STATE OF NEW MEXICO
HEALTH ENVIRONMENT department

MEMORANDUM

TA-67

DATE: April 4, 1983

TO: Raymond Sisneros, Program Manager, PEM Section

FROM: Maxine S. Goad, Program Manager, Ground Water Section MSG

SUBJECT: Los Alamos County Sanitary Landfill

Attached is a report entitled "Suitability of the Geologic and Hydrologic Conditions for Disposal of Small Quantities of 1, 1, 1 Trichloroethane at the Los Alamos County Sanitary Landfill."

This report was delivered to me today by Patrick Longmire of the Ground Water Section staff. It was prepared in response to your memorandum dated February 23, 1983 requesting evaluation of sites for disposal of the above cited hazardous waste generated by the State Highway Department.

MSG:jba

Attachment

APR 4 1983
P.E.M. SECTION

3772

145

Summary and Conclusions

The Los Alamos County sanitary landfill site is suitable for the safe disposal of small quantities of 1, 1, 1 Trichloroethane (TCE), as defined by New Mexico Hazardous Waste Regulations. The geologic and hydrologic characteristics of Bandelier Tuff will prevent TCE from migrating to ground water:

1) The migration rate of TCE under moisture contents equal to field capacity is 1.84 x 10^{-9}m/sec (0.06 m/yr). This is a conservative estimate as the moisture content in the Bandelier Tuff is less than field capacity;

2) Depth to ground water (main-aquifer, Santa Fe Group) is estimated to be 305 meters (1000 ft) below the landfild site. The large depth to ground water in combination with the slow migration rate of TCE will prevent TCE from impacting ground-water quality; and

3) The soils found at the landfill site have moderate to low wind errodibility and should be stable concerning surficial geomorphic processes occurring at the site. The moderately high runoff potential of the soils should help prevent downward percolation of meteoric water to the buried waste.

These conclusions assume that the method of disposal will not induce saturated flow conditions (i.e. ponding) and that fracture permeability is not prevalent at the site.

