arroyo channel may move past the root zone and provide some local recharge. This local recharge does not produce an observable effect within the vadose zone or aquifer at TA-V.

3.2.2 Vadose Zone Flow

The vadose zone at TA-V consists of approximately 500 ft of unconsolidated to semi-consolidated alluvial sediments and provides a contaminant pathway from sources to the Santa Fe Group aquifer. The alluvial-fan sediments are relatively coarse-grained in the upper sections, and become fine-grained and clay rich with depth (Figure 3-1). The unsaturated and saturated hydraulic properties of the vadose zone at TA-V have not been characterized. However, they are highly variable and anisotropic because of the heterogeneous textures, lenticularity, layering, and changes in cementation.

Borehole sediment samples were collected in 2001 during drilling of groundwater monitoring well TAV-MW6, located adjacent to the LWDS drainfield, and monitoring well TAV-MW8, located about 700 ft west of the drainfield (Figure 3-2). These boreholes were drilled in part to compare vadose-zone characteristics beneath the drainfield to those in an area without consistent wastewater disposals. Soil-moisture analyses were conducted on the borehole sediment samples (SNL/NM 2001b). Soil-moisture content above the water table at the LWDS drainfield ranged from 1.42 to 9.94% by weight. This range was comparable to the soil-moisture content away from the drainfield, ranging from 4.16 to 12.6% by weight. The comparable soil-moisture content indicates that no excess moisture remains in the vadose zone from infiltration of LWDS drainfield wastewater. For comparison, soil-moisture measurements of approximately 15% by weight in TAV-MW6 are representative of water saturation at the water table.

Infiltration of wastewater from the LWDS drainfield and the seepage pits resulted in the development of preferential pathways of saturated or nearly saturated flow through the thick vadose zone to the aquifer. Rapid vertical flow through the discontinuous, layered, lenticular sediments in the vadose zone may have been somewhat attenuated or diverted at horizons of contrasting hydraulic properties. Discharge of wastewater to the drainfield was discontinued in 1967. Discharge to the seepage pits was discontinued in 1992. Based on the moisture content measurements in vadose-zone sediment samples, drainage of water from the vadose zone to the aquifer was rapid after discharge ceased; little or no moisture from wastewater discharge at TA-V remains in the vadose zone.

3.2.3 Groundwater Flow in the Santa Fe Group Aquifer at TA-V

Groundwater flow in the Santa Fe Group aquifer at TA-V serves as the primary mechanism of potential contaminant transport to downgradient receptors. Groundwater flow is constrained by local distribution of saturated hydraulic properties. The resultant field of flow defines the local direction and velocity of groundwater flow.

3.2.3.1 Distribution of Hydraulic Properties

Basinal hydrostratigraphic units of significance in the vicinity of SNL/NM TA-V are identified as the alluvial fan lithofacies and the ARG lithofacies of the Santa Fe Group. The Santa Fe Group aquifer underlying TA-V consists of fine-grained, clay-rich sediments of the alluvial fan lithofacies. These units interfinger to the west with coarser fluvial sediments of the ARG. Saturated thickness in the vicinity of TA-V may range from less than 100 ft to several thousand feet across faults. Groundwater flow through these units is controlled by the horizontal and vertical hydraulic conductivity and the effective porosity.

Horizontal hydraulic conductivity – Aquifer tests were conducted in TA-V wells to evaluate horizontal hydraulic conductivity of the alluvial fan lithofacies at TA-V. Aquifer pumping and recovery test data collected in 1996 from monitoring wells TAV-MW2 and AVN-1 (Figure 3-2) were used to calculate minimum and maximum hydraulic conductivity values of and 6.4×10^{-5} and 2.66×10^{-2} ft/minute, respectively, for the production intervals in these two wells (Table 3-2). Since 1995, a series of slug tests have been conducted in eight TA-V wells. Hydraulic conductivity estimates from these tests ranged from 8.02×10^{-5} to 2.46×10^{-2} ft/minute. In general, horizontal hydraulic conductivity estimates from pumping and slug tests ranged from 10^{-5} to 10^{-2} ft/minute.

Vertical hydraulic conductivity – The ratio of vertical to horizontal hydraulic conductivity of a layered heterogeneous sequence commonly is on the order of 1:100 (Freeze and Cherry 1979). Vertical hydraulic conductivity of the unconsolidated sediments of the Santa Fe Group has been estimated to be one-tenth to one-hundredth the horizontal hydraulic conductivity (SNL/NM 1999). Conservative estimates of vertical hydraulic conductivity at TA-V are derived from the maximum horizontal hydraulic conductivity. The vertical hydraulic conductivity at TA-V is estimated to range from 10^{-3} to 10^{-4} ft/minute (Table 3-2).

Table 3-2. Summary of hydraulic properties of the Santa Fe Group aquifer at TA-V.

PROPERTY	VALUE/RANGE	SOURCE	REFERENCE
Horizontal hydraulic conductivity (K) (ft/min)	6.4×10^{-5} to 2.66×10^{-2}	Pumping tests (1996)	SNL/NM 1999 Attachments 5 & 6
	8.02×10^{-5} to 2.46×10^{-2}	Slug tests (multiple years)	Summarized in SNL/NM 1999 Tables 4.2.6.2-1& 4.2.6.2-2
	General range 10^{-5} to 10^{-2}	Pumping & slug tests	SNL/NM 1999
Vertical K (ft/min)	2.66×10^{-4} to 2.66×10^{-3}	Conservative estimate using the highest K of 2.66E-2 and assuming vertical K is 1/10 to 1/100 of horizontal K	SNL/NM 1999 Freeze and Cherry (1979)
Hydraulic gradient (ft/ft) (dimensionless)	Horizontal local TA-V 0.003 regional 0.009	Calculated from potentiometric surface maps	SNL/NM 1999
	Vertical downward 0.02	Calculated from well pair AVN-1 and AVN-2	SNL/NM 1999
Total porosity (dimensionless)	0.24 to 0.43	Calculated from column test at SNL/NM Hydrologic Testing Lab from TA-V sediments	SNL/NM 1999 Attachment 4
Effective porosity (n_e) (dimensionless)	0.25	Accepted values from the literature, approximated from measurements of total porosity, calculated from moisture content data (TA-V MW-6)	Domenico and Schwartz 1990 SNL/NM 2001b
Horizontal flow velocities (ft/min) (ft/yr)	9.6×10^{-7} ft/min 0.5 ft/yr	Using minimum K, minimum n_e, minimum horizontal gradient	Using all above
	3.2×10^{-4} ft/min 168 ft/yr	Using maximum K, minimum n_e, minimum horizontal gradient	Using all above
Vertical flow velocities (ft/min) (ft/yr)	2.1×10^{-5} ft/min 11.2 ft/yr	Using vertical K = 2.66E-4, vertical gradient, minimum n_e	Using all above
	2.1×10^{-4} ft/min 111 ft/yr	Using vertical K = 2.66E-3, vertical hydraulic gradient, minimum n_e	Using all above

Total and effective porosity – Total porosity was determined from tests of sediment samples in TA-V wells (SNL/NM 1999). Total porosity measurements ranged from 0.24 to 0.43 (Table 3-2). These measurements are consistent with ranges of total porosity of unconsolidated sediments discussed by Domenico and Schwartz (1990). A total porosity of approximately 0.25 was estimated at the water table in well TAV-MW6 from a sediment sample containing 15% water content by weight (SNL/NM 2001b) and assuming a material density of 2.65 g/cm^3, which is the density of quartz, the predominant mineral in the alluvial fan lithofacies.

The effective porosity is the percentage of the aquifer volume that consists of interconnected pores effectively transmitting water. In an unconsolidated sand aquifer, this volume may approach the total porosity. Because the Santa Fe Group sediments are unconsolidated, the effective porosity at TA-V may be approximated using the range of total porosity (25 to 43%). Within the context of velocity calculations, an assumed effective porosity of 25% is considered to be a conservative estimate because lower porosity values produce faster calculated velocities (Table 3-2).

Well yields – Aquifer pumping tests on TA-V wells provide information about well yields. Well AVN-1 was pumped for 48 hours at a rate of 19.3 gallons per minute (gpm). Drawdown in this well was 3 ft; specific capacity was 6.2 gpm/ft of drawdown. Well TAV-MW2 was pumped for 6.34 days at a rate of 0.35 gpm. Drawdown was 12 ft; specific capacity was 0.03 gpm/ft of drawdown. Both wells are screened over 20-ft intervals.

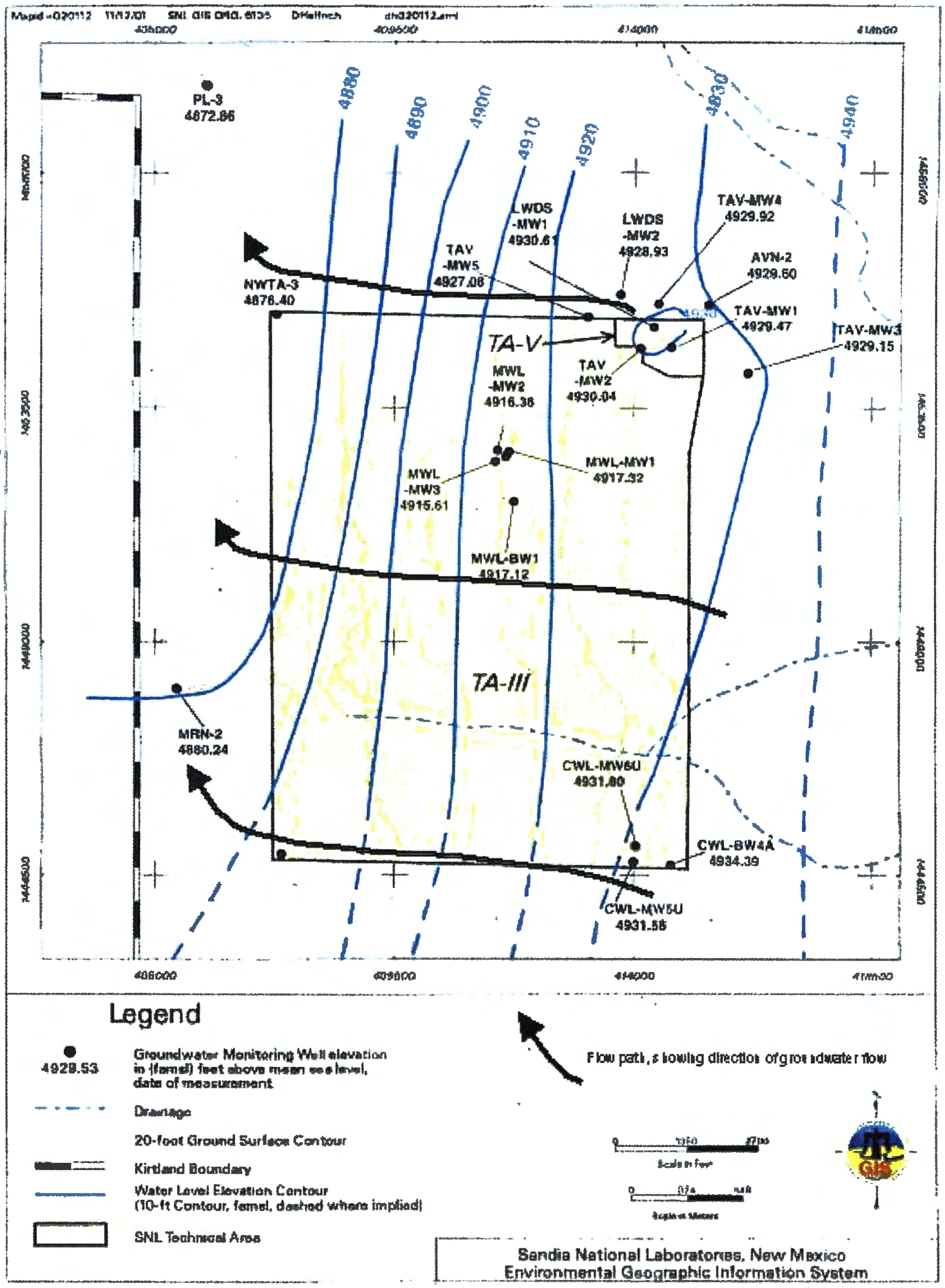
Aquifer tests indicate that well yields at TA-V are smaller than those of wells completed in the more permeable ARG to the west. Well yields at TA-V may range from less than 1 to more than 20 gpm with drawdowns exceeding 10 ft.

3.2.3.2 Field of Flow

This section describes the subregional and local direction of groundwater flow, the hydraulic gradient, and temporal changes in water levels. The section also presents computation of horizontal and vertical flow velocities.

Subregional direction of flow – The subregional potentiometric surface map for February through April 2000 indicates that groundwater in the vicinity of TA-V generally flows to the west (Figure 3-4). TA-V water-level data for 2003 indicate that this larger-scale map adequately represents the present hydraulic gradient and direction of groundwater flow. Groundwater flow paths (shown as arrows on Figure 3-4) derived from water table contours to the west of TA-V turn sharply to the north, forming a north-trending trough that directs groundwater toward COA pumping centers located north of KAFB. The sharp change in flow direction coincides with the location of coarse, well-sorted ARG sediments. These sediments are much more permeable than the fine-grained sediments of the alluvial fan facies at TA-V and permit more rapid flow through them.

A proposed well field at Mesa del Sol, approximately 3 miles west of TA-V, is located on the western side of the north-trending groundwater trough. This proposed well field would only become a downgradient receptor of TA-V contaminant plumes in the unlikely event that COA pumping centers were discontinued and groundwater flow directions reverted to the west and southwest.



From SNL/NM 2001c

Figure 3-4. Subregional potentiometric surface and groundwater flow direction in the vicinity of TA-V, February-April 2000.

Local direction of flow – The TA-V potentiometric surface map for September 2003 is shown in Figure 3-5. The 2003 potentiometric surface shows a subtle groundwater mound that is centered in the northern part of TA-V. The map indicates that groundwater flows radially to the west, northwest, and south from this mound.

The groundwater mound previously was attributed to a local source of recharge. However, wastewater disposals were discontinued in 1992 and no known continued source of local recharge exists (SNL/NM 1999). Without continued local recharge, the mound should have decayed rapidly after disposals ceased. Additionally, the water table beneath TA-V has continued to drop in response to regional pumping. Based on the absence of any substantial local source of recharge, the groundwater mound at TA-V is considered to be an artifact of these regional water-level declines within a heterogeneous aquifer.

The radial flow to the south, west, and northwest at TA-V is a local feature joining with subregional groundwater flow to the north toward production wells in the COA Ridgecrest well field. A numerical modeling particle tracking analysis indicated that the travel time from the LWDS to the nearest downgradient COA production well was approximately 70 years (SNL/NM 1999). A second numerical modeling study evaluated capture zones for production wells (SNL/NM 2001a). Time of travel from the area directly south of TA-V to KAFB production wells, approximately 3 miles to the north, was estimated to be 100 years.

Water-level fluctuations with time – Water-level fluctuations during 1993-2000 are shown for nine TA-V wells screened at or near the water table (Figure 3-6). Water levels in all nine TA-V wells declined steadily throughout the 7-year period, with declines averaging 0.7 ft/year. Water levels have since continued to decline at the same rate. These declines are dominated by long-term regional water-level declines caused by municipal pumping to the north. Some seasonal changes may be attributed to municipal changes in water usage from summer to winter. No local recharge or pumpage effects are evident.

Hydraulic gradient – The westward subregional hydraulic gradient in the area between TA-V and TA-III was estimated from potentiometric surface contours to be 0.009 (SNL/NM 1999). At TA-V, direction of flow is to the west, northwest, and south, and the water table dips approximately 14 ft/mile (from the 2003 potentiometric surface map [Figure 3-5]) for an estimated hydraulic gradient of 0.003 (Table 3-2).

Horizontal flow velocity – The horizontal groundwater flow velocity was estimated at TA-V using the Darcy flow equation, as follows:

$$V = K\,(dh/dx)/n_e$$

where

V	=	linear, or pore, velocity (ft/min)
K	=	hydraulic conductivity (ft/min)
dh/dx	=	the horizontal hydraulic gradient (unitless)
n_e	=	effective porosity.

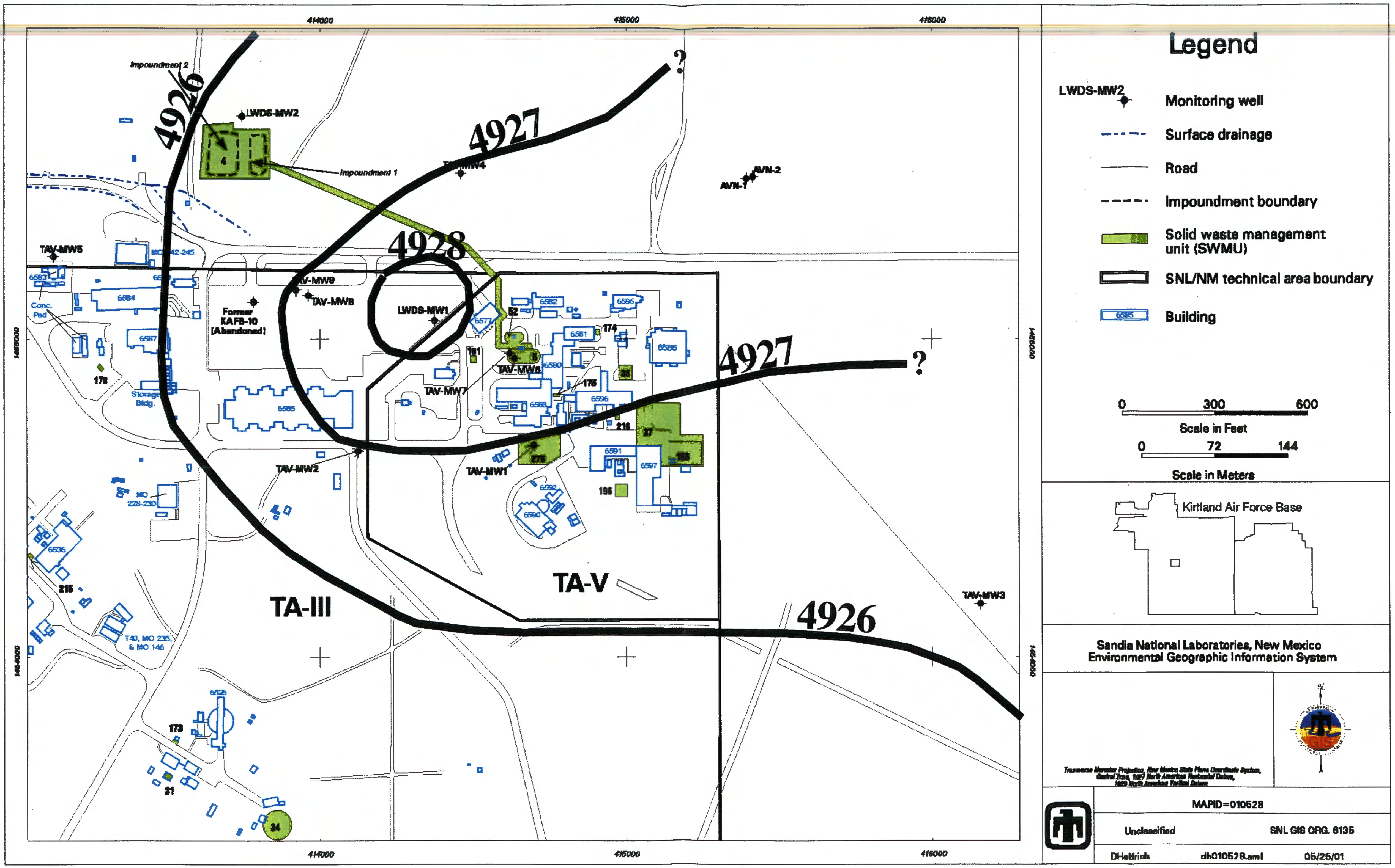


Figure 3-5. Potentiometric surface at SNL/NM TA-V, September 2003.

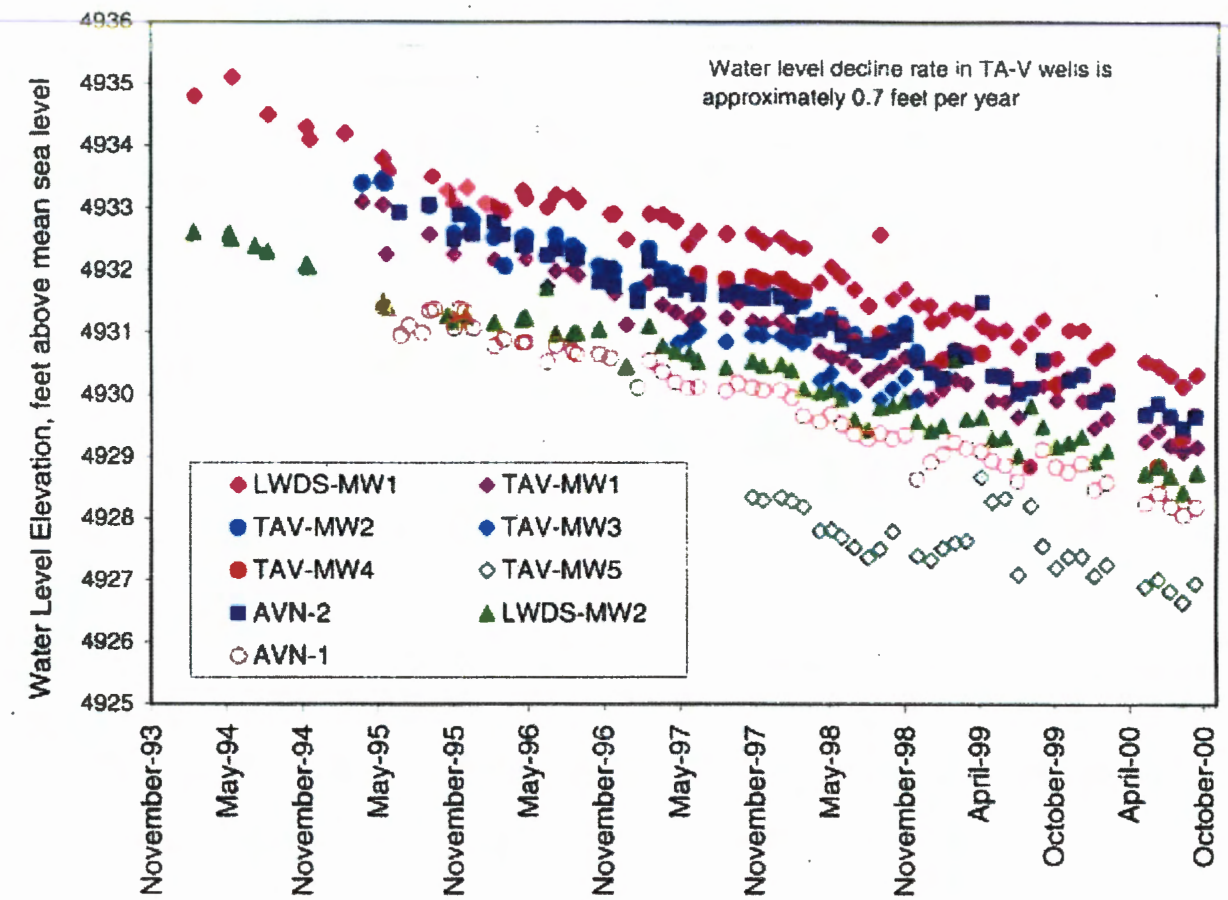


Figure 3-6. Water-level measurements in TA-V wells during 1993-2000.

Velocity estimates are derived from the range of hydraulic conductivities (6.4×10^{-5} and 2.66×10^{-2} ft/min), the horizontal hydraulic gradient of 0.003, and an effective porosity of 0.25. These estimates range from 0.5 to 168 ft/year (10^{-4} to 10^{-6} ft/min) (Table 3-2). Smaller velocities are typical of clays, while larger velocities are representative of medium to fine-grained sand.

Vertical flow velocity – Vertical groundwater flow velocities at TA-V also were estimated from the Darcy flow equation using the range of vertical K (2.66×10^{-4} to 2.66×10^{-3} ft/min), vertical gradient of 0.02 ft/ft, and effective porosity of 0.25 (Table 3-2). Vertical flow velocity estimates range from 2.1×10^{-5} to 2.1×10^{-4} ft/min (11.2 to 111 ft/year) (Table 3-2). These velocity estimates are considered to be maximum estimates because they are derived using the maximum horizontal hydraulic conductivity value at TA-V. These estimates also support the apparent rapid drainage of the overlying vadose zone.

3.3 Distribution of Contaminants in the Subsurface at TA-V

The section describes the source term and release, and contaminant distribution in the vadose zone and aquifer. This section also discusses the adequacy of the existing groundwater monitoring network to define the distribution and transport of contaminants at TA-V. COCs in groundwater at TA-V include TCE, PCE, and nitrate. These contaminants have been identified as COCs because they have been detected above MCLs in water samples from monitoring wells.

3.3.1 Contaminant Source Term and Release

Technical experts at SNL/NM identified and evaluated potential sources ofTCE and nitrate at TA-V. Information, including period of use, types of water, and process-knowledge summary, is compiled in Table 3-3. These potential sources were ranked as high, medium, low, or none based on the location of the source term with respect to contaminated groundwater. Based on this analysis, the LWDS drainfield (SWMU 5) and LWDS holding tanks (SWMU 52) are identified as TCE source locations of high concern. These facilities are described in detail in Section 3.2.1.1. The LWDS surface impoundments (SWMU 4), TA-V seepage pits (SWMU 275), Area of Concern (AOC) Drain and Septic Systems (DSS) 1104 – Building 6595 seepage pit, and AOC DSS 1113 – Building 6597 drywell are identified as TCE source term locations of medium concern.