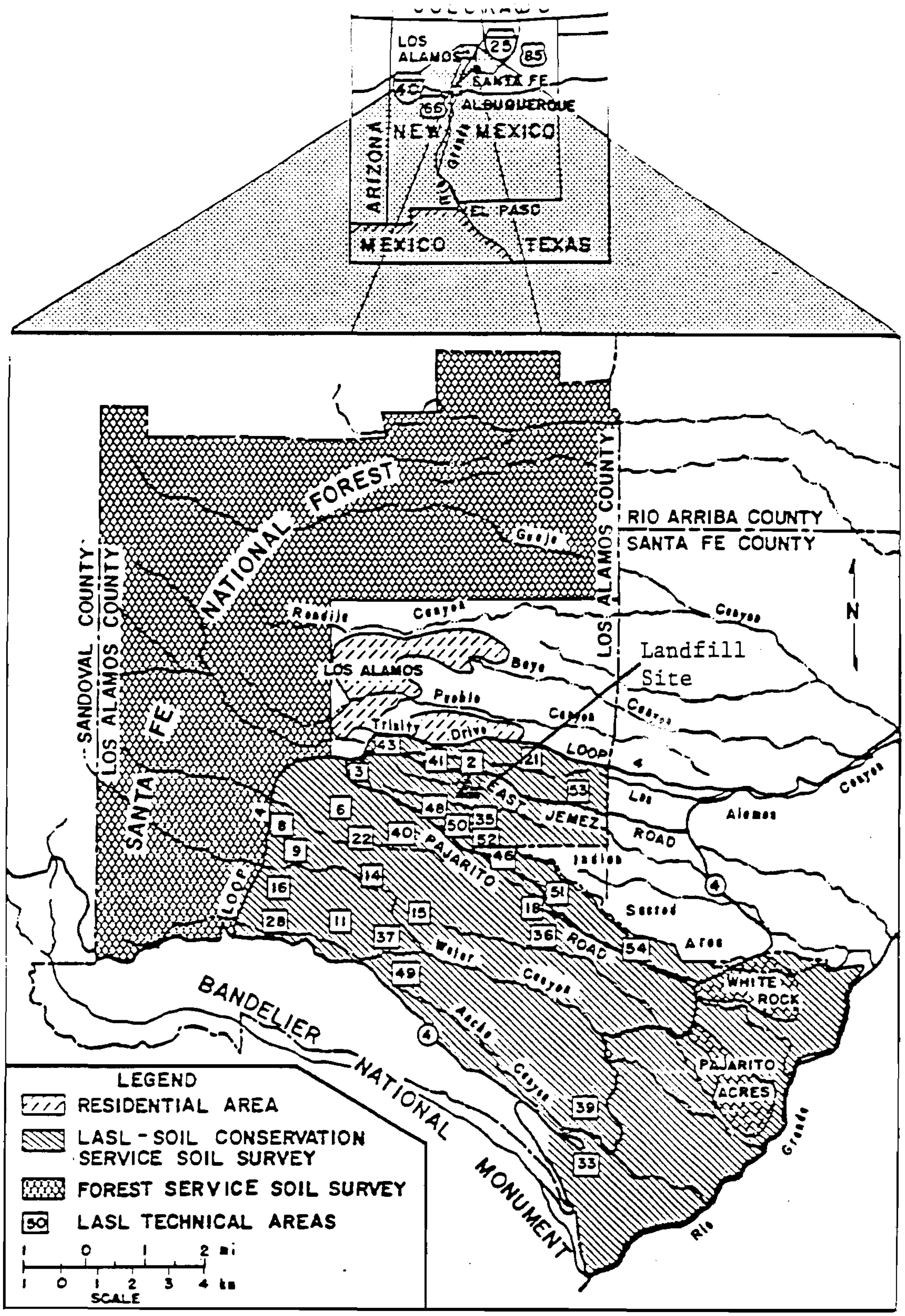

Figure 1. Location of Los Alamos County sanitary landfill(indicated by ▲) (after Nyhan and others,1978).

TABLE 1

Physical and Chemical Properties Carjo Series
(Modified from Nyhan and others, 1978)

	Depth (cm)		
Property	0-10	10-50	50-63
USDA Texture (see Fig. 2)	loam, very fine sandy loam	clay loam, clay	very fine sandy loam
Permeability (cm/hour)	1.5 - 5.0 (moderate)	0.15 - 0.5 (low)	1.5 - 5.0 (moderate)
Available water Capacity (cm of water / cm of soil)	0.15 - 0.18	0.14 - 0.21	0.15 - 0.17
Soil pH	6.3 - 7.3	6.6 - 7.3	7.4 - 7.8
Shrink-Swell Potential	Low	Moderate	Low
K	0.28	0.32	0.24
T	1	1	1
Hydrologic soil group	c	c	c

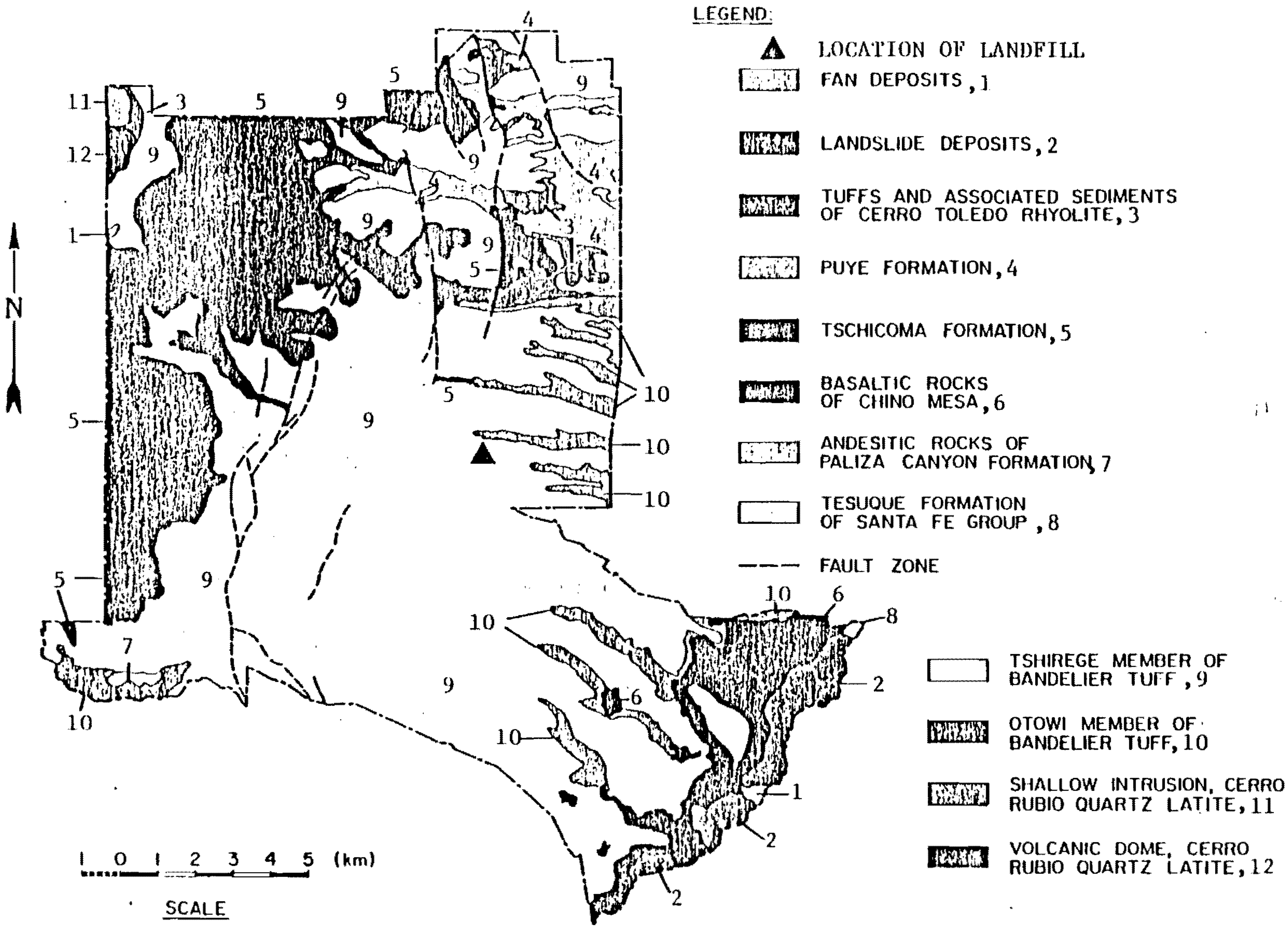

Figure 3. Geology of Los Alamos County(modified from Nyhan and others,1978).