No potential sources of nitrate at TA-V were determined to be of high concern (Table 3-3). The TA-V seepage pits, AOC DSS 1014 (consisting of the former T-12, T-42, and T-43 septic systems), AOC DSS 1015 (consisting of the former MO 231-234 septic system), and AOC DSS 1072 (consisting of Building T-52 and Former Building 6500 septic system), are identified as nitrate source locations of medium concern. The type of water released at all of these medium nitrate concern sites included septic water.

Documentation of historical use and disposal of chemicals at TA-V is limited. Industrial solvents were used in conjunction with operations and activities at TA-V machine shops and chemistry laboratories. Wastewater from these facilities was drained to the seepage pits and to the LWDS (SNL/NM 1999). Concentrations of TCE have been measured in sludges in the LWDS holding tanks (SWMU 52) that were used to distribute wastewater to the LWDS drainfield and LWDS surface impoundments (SNL/NM 1999). Although the amount of solvents that may have been disposed is not documented, solvent disposal was eliminated in the early 1980s when guidance about appropriate disposal methods was provided (SNL/NM 1999). Contaminant releases through wastewater and descriptions of facilities that discharged wastewater are discussed in Section 3.2.1.1. Amounts of wastewater discharge at TA-V are documented in Table 3-1 and Figure 3-3.

Subsurface data collected during TA-V drilling activities and other information do not support the existence of a secondary source of contamination within the vadose zone. Subsurface information is explained in additional detail in Section 3.3.3 and is summarized below:

Table 3-3. Data for potential source terms of TCE and Nitrate in the TA-V study area.

Potential Source	TCE (1) (2) Concern	Nitrate Concern	Years of Use	Type of Water	Summary of Process Knowledge
SWMU 4 - LWDS Surface Impoundments	Medium	Low	1967 – 1971	High volume waste water from cooling system	The LWDS was used for the disposal of reactor cooling process water from the SERF and support facilities. The unlined surface impoundments (SWMU 4) received approximately 12.6 M gal, and were constructed after the Drainfield (SWMU 5) became inoperable. Waste water was monitored for radionuclides but not chemical constituents. Groundwater monitoring analytical data suggests a distal TCE source; therefore, a medium TCE concern is warranted.
SWMU 5 - LWDS Drainfield	High	Low	1963 – 1967	High volume waste water from cooling system	The LWDS was used for the disposal of reactor cooling process water from the SERF and support facilities. The drainfield (SWMU 5) received approximately 6.4 M gal before it collapsed in 1967. Waste water was monitored for radionuclides but not chemical constituents. Groundwater monitoring analytical data suggests a proximal TCE source; therefore, a high TCE concern is warranted.
SWMU 36 - HERMES Oil Spill	None	None	1968 – 1989	None	Transformer oil was used as an electrical insulating medium for radiation-effects testing operations associated with the HERMES II facility. Mineral oil was stored in five 35,000-gal USTs in a closed-loop system. The 15-ft diameter tanks had a vent and were connected in parallel with 8-in. piping. Spills occurred when unregulated flow of oil would discharge through the vent. Releases of up to 1,600 gal of mineral oil were documented. The USTs and associated piping were removed and the excavated pit had extensive TPH soil contamination. An NFA for SWMU 36 was approved by NMED in November 2001.
SWMU 37 - PROTO Oil Spill	None	None	1978 – 1989	None	Surface releases of transformer oil in SWMU 37 were in the form of leaks that occurred as a result of tank vent overflow from the associated USTs (SWMU 155). There were two reported surface spills of approximately100 gal each at a former trailer near the tanks. Potential surface spills of TPH from the PROTO I facility were investigated and no contamination above background was found.
SWMU 52 - LWDS Holding Tanks	High	Low	1963 – 1971	High volume waste water from cooling system	The LWDS was used for the disposal of cooling process water from the SERF. A set of three holding tanks with associated pumping system (SWMU 52) serviced the LWDS Drainfield (SWMU 5) then the LWDS Surface Impoundments (SWMU 4). Waste water was monitored for radionuclides but not chemical constituents. Groundwater monitoring analytical data suggests a proximal TCE source; therefore a high TCE concern is warranted.

Table 3-3. (Continued).

Potential Source	TCE (1) (2) Concern	Nitrate Concern	Years of Use	Type of Water	Summary of Process Knowledge
SWMU 155 - Bldg 6597 25,000 gal Tank	None	None	1978 – 1989	None	The PROTO USTs contained transformer oils and were removed and a UST investigation was conducted. Undocumented spills occurred during the transfer of oil from the building to the USTs. The tanks were excavated and soil samples from beneath the tanks did not exceed 100 ppm of TPH.
SWMU 174 - Bldg 6581 UST	None	None	1961 – 1990	None	A 560-gal fuel oil UST was removed. Subsequent soil sampling revealed TPH levels of less than 25 ppm and SWMU 174 was dropped from the RCRA Permit list.
SWMU 175 - Bldg 6588 UST	None	None	1978 – 1990	None	A 5,000-gal fuel oil UST was removed. Subsequent soil sampling revealed TPH levels of less than 25 ppm and SWMU 175 dropped from the RCRA Permit list.
SWMU 181 - Bldg 6500 UST	None	None	1976 – 1991	None	600-gal fuel oil UST removed. Subsequent soil sampling revealed TPH levels of less than 25 ppm and SWMU 181 dropped from the RCRA Permit list.
SWMU 196 - Bldg 6597 Cistern	None	None	1978 – 1989	Minor waste/storm water	The cistern is a concrete-walled cylinder, 25 ft by 28 ft with no concrete base (open at bottom). Designed as a temporary storage container for transformer oil from the PROTO I facility. Occasional, small quantities (5 gal per week) of transformer oil contaminated with water were discharged into the cistern. Waste oil was routinely removed from the cistern for offsite disposal. Residual waste oil remains in the soil beneath the cistern.
SWMU 275 – TA-V Seepage Pits	Medium	Medium	Early 1960s – 1992	High volume waste/ septic/ process water	Two septic tanks and six seepage pits associated with numerous TA-V buildings received 3 to 5 K gal of water per day. In 1992 TA-V buildings were connected to the COA sanitary sewer system. Groundwater monitoring analytical data suggests a distal TCE source; therefore a medium TCE concern is warranted.
AOC DSS 1014 - Former T-12, T-42 and T-43 Septic System	Low	Medium	Unknown – 1992	Septic water	Single septic tank and seepage pit that serviced 3 temporary buildings. Abandoned in the early 1990s when COA sanitary sewer system came on line.
AOC DSS 1015 - Former MO 231-234 Septic System	Low	Medium	Unknown – 1992	Septic water	Single septic tank and drainfield that serviced 4 MOs. Abandoned in the early 1990s when COA sanitary sewer system came on line.
AOC DSS 1072 - Bldg T-52 and Former Bldg. 6500 Septic System	Low	Medium	Early 1960s – 1992	Septic water	Single septic tank and drainfield that serviced 1 MO and 1 small permanent building. Abandoned in the early 1990s when COA sanitary sewer system came on line.

Table 3-3. (Continued).

Potential Source	TCE (1) (2) Concern	Nitrate Concern	Years of Use	Type of Water	Summary of Process Knowledge
AOC DSS 1073 - Bldg. 6580 Seepage Pit	Low	Low	1962 – 1992	Process water	Building 6580 housed chemistry labs and a machine shop with sink and floor drains connected to the LWDS. Abandoned in the early 1990s when COA sanitary sewer system came on line.
AOC DSS 1098 - TA-V Plenum Rooms Drywell	None	Low	Early 1960s – 1992	Storm water	Drywell or seepage pit that serviced a tall, metal emission stack. Currently connected to the sanitary sewer system.
AOC DSS 1104 - Bldg. 6595 Seepage Pit	Medium	Low	1966 – 1992	Process water	Abandoned in the early 1990s when COA sanitary sewer system came on line. Minor concentrations (below MDL) of PCE and TCE were found in DSS soil samples.
AOC DSS 1105 - Bldg. 6596 Drywell	Low	Low	Unknown – 1992	Process water	Building 6596 was a machine shop. Drywell was a 10 ft × 10 ft × 5 ft gravel-filled structure.
AOC DSS 1112 - Bldg. 6590 Reactor Sump Drywell	None	Low	1961 – 1992	Storm water	4 ft × 4 ft gravel-filled drywell plumbed to a sump/pit beneath the SPR.
AOC DSS 1113 – Bldg. 6597 Drywell	Medium	Low	1971 – 1992	Process water	4 ft × 4 ft × 2 ft gravel filled drywell from a floor drain in a small compressor room. Mineral oil found in drywell and minor concentrations (below MDL) of PCE were found in DSS soil samples.

Notes:
Bold denotes potential sources with the greatest level of concern.

1) Although no historic documentation exists, TCE was presumably used in buildings and facilities throughout TA-V. Undocumented use makes it impossible to further pinpoint specific buildings or facilities as sources of TCE.

2) The geographic distribution of TCE in groundwater has aided investigators in justifying the level of TCE concern at specific SWMUs. Non-detect to low concentrations of TCE in wells associated with SWMUs 4 and 275 have prompted a "medium" TCE concern level; whereas, medium to high (relatively) concentrations of TCE in wells associated with SWMUs 5 and 52 have prompted a "high" TCE concern level.

AOC = area of concern
COA = City of Albuquerque
DSS = Drain and Septic Systems
gal = gallons
HERMES = High Energy Radiation Megavolt Electron Source
LWDS = Liquid Waste Disposal System
MDL = method detection limit
MO = mobile office
M gal = million gallons
PCE = tetrachloroethene
ppm = parts per million
RCRA = Resource Conservation and Recovery Act
SERF = Sandia Engineering Reactor Facility
SPR = Sandia Pulse Reactor
SWMU = Solid Waste Management Unit
TCE = trichloroethene
TPH = total petroleum hydrocarbons
UST = underground storage tank

- Low TCE concentrations in vapor samples collected from sediments beneath contaminant release areas indicated that no secondary source of TCE presently exists in the vadose zone.
- No excess soil moisture is present in the vadose zone from wastewater disposal.
- Movement of water and contaminants through the vadose zone was rapid during the seepage pit and LWDS disposals, and vadose-zone drainage occurred soon after cessation of wastewater disposal.
- Solvent disposals were eliminated in the early 1980s, but wastewater disposal to the seepage pits continued.
- Continued disposals flushed contaminants in the vadose zone into the aquifer.

The SNL/NM Environmental Restoration (ER) Project is separating surface contamination sites from the underlying contaminated groundwater sites. The surface sites, such as the seepage pits, will be proposed as No Further Action (NFA) sites that are not potential sources of contamination.

3.3.2 Contaminant Transport Through the Vadose Zone

Potential mechanisms of contaminant transport from TA-V sources through the vadose zone include dissolved-phase transport in recharge water and subsurface vapor-phase transport. Characterization to evaluate the presence of contaminants in the vadose zone consisted of soil-vapor and soil-moisture sampling activities. Locations of investigations were based upon potential source terms (Table 3-3).

Soil vapor studies were conducted as part of 1994 and 2001 drilling projects. Within the LWDS drainfield, estimated quantities of TCE (4 parts per billion by volume [ppbv]), PCE (4 ppbv), and benzene (7 to 15 ppbv) were detected in shallow borehole active soil vapor characterization samples collected during 1994 (SNL/NM 1999). The potential of vadose zone contamination was further investigated with the installation of wells TAV-MW6, TAV-MW7, TAV-MW8, and TAV-MW9 in March and April 2001. Results of soil and soil-vapor samples collected from the shallow wells show no residual soil contamination in the vadose zone. Soil-vapor samples collected at depth from the TAV-MW6 borehole contained detectable TCE concentrations. Twenty-six samples were collected between 20 and 500 ft bgs; estimated concentrations (J flag) were detected in 10 samples. These concentrations, all less than 0.17 parts per million by volume (ppmv), were from samples collected between 200 and 480 ft. A concentration of 0.2 ppmv was measured in the sample collected from 500 ft. The remaining sample results were below the method detection limit (MDL) of 0.022 or 0.044 ppmv. Concentrations of TCE in all eight samples collected from the TAV-MW8 borehole between 40 and 480 ft also were below the MDLs for TCE. The detections of TCE in TAV-MW6 may be TCE contamination in the lower part of the vadose zone, and TCE detected just above the surface of the groundwater may be attributed to vapor-phase contamination originating from TCE that has equilibrated in the groundwater (SNL/NM 2001b).

Soil-moisture studies identified no continuing source of wastewater in the vadose zone beneath the LWDS drainfield. Soil moisture in the TAV-MW6 borehole above the water table ranged from 1.42 to 9.94% by weight. Well TAV-MW8 was drilled at a location that has not been impacted by wastewater discharges to the subsurface. Soil moisture in the TAV-MW8 borehole ranged from 4.16 to 12.6% by weight. Comparisons of soil-moisture data for TAV-MW6 and TAV-MW8 show that soil-moisture contents from both boreholes are generally similar, and that TAV-MW6 does not contain anomalous amounts of soil moisture compared to the TAV-MW8 samples (SNL/NM 2001b).