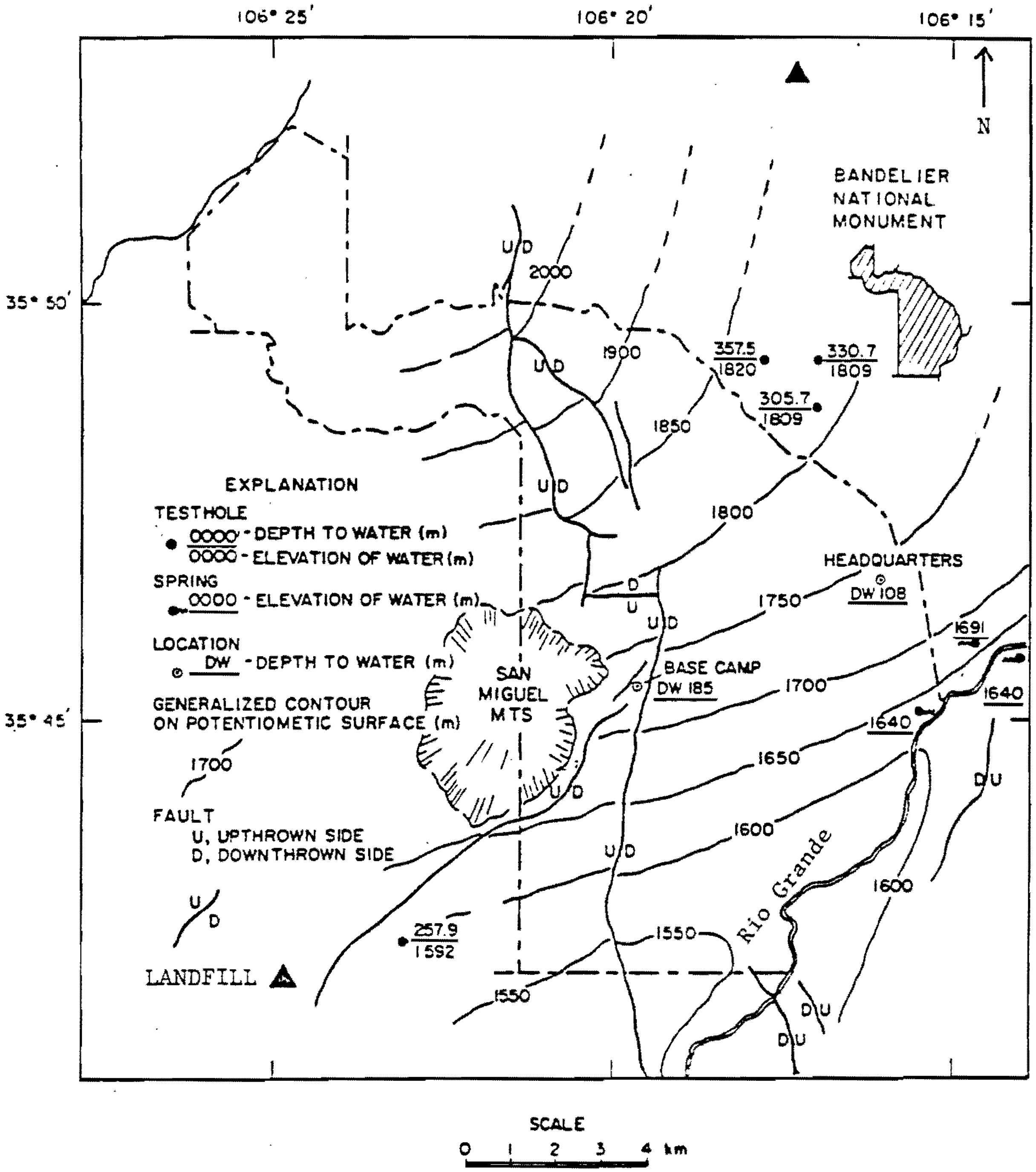

Figure 4. Generalized contours on the potentiometric surface of the Santa Fe Group(main aquifer)(after Purtymun and Adams,1980).

Ku is the hydraulic conductivity of the Bandelier Tuff (conservative value) at field capacity (Ku = 1.2×10^{-8}m/sec, Abeele and others, 1981); and

$\bar{\nabla}\phi$ is the gradient of the moisture potential ($\bar{\nabla}\phi$ = unity for vertical-unsaturated flow). Solving for V in equation (2),

$$V = \frac{1.2 \times 10^{-8}\text{m/sec}\ (1)}{0.22} = 5.45 \times 10^{-8}\text{m/sec.}$$

Now solving for V_{TCE} in equation (1)

$$\frac{5.45 \times 10^{-8}\text{m/sec}}{V_{TCE}} \cong \frac{1.84\ \text{gm/cm}^3\ (0.63)(357)(0.02)}{0.28}$$

$$V_{TCE} = 1.84 \times 10^{-9}\text{m/sec (0.06 m/yr).}$$

The actual migration rate of TCE should be much lower than this calculated value, because the moisture content of the Tshirege Member is less than field capacity. The unsaturated hydraulic conductivity is 1.1×10^{-9}m/sec for a moisture content of 10 percent, the average moisture content of the Tshirege Member. The migration rate of TCE, calculated by using the above method at a moisture content of 10 percent, is 3.72×10^{-10}m/sec (0.01 m/yr). This calculation assumes that fracture permeability is insignificant and that no other chemical compounds are mixed with TCE. The latter assumption is of prime importance because other chemical compounds mixed with TCE could effect the physical and chemical properties of TCE, such as solubility and volatility characteristics and decomposition products.

The Los Alamos County sanitary landfill appears to be suitable for accepting small quantities (as defined by the New Mexico Hazardous Waste Regulations) of TCE, provided that migration pathways, such as fracture and dissolution features, in the Tshirege Member are insignificant. If open (non-sealed) fractures are encountered upon excavation of soil at the landfill site, the following studies should be undertaken:

1) Site Specific Geologic - Stratigraphic Studies - Determine the presence (or absence) of fracture zones that could serve as conduits for leachate migration in and adjacent to the Los Alamos County sanitary landfill.

2) Field Hydrology Testing - It is important to determine how primary and secondary fractures in the Tshirege Member of Bandelier Tuff (host rock) control hydrologic transport rates of leachate migrating through the soil and Bandelier Tuff. However, recent hydrologic tests conducted by Abeele (1982) may indicate that the Tshirege Member is characterized by a very low hydraulic conductivity (unsaturated-flow conditions) at the site of the Los Alamos County sanitary landfill.

April 7, 1983

Addendum to Suitability of the Geologic and Hydrologic Conditions for the disposal of small quantities of 1,1,1 Trichloroethane at the Los Alamos County Sanitary Landfill:

Fractures and Fracture Permeability in the Bandelier Tuff

The migration of 1,1,1 Trichloroethane (TCE) through an open fracture, under unsaturated conditions, in the Bandelier Tuff in and adjacent to the Los Alamos County sanitary landfill is remote. The flow direction of TCE through the Bandelier Tuff (unsaturated conditions) will be vertical, under the influence of gravity, and not into a given fracture. It is likely that the fractures will be sealed and filled with fine-grain materials, such as clay minerals, that can efffectively adsorb the TCE. In addition, the fractures should be dry as the moisture content of the Bandelier Tuff is low (10 percent). The fractures may occupy less than 5 percent of the total volume of the Bandelier Tuff in and adjacent to the landfill.

HEALTH & ENVIRONMENT department

STATE OF NEW MEXICO

ENVIRONMENTAL IMPROVEMENT DIVISION
P.O. Box 968, Santa Fe, New Mexico 87504-0968
(505) 984-0020
Russell F. Rhoades, MPH, Director

Suitability of the Geologic and Hydrologic Conditions for the Disposal of Small Quantities of 1, 1, 1 Trichloroethane at the Los Alamos County Sanitary Landfill

Patrick A. Longmire

Water Pollution Control Bureau

April 4, 1983

Summary and Conclusions

The Los Alamos County sanitary landfill site is suitable for the safe disposal of small quantities of 1, 1, 1 Trichloroethane (TCE), as defined by New Mexico Hazardous Waste Regulations. The geologic and hydrologic characteristics of Bandelier Tuff will prevent TCE from migrating to ground water:

1) The migration rate of TCE under moisture contents equal to field capacity is 1.84×10^{-9} m/sec (0.06 m/yr). This is a conservative estimate as the moisture content in the Bandelier Tuff is less than field capacity;

2) Depth to ground water (main-aquifer, Santa Fe Group) is estimated to be 305 meters (1000 ft) below the landfild site. The large depth to ground water in combination with the slow migration rate of TCE will prevent TCE from impacting ground-water quality; and

3) The soils found at the landfill site have moderate to low wind errodibility and should be stable concerning surficial geomorphic processes occurring at the site. The moderately high runoff potential of the soils should help prevent downward percolation of meteoric water to the buried waste.

These conclusions assume that the method of disposal will not induce saturated flow conditions (i.e. ponding) and that fracture permeability is not prevalent at the site.

Introduction

A literature review was conducted on the geologic and hydrologic conditions at the Los Alamos County sanitary landfill site. The purpose of this review is to determine the suitability of this site for the disposal of 1, 1,1 Trichloroethane (TCE). Each producer of TCE can dispose of small quantities of TCE (a maximum of 1000 kg/month) in a sanitary landfill site pursuant to the New Mexico Hazardous Waste Regulations.

Location

The Los Alamos County sanitary landfill is located approximately 0.5 miles south of Los Alamos, New Mexico on the East Jemez Road (Figure 1). The landfill is constructed on South Mesa, bounded to the north by Los Alamos Canyon and to the south by Sandia Canyon. The approximate elevation of the landfill is 2231 meters (7320 feet) above mean sea level. The topography in the vicinity of the landfill is generally flat, with a gentle slope increasing toward the west.

Soil Conditions

The soils found in the vicinity of the Los Alamos County sanitary landfill are conducive for the safe disposal of small quantities of TCE. The landfill is excavated in soils produced by the physical and chemical weathering of the Bandelier Tuff, a fine-grained volcanic rock. The soils are moderately composed of clay minerals (46 percent) that have high sorptive properties, the porosity is low (less than 20 percent), soil pH is neutral and permeability is moderately low (1.4×10^{-3}cm/sec). In addition, the depth to bedrock (Bandelier Tuff) is on the order of 1.22 meters (4 ft). A brief description of the soils found at the landfill is given below.