In the vicinity of the TA-V seepage pits, concentrations of TCE (3 to 17 ppbv estimated and 25 ppbv), PCE (5 ppbv), benzene (9 to 19 ppbv), toluene (9 to 22 ppbv), and total xylene were detected in shallow vadose-zone borehole soil vapor samples and from passive, surficial characterization studies during 1994-1995. Vapor-phase TCE was detected at 44 ppbv at a depth of 80 ft in borehole TAV-BH-01 (SNL/NM 1999). Solvent disposals to the seepage pits were eliminated in the early 1980s (SNL/NM 1999), but wastewater disposal continued. Continued disposal flushed vapor- and aqueous-phase concentrations of contaminants that may have been present in the vadose zone into the aquifer.

Other surface contamination sites have been investigated at TA-V. Investigations included surficial and subsurface passive and active vapor-phase sampling for contaminants. Concentrations of TCE, methylene chloride, trichloroethane, benzene, and toluene (concentrations are reported in the TA-III/V RFI [SNL/NM 1996]) were detected in shallow soil samples collected at the Building 6597 cistern (SWMU 196). Subsequent investigations revealed that these contaminants were not present at depth beneath the cistern. Based on these investigations, it was concluded these surface contamination sites have not contributed to groundwater contamination at TA-V (SNL/NM 1999).

Because TCE is volatile and the vapors are dense compared to the density of soil air, the physical properties of TCE are conducive to vapor-phase transport. Vapor-phase transport is one potential mechanism that may account for the presence of TCE in the aquifer. Three vadose zone physical processes may have affected the vapor-phase migration of TCE to the aquifer. These processes consist of (1) vaporization from the source, (2) vapor-phase transport to the capillary fringe, and (3) dissolution into groundwater. Small concentrations of TCE that may remain in the vadose zone from vapor-phase transport could provide a secondary source of contamination. The absence of TCE in most vapor samples that were collected at depth indicates that no secondary source of vapor-phase TCE remains at TA-V.

Absence of excess moisture in the vadose zone indicates that wastewater containing dissolved TCE moved rapidly downward to the aquifer. Rapid drainage of wastewater and the flushing of any contaminants beneath the seepage pits removed most of the dissolved TCE in the vadose zone.

Nitrate occurs primarily in the aqueous phase in both the vadose zone and the aquifer. It is typically not sorbed in the subsurface and for the most part does not exchange on sediment surfaces in the vadose zone or groundwater. Therefore, any locally-derived nitrate was most likely transported conservatively through the vadose zone with the initial disposed wastewater. However, because nitrate concentrations were detected above MCLs in upgradient wells, these nitrate detections are generally not considered to be derived from continuing local sources.

3.3.3 Contaminant Distribution in Groundwater

Distribution and transport of COCs and additional parameters in the aquifer are discussed in following sections. In subsequent concentration plots, data that were reported below the MDL (reported with a less than sign "<") are represented at the MDL (i.e., < 2 was represented as 2) to expedite visual representation.

<u>3.3.3.1 TCE</u>

TCE is present in concentrations ranging from less than detection limits to approximately 20 µg/L in groundwater from the Santa Fe Group aquifer beneath TA-V. Figure 3-7 shows the distribution of TCE based on May 2003 data. The plume dimensions at concentrations exceeding the MCL of 5 µg/L were about 600 × 1,200 ft in 2003. The distribution of TCE indicates migration to the west, northwest, and to the south. The highest TCE concentrations are not directly under the drainfield source but to the northwest. The center of contaminant mass is presently near well LWDS-MW1, about 300 ft northwest of the drainfield and about 450 ft northwest of the seepage pits.

The maximum May 2003 TCE concentration in water from well LWDS-MW1 was 20.9 µg/L. The peak TCE concentration at TA-V was reported as 23 to 26 µg/L from LWDS-MW1 on November 13, 2000. TCE has consistently been detected above the MCL at LWDS-MW1 since 1993 (Figure 3-8), and concentrations at TAV-MW8 have been above the MCL since 2002 (Figure 3-9). A detailed depiction of vertical distribution of contaminants has not been performed, but TCE has not been detected at depths exceeding 100 ft below the water table based on data collected from deep wells TAV-MW7 and TAV-MW9 drilled in 2001 (Figure 3-10).

The distribution of TCE in 2003 indicates that the center of TCE mass has migrated approximately 300 ft northwest from the drainfield source term in the 36 years since disposal was terminated in 1967. Based on this lateral movement, TCE has migrated approximately 8 ft/year, within the range of flow velocities of 0.5 to 168 ft/year described in Section 3.2.3.2. This migration to the northwest is supported by increasing TCE concentrations in groundwater from well MW8 (Figure 3-9). The expansion of a dilute lobe of the TCE plume to the south may represent additional input of TCE through the TA-V seepage pits and subsequent dilution as wastewater disposal continued after reduction of TCE disposals in the early 1980s. TCE migration to the northwest and south from TA-V sources is consistent with radial hydraulic gradients and flow away from the subtle mound at TA-V.

<u>3.3.3.2 PCE</u>

PCE has been detected in nine water samples from well TAV-MW7. Concentrations exceeded the 5-µg/L MCL in three of those samples collected on November 12, 2001 (5.2 µg/L); February 26, 2002 (7.5 µg/L); and August 13, 2002 (5.15 µg/L) (Figure 3-11). Concentrations were below the MCL in the four samples collected since August 2002. PCE has not been detected above 1 µg/L or reported above the MDL in any of the other TA-V wells.

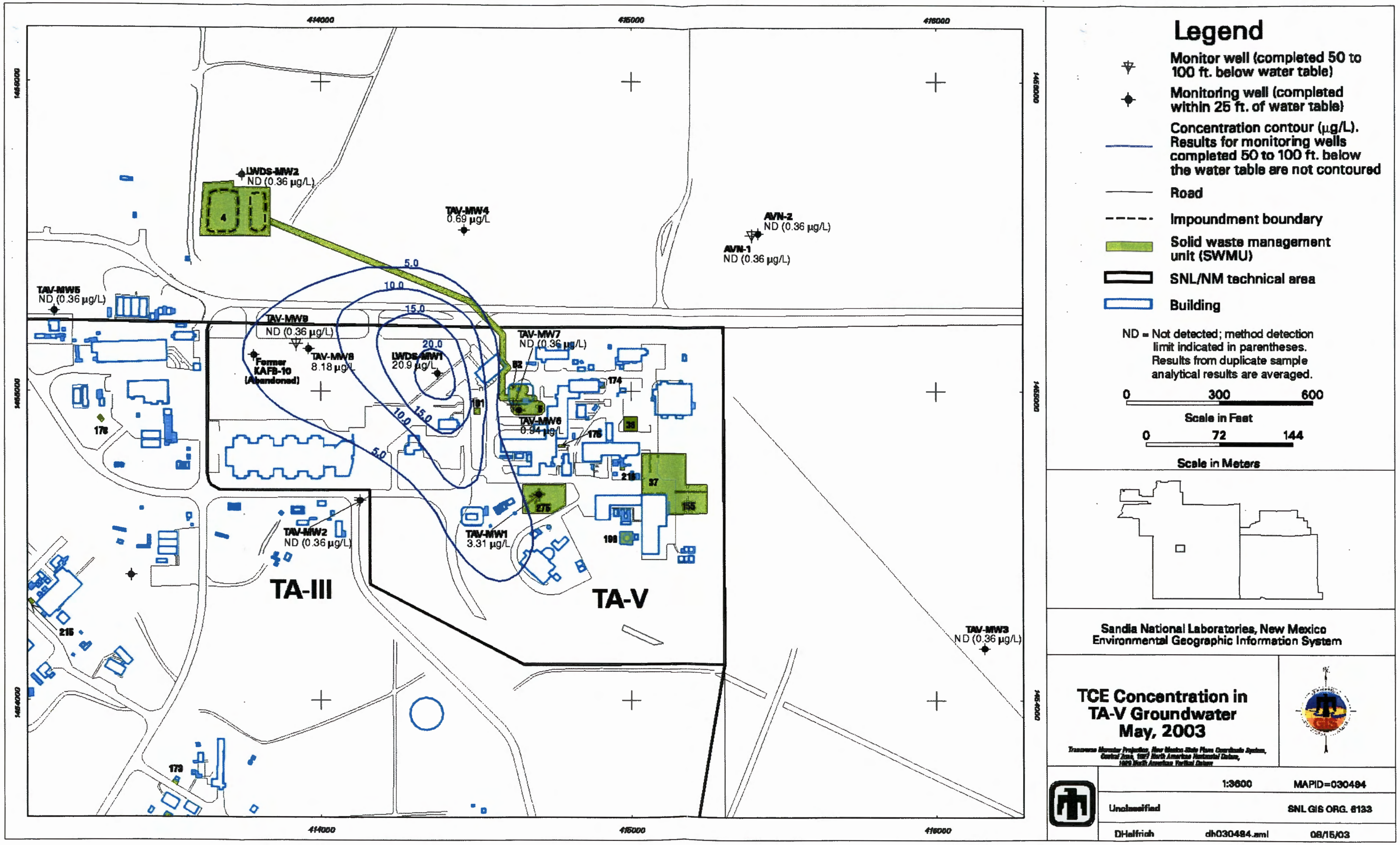


Figure 3-7. Distribution of TCE in groundwater at SNL/NM TA-V, May 2003.

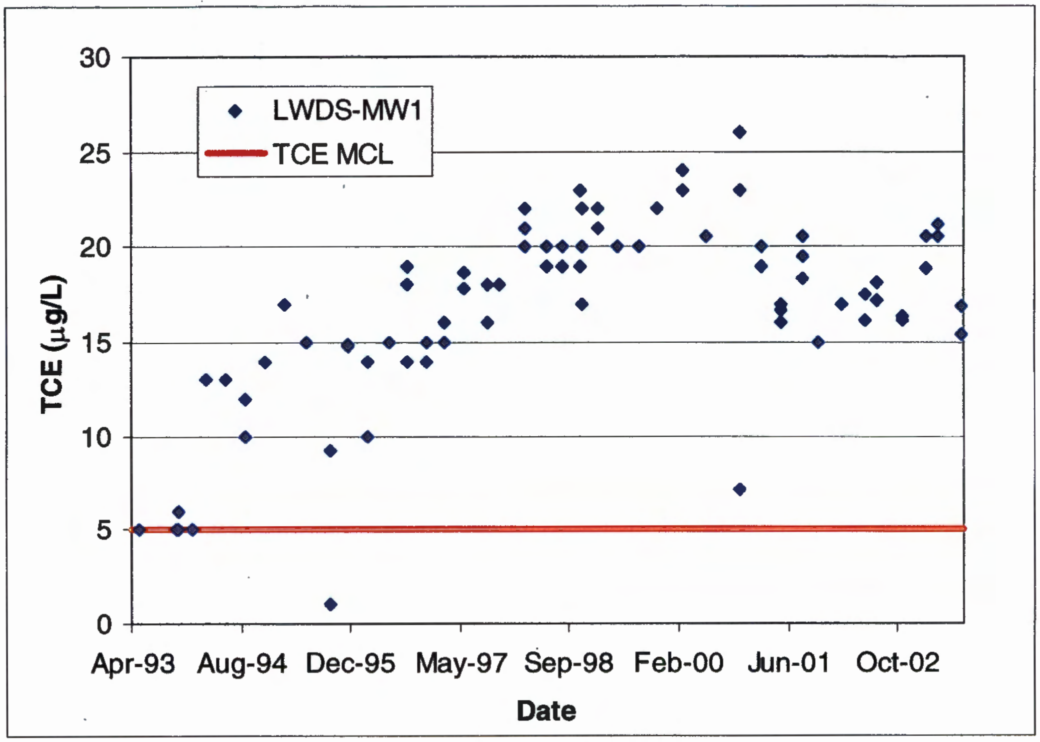


Figure 3-8. TCE concentrations over time at LWDS-MW1.