The Los Alamos County sanitary landfill is excavated in soils belonging to the Carjo series (Nyhan and others, 1978). The Carjo series consists of moderately deep, well-drained soils. The surface layer of Carjo soil is a grayish brown loam (see Figure 2), about 10 centimeters (cm) (0.33 ft) thick. The subsoil is a brown and reddish brown clay-loam and clay about 40 cm (1.31 ft) thick. The sub-stratum is a light brown, very fine sandy loam about 10 cm (0.33 ft) thick. Depth to the Bandelier Tuff ranges from 50 to 102 cm (1.67 to 3.35 ft). Runoff from this moderately-low permeable soil is significant.

Table 1 lists several important properties of the Carjo series that make this soil suitable for safe disposal of TCE.

Definitions

Available Water Capacity is the capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of water at field capacity (maximum water saturation in soil where the force of gravity equals forces that hold water films on the particle surfaces) and the amount at the wilting point (water is held tightly by particles so that the roots can no longer extract it). This property is estimated from the texture and depth of the solum (the upper part of a soil profile, in which soil-forming processes occur) and may be modified according to the effective rooting depth of the soil profile (Nyhan and others, 1978; Birkeland, 1974). The available water capacity in the Carjo series is very low.

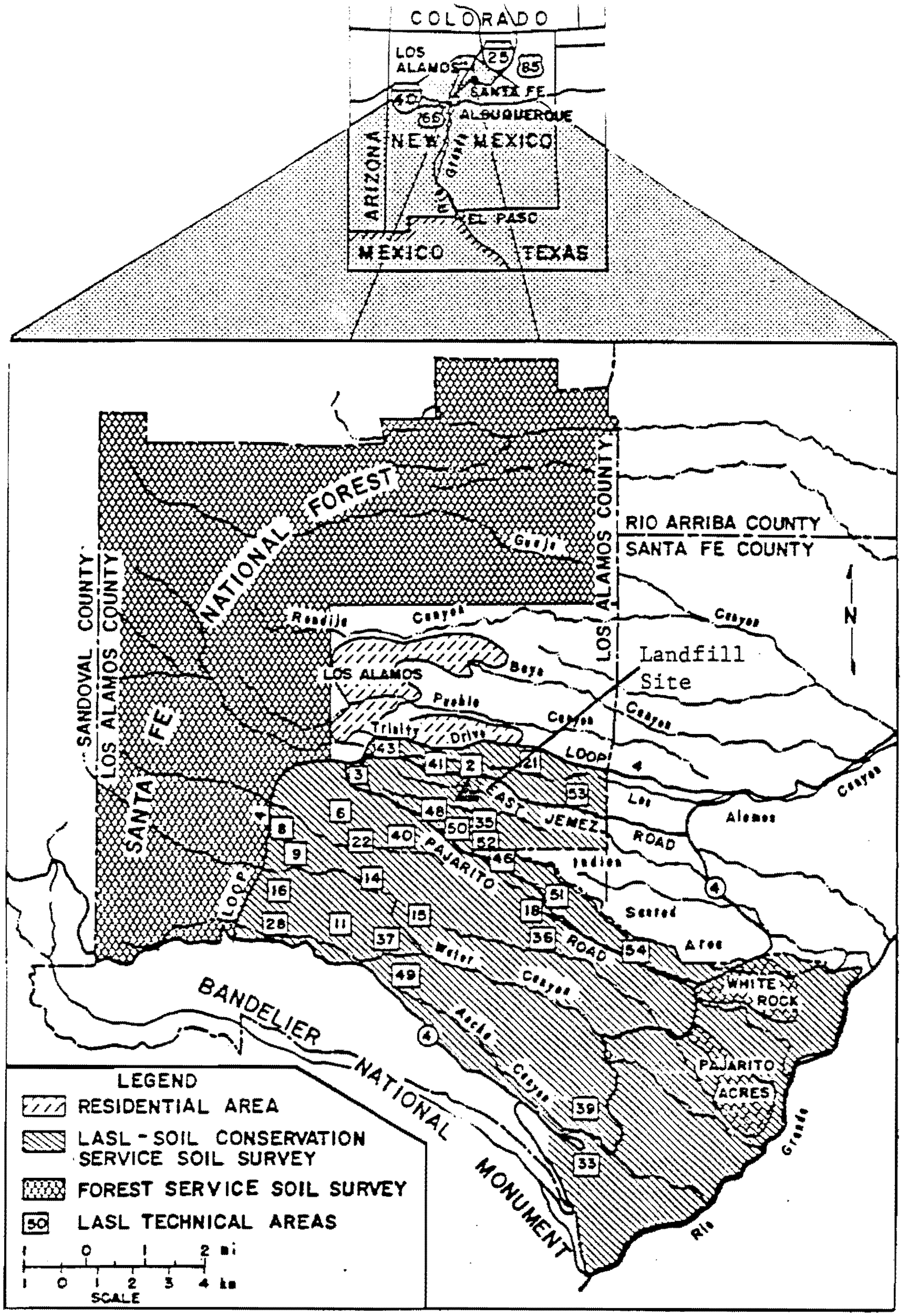

Figure 1. Location of Los Alamos County sanitary landfill(indicated by ▲) (after Nyhan and others,1978).