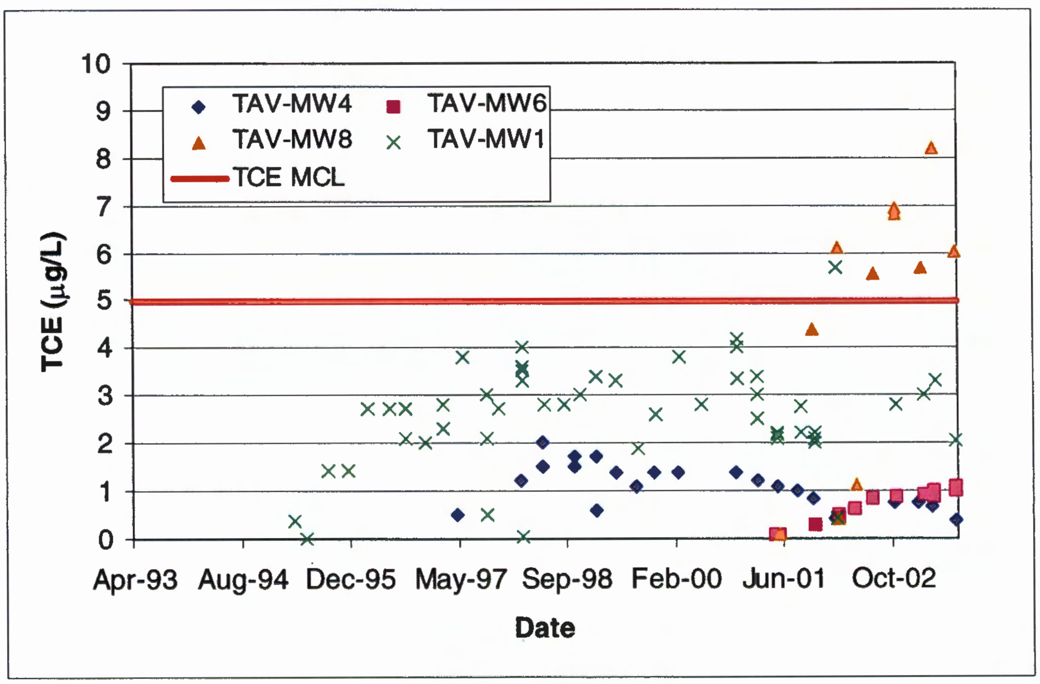


Figure 3-9. TCE concentrations over time at selected TA-V wells.

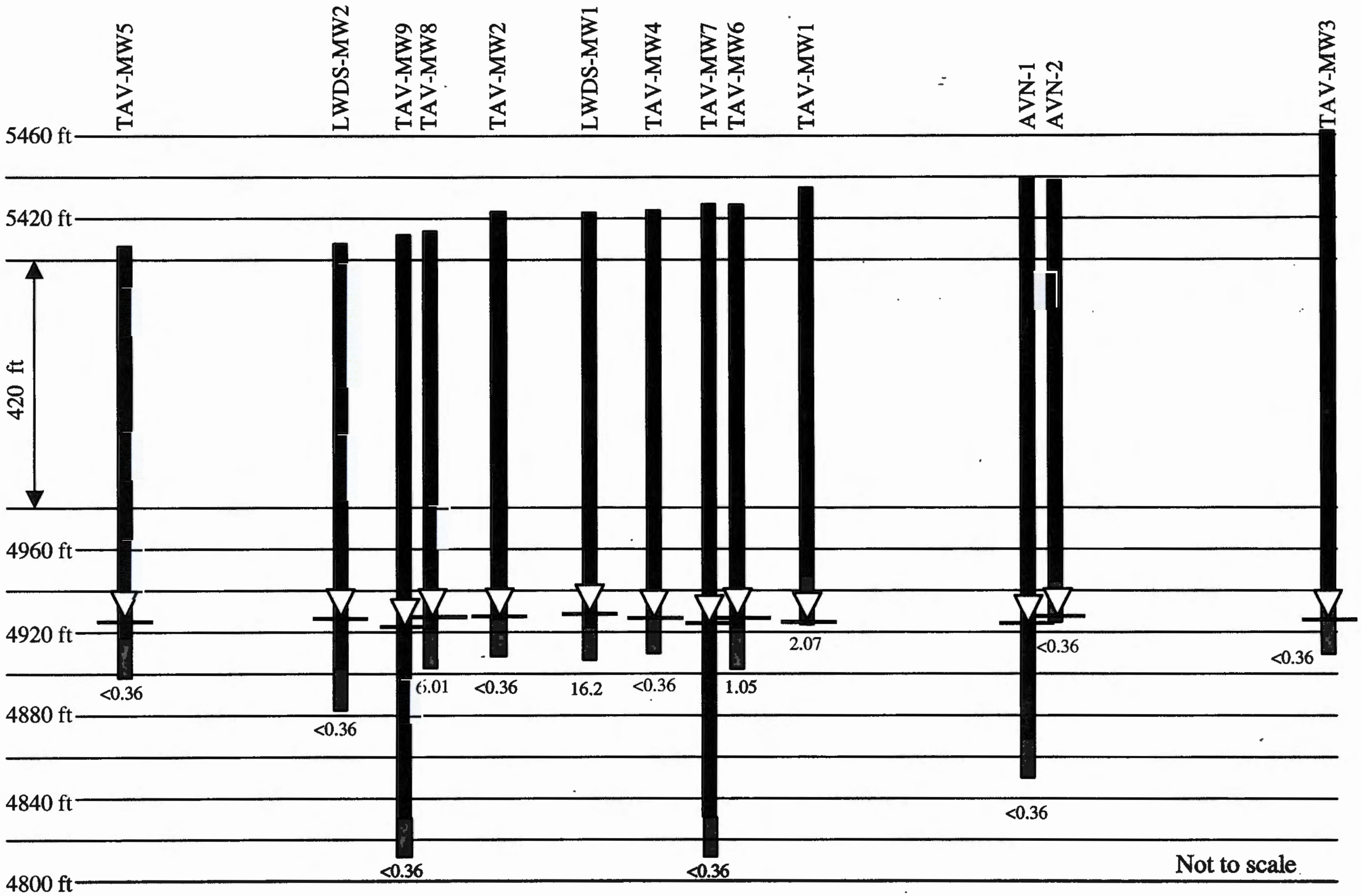


Figure 3-10. Well completions, depth to water (ft bgs) reported in September 2003 and TCE concentrations (µg/L) reported in August 2003.

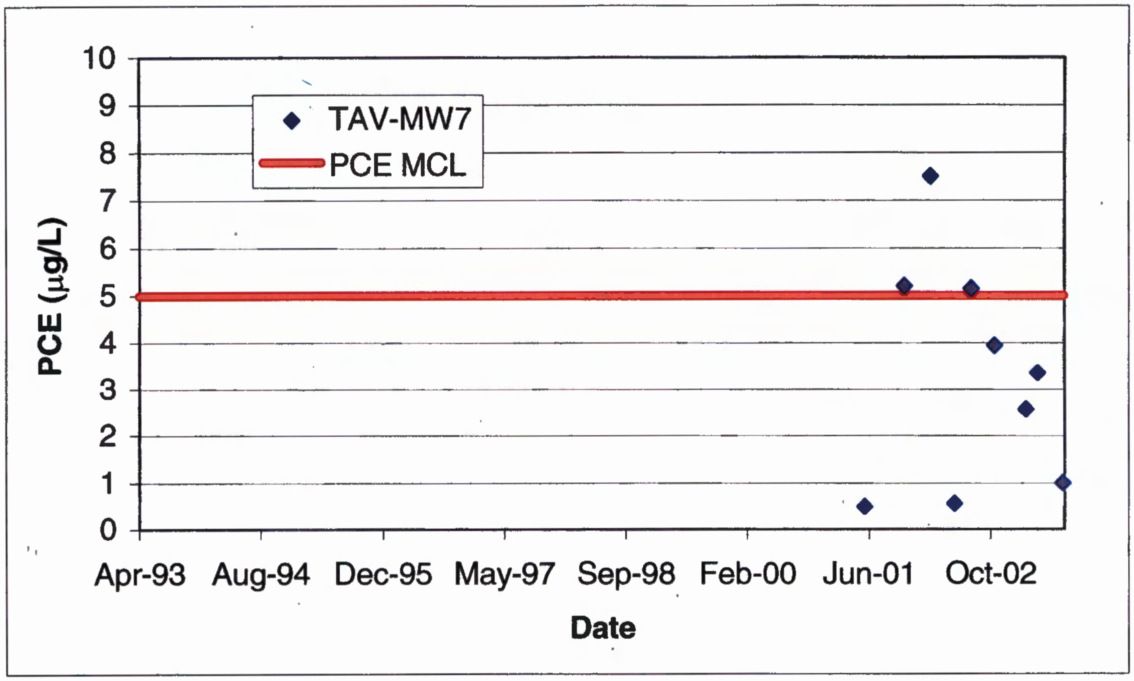


Figure 3-11. PCE concentrations over time at TAV-MW7.

The determination that PCE is a COC at TA-V was made because of the three samples at or near the MCL in well TAV-MW-7. However, concentrations have since decreased to below the MCL. Because of the limited distribution and low concentration of this contaminant, PCE is not considered to be a major groundwater contaminant at TA-V.

<u>3.3.3.3 Nitrate</u>

Nitrate is present in groundwater in all wells at TA-V. Nitrate concentrations have exceeded the MCL in AVN-1, AVN-2, LWDS-MW1, and TAV-MW5, although concentrations are not increasing over time (Figures 3-12 through 3-14). The highest reported concentrations (expressed in terms of nitrogen) in water from TA-V wells include AVN-1, 13 mg/L on May 14, 2001; AVN-2, 16 mg/L on October 27, 1999; TAV-MW5, 13 mg/L on August 18, 1999; and LWDS-MW1, 19 mg/L on November 13, 2000 and February 16, 2001. Upgradient wells AVN-1 and AVN-2 were completed at different depths and show relatively consistent concentrations over time between the two screen depths.

The nitrate data from November 1997 are suspect because they contained extremely high and anomalous nitrate concentrations (ranging from 88 to 560 mg/L as N) with respect to previous and subsequent data (SNL/NM 1999). These data are not included in Figures 3-12 through 3-14.

Nitrate in water from TA-V may be partially derived from disposals to the subsurface in TA-V sanitary wastes, but nitrate concentrations exceeding the MCL in the AVN wells suggest that the principal source of nitrate is upgradient and to the northeast of TA-V. This source may be derived from the incremental contribution of nitrate from known upgradient sites that emulate a non-point source. Another potential contributor may be from sub-regional natural enrichment of nitrate in soils or groundwater-bearing sediments. A third potential contributor may be from an unidentified anthropogenic nitrate source.

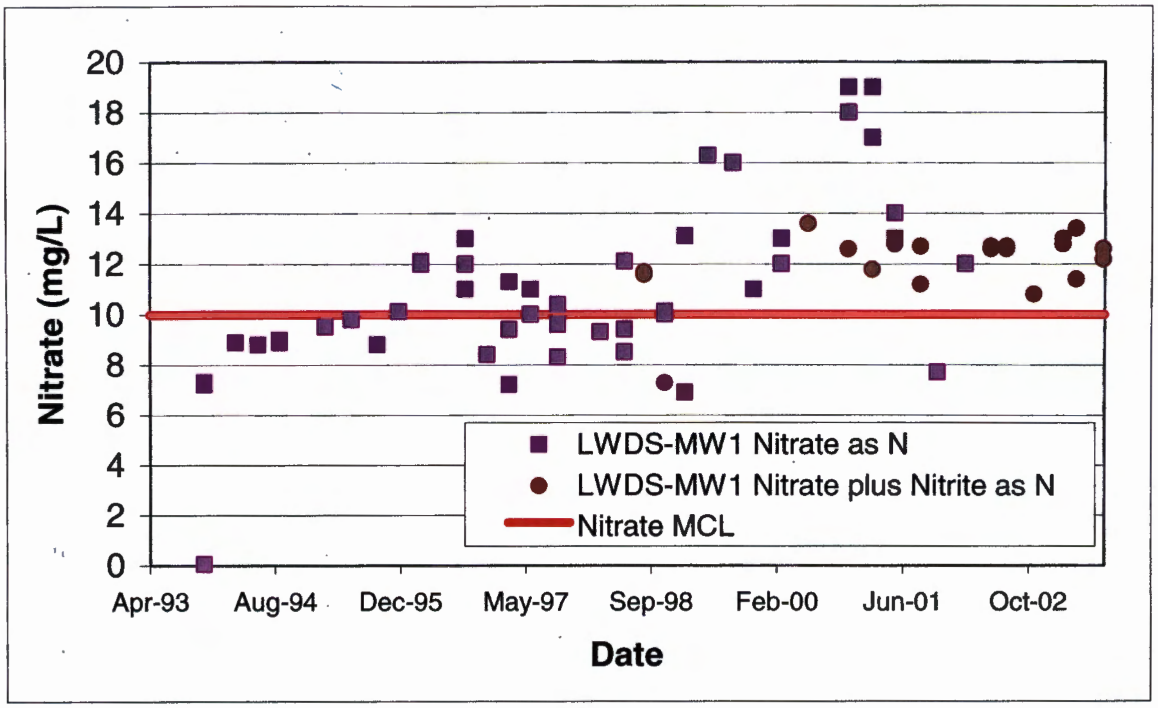


Figure 3-12. Nitrate concentrations over time in LWDS-MW1.