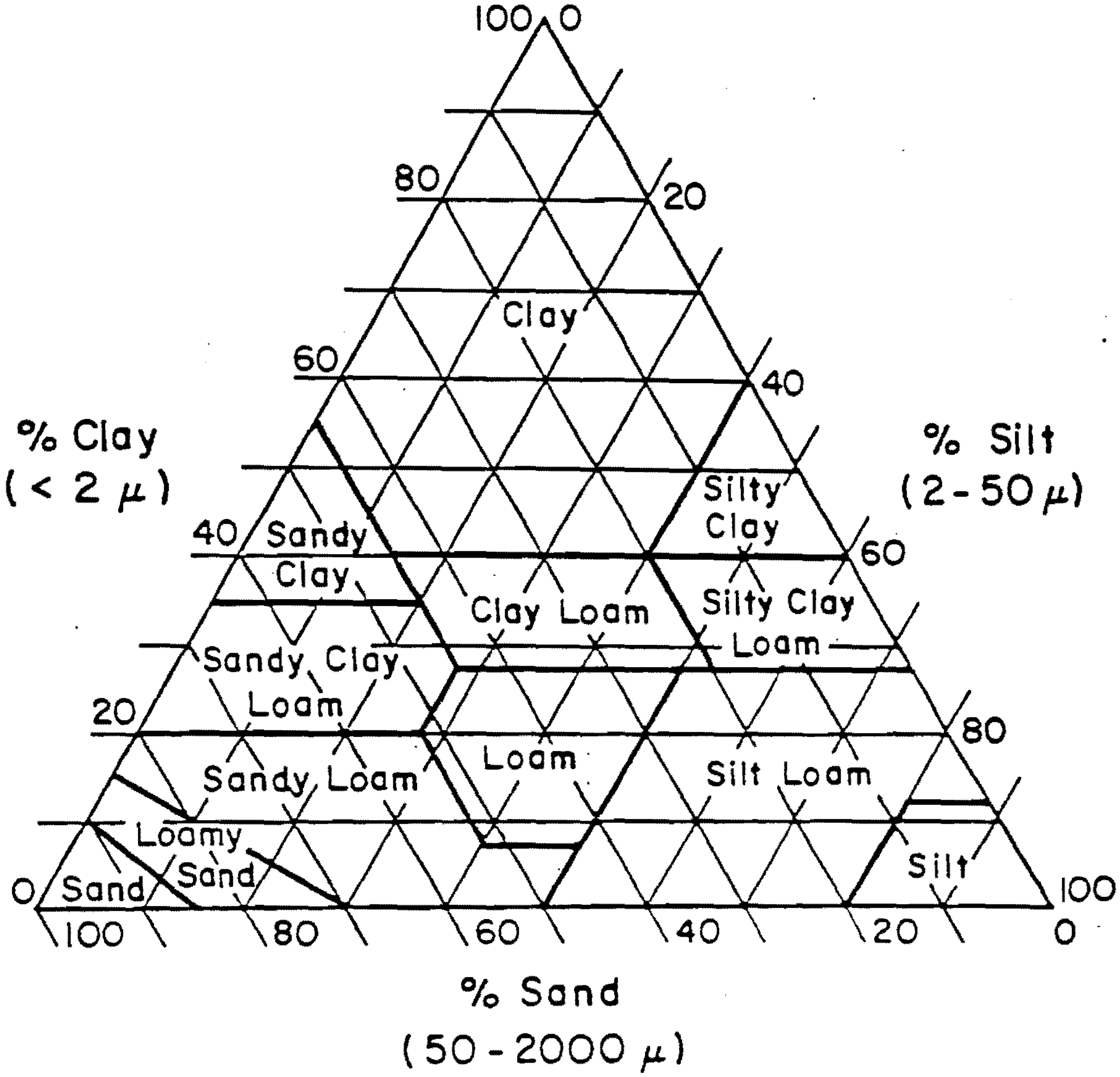

Figure 2. Soil texture triangle(u= 10^{-6} meter)(after Nyhan and others,1978).

TABLE 1

Physical and Chemical Properties Carjo Series
(Modified from Nyhan and others, 1978)

	Depth (cm)		
Property	0-10	10-50	50-63
USDA Texture (see Fig. 2)	loam, very fine sandy loam	clay loam, clay	very fine sandy loam
Permeability (cm/hour)	1.5 - 5.0 (moderate)	0.15 - 0.5 (low)	1.5 - 5.0 (moderate)
Available water Capacity (cm of water / cm of soil)	0.15 - 0.18	0.14 - 0.21	0.15 - 0.17
Soil pH	6.3 - 7.3	6.6 - 7.3	7.4 - 7.8
Shrink-Swell Potential	Low	Moderate	Low
K	0.28	0.32	0.24
T	1	1	1
Hydrologic soil group	c	c	c

Shrink-Swell Potential is the extent to which the soil shrinks as it dries out and swells when it gets wet (Nyhan and others, 1978). The magnitude of change is influenced by the amount and kind of clay in the soil. In general, a higher shrink-swell potential indicates a higher cation-exchange capacity (CEC) and therefore, a higher adsorptive capacity.

K - Soil Erodibility Factor is a unitless constant used in the universal soil loss equation which is function of the texture, structure, permeability and organic matter content of a soil series (Nyhan and others, 1978). An increasing amount of silt and very fine sand causes many soils to be more erodible. The K values for soils range from 0.02 to 0.69 with larger K values reflecting more erosive soils. The Carjo soils found at the landfill are characterized by a moderate soil erodibility factor. These soils are stable in terms of active-surficial geomorphic processes taking place.