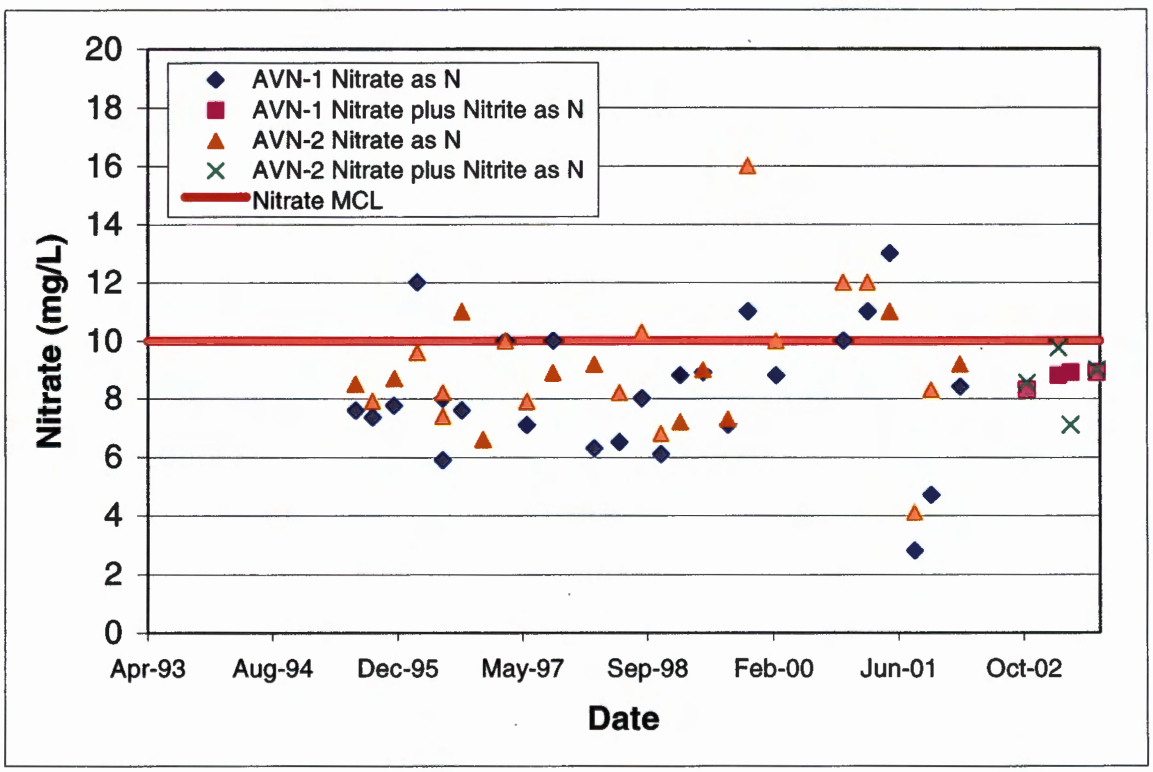


Figure 3-13. Nitrate concentrations over time at AVN-1 and AVN-2.

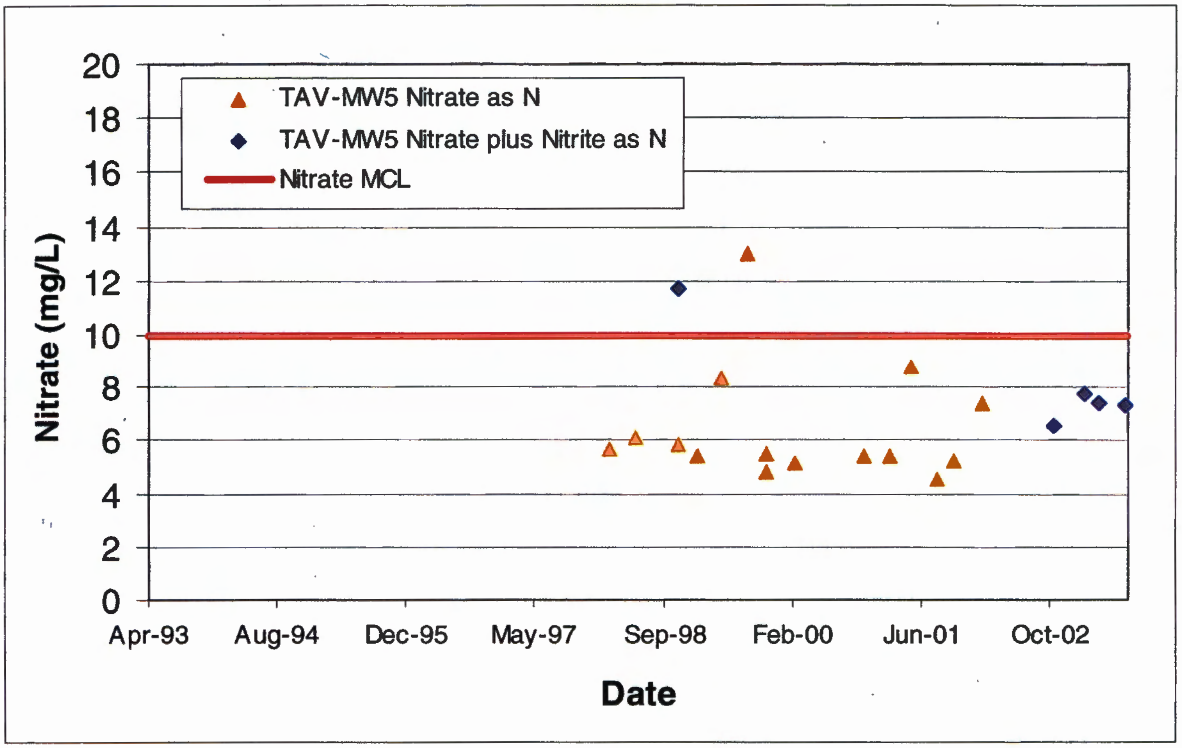


Figure 3-14. Nitrate concentrations over time at TAV-MW5.

3.3.4 Geochemistry

The presence and distribution of geochemical parameters is discussed in subsequent sections to further characterize aquifer conditions at TA-V. These parameters provide additional information for technical evaluation of possible TA-V remedial alternatives. The dechlorination products, reduction/oxidation (redox) parameters, available electron donor, and additional parameters are evaluated to assess contaminant biodegradation.

3.3.4.1 Dechlorination Products

Several dechlorination products are produced during anaerobic biodegradation of chlorinated solvents. Identification of the presence of these parameters is helpful in determining the effectiveness of the degradation process. Past data collection and current voluntary monitoring activities include these degradation products, specifically cis-dichloroethene (cis-DCE), trans-dichloroethene (DCE), vinyl chloride, and chloride.

All cis-DCE concentrations between 1994 and 2003 were below the MCL of 70 μg/L. Results for cis-DCE showed concentrations at LWDS-MW1 of 5 and 5.2 μg/L on February 21, 2000 and 5 and 5.6 μg/L on November 13, 2000. Concentrations of cis-DCE at TAV-MW8 were all below 1.28 μg/L. No cis-DCE was detected in the other TA-V wells. Trans-DCE and vinyl chloride were not detected in any TA-V wells. This indicates that no significant biodegradation of TCE has occurred near TA-V.

Chloride concentrations in excess of 70 mg/L have been measured in groundwater in the vicinity of TA-V. Derivation of these chloride concentrations from degradation of TCE would require the original TCE concentration in groundwater to have been 20,000 to 30,000 µg/L, at least three orders of magnitude larger than current concentrations. Rather, the present distribution of chloride in groundwater at TA-V (Figure 3-15) is similar to the areal distribution of TCE (Figure 3-7) and represents disposals of wastewater containing chlorine to the seepage pits and the drainfield. This conclusion is supported by the highest average concentrations in wells LWDS-MW1 and TAV-MW2 (Table 3-4) directly downgradient of the LWDS drainfield and TA-V seepage pits.

3.3.4.2 Redox Parameters

Redox parameters are used to evaluate active microbial metabolic pathways. These parameters include ferrous iron, manganese II, sulfate, nitrate (as nitrogen), methane, oxidation reduction potential (ORP), and dissolved oxygen (DO). DO measurements in all TA-V wells averaged 49% saturation, indicating that aerobic conditions are present in the aquifer. Past data collection and current voluntary monitoring activities include collection of sulfate, nitrate (as nitrogen), ORP, and DO.

Average sulfate concentrations at TA-V monitoring wells are presented in Table 3-4. These averages represent background sulfate concentrations because the concentrations appear to be relatively stable over the range of collection dates. Several exceptions of high and low data values may be the result of analytical error, but these values are included in the average concentration results.

3.3.4.3 Available Electron Donor

Natural biodegradation may have occurred in the vadose zone and groundwater beneath TA-V when organic carbon was available as an electron donor. Sanitary wastes, disposed to the SWMU 275 TA-V seepage pits and three other septic tank locations with their own drainfield or seepage pits, may have provided a source of carbon to enhance the natural biodegradation processes. Total organic carbon (TOC) data, collected between 1993 and 1995, indicated the presence of low concentrations of TOC at some wells (Table 3-5).

3.3.5 Adequacy of TA-V Groundwater Monitoring Networks

The monitoring-well locations in the vicinity of TA-V are shown in Figure 3-2. The vertical extent of monitoring well completions and water elevations are presented in Figure 3-10 and Table 3-6. The TA-V monitoring well network includes wells determined in a TA-V groundwater assessment (SNL/NM 1999) to be located at potential sources for groundwater contamination (performance wells), upgradient locations (background wells), and downgradient locations (sentry wells). Three pairs of wells completed at shallow and deep locations are included in the monitoring network to provide information about vertical distribution of contaminants. Comparisons of shallow and deep aquifer monitoring locations (discussed in Section 3.3.4.1) indicate that TCE is present only in the upper part of the aquifer; therefore, the remaining wells are appropriately completed at shallow depths.

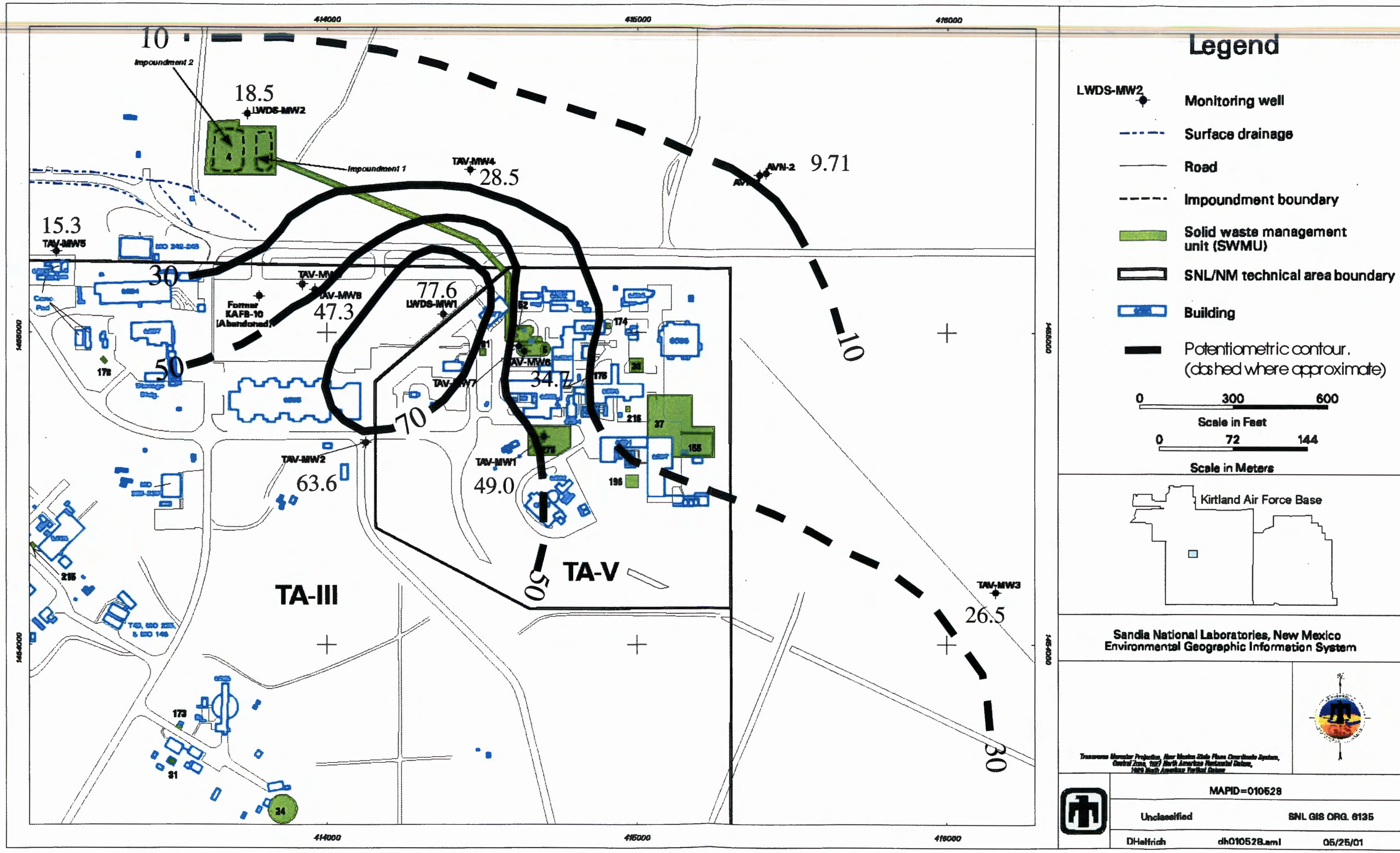


Figure 3-15. Distribution of chloride in groundwater at SNL/NM TA-V, May 2003.

Table 3-4. Average chloride and sulfate concentrations at TA-V monitoring wells.

Well	Dates of Sample Collection	Average Chloride Concentration (mg/L)	Average Sulfate Concentration (mg/L)
AVN-1	1995-2003	11.0	31.5
AVN-2	1995-2003	11.8	29.8
LWDS-MW1	1993-2003	76.6	42.5
LWDS-MW2	1993-2003	16.4	43.1
TAV-MW1	1995-2003	48.7	55.6
TAV-MW2	1995-2003	70.4	59.9
TAV-MW3	1998-2003	27.7	66.3
TAV-MW4	1998-2003	40.0	30.5
TAV-MW5	1998-2003	15.3	42.4
TAV-MW6	2001-2003	33.6	55.1
TAV-MW7	2001-2003	28.5	64.2
TAV-MW8	2001-2003	46.4	43.8
TAV-MW9	2002-2003	35.3	58.4

Table 3-5. Total organic carbon data.

Well	Sample Date	TOC Concentration (mg/L)
AVN-1	December 13, 1995	2.23
AVN-2	December 14, 1995	1.45
LWDS-MW1	March 10, 1994	< 0.5
LWDS-MW1	November 2, 1993	< 0.5
LWDS-MW1	November 3, 1993	0.93
LWDS-MW1	November 3, 1993	0.94
LWDS-MW1	December 19, 1995	3.22
LWDS-MW1	December 19, 1995	3.52
LWDS-MW2	March 11, 1994	< 0.5
LWDS-MW2	March 11, 1994	< 0.5
LWDS-MW2	June 24, 1993	< 0.5
LWDS-MW2	June 24, 1993	< 0.5
LWDS-MW2	December 14, 1995	1.98
TAV-MW1	December 18, 1995	1.83
TAV-MW2	December 18, 1995	2.99

Table 3-6. TA-V sampling locations.

Monitoring Well Name	Date Installed	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Depth to Water[a] (ft bgs)
Background Wells (Upgradient)				
TAV-MW3	April 1997	532	552	535.62
AVN-1	May 1995	570	590	515.12
AVN-2	June 1995	495	515	512.69
Performance Wells (Near contaminant sources)				
TAV-MW1	February 1995	489.5	509.5	508.33
TAV-MW6	April 2001	507	527	501.55
TAV-MW7	April 2001	597	617	503.66
LWDS-MW1	May 1993	500	515	493.47
TAV-MW8	April 2001	491	511	486.81
TAV-MW9	March 2001	582	602	490.23
TAV-MW2	March 1995	497.5	517.5	497.56
TAV-MW4	April 1997	495	515	498.08
Sentry Wells (Downgradient)				
TAV-MW5	April 1997	487	507	480.91
LWDS-MW2	October 1992	506	526	483.23

a. Depth to water was measured in September 2003.

Contaminant concentrations in groundwater are monitored at the LWDS drainfield contaminant source using a vertically discrete pair of monitoring wells, TAV-MW6 (shallow) and TAV-MW7 (deep). AVN-1 (deep) and AVN-2 (shallow) are located upgradient about 1,000 ft northeast of the drainfield. Monitoring wells downgradient of the drainfield include LWDS-MW1, located about 300 ft northwest; the well pair of TAV-MW8 (shallow) and TAV-MW9 (deep), located about 700 ft northwest; and TAV-MW5, located about 1,500 ft northwest.

The seepage pits are monitored at the contaminant source using TAV-MW1, upgradient at TAV-MW3, about 1,600 ft southeast of the seepage pits, and downgradient at TAV-MW2 about 600 ft west of the seepage pits. Monitoring of the surface impoundments includes LWDS-MW2, located slightly north of the seepage pits, and TAV-MW4, located upgradient about 700 ft to the east.

The TA-V monitoring well network is adequate for evaluation of the distribution of TA-V-derived contaminants because the wells are areally distributed, the three pairs of wells completed at shallow and deep locations provide data for vertical distribution of contaminants, and most wells are screened near the water surface where TCE concentrations are highest.

3.4 Numerical Simulation

Previous groundwater modeling studies are discussed in Section 6 of the "Summary Report of Groundwater Investigations at Technical Area V, Operable Units 1306 and 1307" (SNL/NM 1999). Discussions include a description of studies conducted to evaluate the effects of wastewater seepage from the LWDS drainfield (SWMU 5) and the TA-V seepage pits (SWMU 275), evaluation of the cause of the apparent groundwater mound beneath TA-V, and other studies conducted for nearby sites in TA-III. These studies include an infiltration study at the Mixed Waste Landfill and an analysis of the fate and transport of TCE in groundwater at the Chemical Waste Landfill. These studies concluded that the estimated travel times for wastewater from the LWDS drainfield and the TA-V seepage pits to reach groundwater is 2 to 20 years. Also, simulations support the concept that an apparent subtle groundwater mound at TA-V can be attributed to geologic controls and declining water levels.

The U.S. Geological Survey (Kernodle et al. 1995) prepared a regional numerical model based on a conceptual model developed by Hawley and Haase (1992) and Thorn et al. (1993). The purpose of this numerical model was to evaluate the groundwater resources of the Middle Rio Grande Basin. In 1998, a subdomain of this model was used to incorporate geohydrologic data from the SNL/NM Sitewide Hydrogeologic Characterization Project (SNL/NM 1998). Subsequent modifications were made to the regional model by Tiedeman (1998) and Barroll (1999). A modified version of the Barroll (1999) model currently is used to support conceptual model development and may be utilized during the CME process for SNL/NM TA-V.

4.0 SUMMARY

In Section IV.C of the Draft Final Compliance Order on Consent (NMED 2003), NMED requires a CME of SNL/NM TA-V groundwater contamination. Evaluation of remedial alternatives for COCs in groundwater at TA-V requires a current conceptual model of contaminant transport that will provide the basis for a technically defensible evaluation.

Contaminants of concern in groundwater at TA-V consist of TCE, PCE, and nitrate. Key elements of the current conceptual model of contaminant transport at TA-V are shown in Figure 4-1 and discussed in subsequent sections. These elements consist of contaminant releases, contaminant transport in the vadose zone, and contaminant transport in groundwater.

4.1 Contaminant Releases

Local recharge at TA-V is attributed mainly to wastewater disposal to the LWDS drainfield (SWMU 5) (6.5 million gal during 1963-1967) and surface impoundments (SWMU 4) (12 million gal during 1967-1971), and to the TA-V seepage pits (SWMU 275) (30 to 50 million gal during the 1960s to 1992). After 1992, wastewater was disposed to the COA sewage system. There is no ongoing recharge from wastewater disposal. Contaminants in wastewater included VOCs and nitrate.

4.1.1 Volatile Organic Compounds

TCE was present in water that was disposed to the LWDS drainfield during 1963-1967 and to the TA-V seepage pits from the 1960s until the early 1980s when TCE disposals were eliminated. Wastewater disposal to the seepage pits continued until 1992 and is no longer a source of contaminants to the subsurface.

Based on the distribution of contaminants in groundwater, the drainfield and seepage pits were the two probable sources of organic contaminants in the aquifer at TA-V. Disposal of VOCs to the surface impoundments may have increased volatization of those compounds in the open air. Evaporative losses also were enhanced through surface disposal, which may have decreased the recharge from infiltrating impoundment water.

Low TCE concentrations in soil-gas samples collected from sediments beneath the release areas indicated that a secondary source of TCE does not exist within the vadose zone. No excess soil moisture is present in the vadose zone. Water and contaminants moved rapidly through the vadose zone during the seepage pit and LWDS disposals, and vadose zone drainage occurred soon after cessation of wastewater disposal. Because of increased environmental awareness, solvent disposals were eliminated in the early 1980s but wastewater disposal to the seepage pits continued. These continued disposals probably flushed contaminants that may have been present in the vadose zone into the aquifer. No additional vadose zone sampling is required.

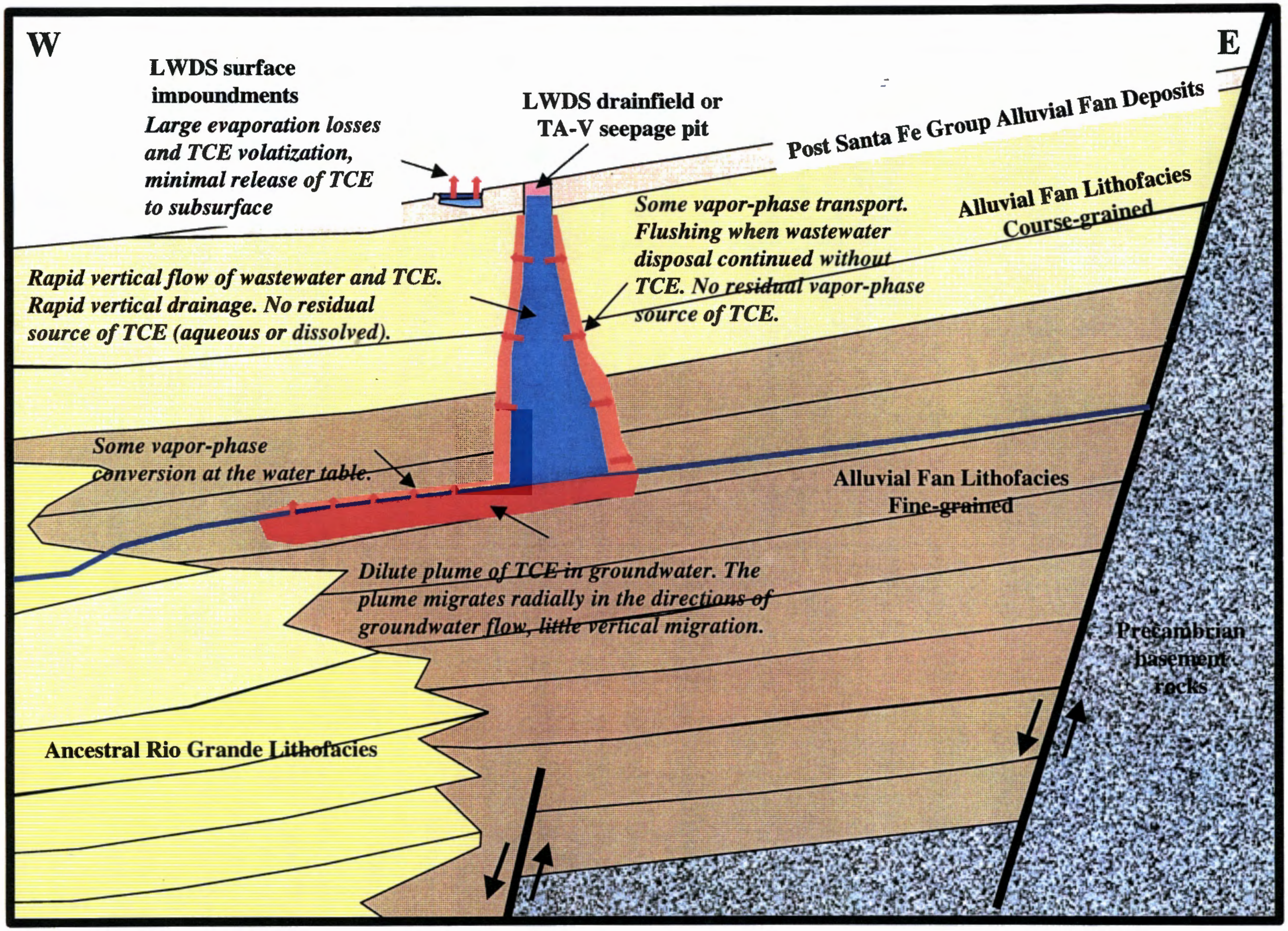


Figure 4-1. Key elements of the current conceptual model of contaminant transport at SNL/NM TA-V.

4.1.2 Nitrate

Sanitary wastewater disposed to the TA-V seepage pits and to other septic systems contained nitrate. Nitrate releases continued until 1992 when the disposals to these septic systems were transferred to the COA sanitary wastewater disposal system.

Nitrate is considered to be a conservative constituent with regard to transport because it is highly soluble in water, is not typically sorbed by sediments, and is not biotransformed under aerobic conditions. As nitrate rapidly moved through the vadose zone with wastewater, no residual source was accumulated and no secondary nitrate releases have occurred.

4.2 Contaminant Transport through the Vadose Zone

The vadose zone at TA-V, consisting of approximately 500 ft of unconsolidated to semi-consolidated alluvial sediments, forms the contaminant pathway by which contaminants migrated from shallow sources to the Santa Fe Group aquifer. Upper sections of the alluvial-fan sediments are relatively coarse-grained, becoming fine-grained and clay-rich with depth. The unsaturated and saturated hydraulic properties of the vadose zone at TA-V have not been characterized. However, they probably are highly variable and anisotropic because of the heterogeneous textures, lenticularity, layering, and changes in cementation.

4.2.1 Flow in the Vadose Zone

Infiltration of wastewater from the LWDS drainfield and the TA-V seepage pits resulted in the development of preferential pathways of saturated or partially saturated flow through the thick vadose zone to the aquifer. Disposal to the surface impoundments did not result in a significant contribution of wastewater and contaminants to the vadose zone or aquifer due to evaporative losses and volatization of VOCs in the open air during surface disposal. Other sources of recharge (i.e., precipitation or streamflow) do not constitute a significant source of water in the vadose zone at TA-V.

Infiltrating wastewater from the LWDS drainfield and the TA-V seepage pits flowed rapidly downward through the discontinuous, layered, lenticular sediments in the vadose zone. Discharge of wastewater to the LWDS drainfield was discontinued in 1967; discharge to the TA-V seepage pits was discontinued in 1992. Based on the moisture content measurements in vadose-zone sediment samples, drainage of excess water from the vadose zone to the aquifer was rapid after discharge ceased. Insignificant moisture from wastewater discharged at TA-V remains in the vadose zone.

4.2.2 Transport of Volatile Organic Compounds through the Vadose Zone

Past mechanisms of contaminant transport from TA-V sources through the vadose zone included rapid dissolved-phase transport in wastewater and a potentially slight contribution from subsurface vapor-phase transport. No transport of contaminants presently exists from the vadose zone to groundwater.

Subsurface data collected during TA-V drilling activities indicate that water and contaminants from disposal facilities moved rapidly through the vadose zone during the seepage pit and LWDS disposals, and vadose-zone drainage occurred soon after cessation of wastewater disposal. TCE was not detected in most vapor samples collected from the vadose zone beneath the release areas. No excess soil moisture is present in the vadose zone.

Solvent disposals were eliminated at TA-V in the early 1980s, but wastewater disposal to the seepage pits continued. Continued disposals flushed contaminants that may have been present in the vapor phase or aqueous phase into the aquifer. No additional site investigations are required to characterize contaminant distribution and transport through the vadose zone.

4.2.3 Transport of Nitrate through the Vadose Zone

Nitrate moved conservatively and rapidly with disposed wastewater through the vadose zone to the aquifer. Transport of nitrate ceased in 1992 when septic system disposals were discontinued. Because of the conservative transport characteristics and high solubility of nitrate, no secondary source of nitrate exists within the vadose zone from wastewater disposals.

4.3 Contaminant Distribution in Groundwater

Flow in the Santa Fe Group aquifer at TA-V is the only mechanism for potential contaminant transport to downgradient receptors. Subsequent sections summarize key elements of groundwater flow, distribution of VOCs and nitrate in groundwater, and the adequacy of the monitoring network to evaluate the transport of contaminants.

4.3.1 Groundwater Flow

Hydrostratigraphic units of significance in the vicinity of SNL/NM TA-V are identified as the alluvial fan lithofacies and ARG lithofacies of the Santa Fe Group. The Santa Fe Group aquifer underlying TA-V consists of fine-grained, clay-rich sediments of the alluvial fan lithofacies. These units interfinger to the west with coarser fluvial sediments of the ARG. Saturated thickness in the vicinity of TA-V may range from less than 100 ft to several thousand feet across faults.

Horizontal hydraulic conductivity of saturated sedimentary units at TA-V ranges from 10^{-5} to 10^{-2} ft/minute. Vertical hydraulic conductivity at TA-V ranges from 10^{-3} to 10^{-4} ft/minute. Laboratory and field measurements of total porosity measurements range from 0.24 to 0.43. Within the context of velocity calculations, an assumed effective porosity of 0.25 is considered to be a conservative estimate. The clay-rich sediments that comprise the Santa Fe Group aquifer at TA-V are characterized by small well yields, ranging from less than 1 to more than 20 gpm with drawdowns exceeding 10 ft.

The subregional potentiometric surface map for February through April 2000 indicates that groundwater flow in the vicinity of TA-V is generally to the west. Groundwater flow to the west of TA-V turns sharply to the north moving toward COA pumping centers located north of KAFB. The sharp change in flow direction coincides with the location of coarse, well-sorted ARG sediments. These sediments are much more permeable than the fine-grained sediments of the alluvial fan facies at TA-V and permit more rapid groundwater flow. Model-estimated time of travel from the area directly south of TA-V to the production wells exceeds 100 years.

The 2003 potentiometric surface map for TA-V shows a subtle groundwater mound that is centered in the northern part of TA-V and illustrates that groundwater flow occurs radially to the west, northwest, and south. Based on the absence of any source of local recharge, the groundwater mound at TA-V is considered to be an artifact of the regional water-level decline within the heterogeneous aquifer. At TA-V, the water table slopes approximately 14 ft/mile for a horizontal hydraulic gradient of about 0.003.

Water levels at TA-V have declined steadily, averaging 0.7 ft/year during 1993 through 2000. These declines are characteristic of long-term regional water-level declines resulting from municipal pumpage to the north. Seasonal variations in water levels are attributed to changes in municipal water usage from summer to winter. No short-term water-level changes resulting from local recharge or pumpage effects are evident.

Calculated horizontal flow velocities range from 0.5 to 168 ft/year (10^{-6} to 10^{-4} ft/min). The lower velocities are typical of clays and higher velocities are typical of medium to fine-grained sand. Calculated vertical flow velocities range from 11.2 to 111 ft/year (10^{-5} to 10^{-4} ft/min).

4.3.2 Distribution of Volatile Organic Compound Contaminants of Concern in Groundwater at TA-V

TCE and PCE are contaminants of concern in groundwater at TA-V because they have been detected above MCLs. TCE has been detected above the MCL in three wells. PCE was detected at or slightly above the MCL in three water samples from one well.

The center of TCE mass in TA-V groundwater has migrated approximately 300 ft northwest from the drainfield contaminant release area in the 36 years since disposal was terminated in 1967. Based on this lateral movement, TCE has migrated approximately 8 ft/year, which is within the calculated range of groundwater flow velocity of 0.5 to 168 ft/year. The expansion of a lobe of the TCE plume to the south may represent additional input of TCE through the TA-V seepage pits and subsequent dilution as wastewater disposal continued after cessation of TCE disposals in the early 1980s. TCE migration to the northwest and south from TA-V sources is consistent with radial groundwater flow away from the subtle mound at TA-V attributed to residuals from regional water-level declines.

PCE concentrations were at or near the MCL in three samples from one well. They since have decreased to below the MCL in that well. PCE concentrations in other TA-V wells generally were less than the MDL. Although PCE was determined to be a COC based on those three samples, PCE is not a major groundwater contaminant at TA-V based on the low concentrations and limited distribution. However, groundwater sampling for PCE will continue.

The COA municipal wells and KAFB supply wells have been identified as the only potential downgradient receptors of contaminants from TA-V. Contaminant travel times are in excess of 100 years. The potential TCE concentrations in groundwater along flow paths to these downgradient receptors are unknown. Additional numerical modeling studies will provide an understanding of TCE concentration changes along flowpaths. This understanding will assist in evaluation of remediation technologies.

The proposed Mesa del Sol well field, approximately 3 miles west of TA-V, is located on the western side of the north-trending groundwater trough. This proposed well field would only become a downgradient receptor of contamination from TA-V in the unlikely event that COA pumping centers were discontinued and groundwater flow systems reverted to the west and southwest. The effect of this scenario on potential contaminant concentrations at these downgradient receptors is unknown.

Geochemical conditions in groundwater at TA-V are sufficiently known to begin technology evaluations. Dissolved oxygen concentrations in groundwater indicate that aerobic conditions exist within the aquifer. Major ion analyses demonstrate that geochemical conditions are stable. The presence of increased concentrations of dissolved chloride are indicative of disposal of wastewater with elevated chloride concentrations and do not represent dechlorination products from contaminant degradation. The presence of very low concentrations of TOC in groundwater indicates that little carbon is available as an electron donor for natural biodegradation.

4.3.3 Distribution of Nitrate in Groundwater at TA-V

Nitrate is an inorganic contaminant of concern at TA-V. Nitrate was detected above the MCL in four wells in the vicinity of TA-V, including two wells within the TCE plume and two wells (AVN wells) east of TA-V. Nitrate concentrations in groundwater within the TCE plume at TA-V are considered to be derived from disposals of sanitary wastes to the TA-V septic systems.

The AVN wells are hydraulically upgradient of TA-V septic-system nitrate releases. Nitrate concentrations above the MCL in the AVN wells could not have been derived from those releases. These concentrations indicate that the principal source of nitrate may be present upgradient and to the northeast of TA-V. The upgradient source may be derived from the incremental contribution of nitrate from upgradient sites that emulate a non-point source. Another potential contributor may be from sub-regional natural enrichment of nitrate in soils or groundwater-bearing sediments. A third potential contributor may be from an unidentified anthropogenic nitrate source. Evaluation and investigation of this upgradient source is beyond the scope of TA-V remedial activities.

4.3.4 Adequacy of the Monitoring Network to Evaluate the Distribution of Contaminants

The groundwater monitoring network at TA-V consists of upgradient, background wells to characterize the chemical quality of groundwater moving into the TA-V area, performance wells that define the present distribution of contaminants at TA-V, and downgradient sentry wells to evaluate future contaminant migration. Assessment of the configuration of existing monitoring wells at TA-V indicates that the network is sufficient to adequately characterize the distribution of contaminants at TA-V. The screen intervals of nine TA-V monitoring wells are at or near the water table. Three well pairs provide vertical monitoring capability and are located in areas proximal to known releases. No additional wells are required.

4.4 Conclusions

The LWDS drainfield and the TA-V seepage pits were the principle sources of wastewater recharged to the subsurface at SNL/NM TA-V. Water disposed to these facilities contained COCs, including TCE and nitrate. TCE was derived from solvent disposals. Nitrate was contained in sanitary wastes disposed to TA-V septic systems.

Wastewater and contaminants moved rapidly downward through the 500-ft thick vadose zone to the aquifer. The vadose zone drained rapidly after cessation of disposals. No residual amounts of TCE or nitrate remain in the vadose zone as secondary contaminant source terms.

Concentrations of TCE have exceeded the MCL in three wells near the LWDS drainfield. The center of TCE mass has migrated approximately 300 ft west and northwest from the LWDS drainfield since disposals ceased. A dilute lobe of the plume to the south may represent continued wastewater disposals to the TA-V seepage pits after TCE disposals ceased in the early 1980s. The distribution of TCE in groundwater is controlled by the radial flow of water away from the residual groundwater mound underlying TA-V.

Nitrate in groundwater within the extent of the TA-V TCE plume is attributed to septic system disposals. Nitrate above MCLs in groundwater east of TA-V is derived from upgradient sources and is not within the scope of TA-V remedial activities.

The distribution of contaminants in groundwater at TA-V is adequately defined from the existing monitoring network. Based on the information available from the groundwater-monitoring network, geohydrologic conditions at TA-V are sufficiently characterized to conduct the TA-V CME.

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Appendix A. List of Geohydrologic Studies at TA-V

Table A-1. Series of studies concerning elements of conceptual models of contaminant release and transport through the vadose zone and Santa Fe Group aquifer.

Date	Title	Reference
1993	*Sandia National Laboratories/New Mexico. Site-Wide Hydrogeologic Characterization Project Calendar Year 1992 Annual Report*	SNL/NM 1993
1994	*Sandia National Laboratories/New Mexico. Site-Wide Hydrogeologic Characterization Project Calendar Year 1993 Annual Report*	SNL/NM 1994
1995	*Sandia National Laboratories/New Mexico. Site-Wide Hydrogeologic Characterization Project Calendar Year 1994 Annual Report*	SNL/NM 1995
1995	*Conceptual Geologic Model of the Sandia National Laboratories and Kirtland Air Force Base*	SNL/NM 1995
1996	*Sandia National Laboratories/New Mexico. Site-Wide Hydrogeologic Characterization Project Calendar Year 1995 Annual Report*	SNL/NM 1996
1998	*Sandia National Laboratories/New Mexico. Site-Wide Hydrogeologic Characterization Project Calendar Year 1995 Annual Report*	SNL/NM 1998
1999	*SNL/NM Summary Report of Groundwater Investigations at Technical Area V, Operable Units 1306 and 1307*	SNL/NM 1999
2001	*SNL/NM Environmental Restoration Project Long-Term Monitoring Strategy for Groundwater*	SNL/NM 2001
2001	*SNL/NM TA-V Groundwater Investigation Fiscal Years 1999 and 2000*	SNL/NM 2001
2001	*SNL/NM Summary of Monitoring Well Drilling Activities, TA-V Groundwater Investigation*	SNL/NM 2001
2002	*Groundwater Resources of the Middle Rio Grande Basin*	Bartolino and Cole 2002
2003	"Review of latest Middle Rio Grande Model (WRIR 02-4200) applicability to SNL/KAFB use"	Memo from G. Ruskauff to S. Collins
2003	*Geologic Investigation: An Update of Subsurface Geology on Kirtland Air Force Base, New Mexico*	Van Hart 2003

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