T - Soil Loss Tolerance is strictly a function of soil depth and is expressed in units of tons of allowable soil loss/acre/year (Nyhan and others, 1978). The values of T range from 1 to 5, with larger T values generally being assigned to deeper soils. The Carjo soils are characterized by a low-allowable soil loss, which makes this soil less likely to be eroded. This property enhances the soil's ability to retain buried waste and prevents exposure of the waste to the biosphere.

Hydrologic Soil Group is a technique used to estimate run off from rainfall. Depth to seasonal-high water table, intake rate, permeability after prolonged wetting and depth to very slowly permeable layers are considered hydrologic soil groupings (Nyhan and others, 1978). Soils, such as Carjo series, belonging to group C have slow infiltraton and water transmission rates and high skrink-swell potentials. Accordingly, the Carjo series have a moderately high-run off potential which inhibits water from accumulating in the interstices of the soil. This property would prevent the accumulation of fluid (water and leachate) in the soil.

Site Geologic Conditions

The Carjo soil, at the site of the Los Alamos County sanitary landfill, has formed from the weathering of the Bandelier Tuff. The Bandelier Tuff is a volcanic rock that consists of a lower sequence of air-fall and ash-flow deposits, including the Otowi Member, disconformably overlain by an upper sequence of air-fall and ash-flow deposits (Tshirege Member)(Crowe and others, 1978). Figure 3 shows a generalized geological map of Los Alamos County. The landfill is excavated in the Tshirege Member of the Bandelier Tuff.

Tshirege Member

The Tshirege Member of the Bandelier Tuff is a welded rhyolite tuff composed of small fragments of crystallized pumice and crystal fragments of sanidine (high temperature-form of $KAlSi_3O_8$) and quartz in a welded tuff matrix (Griggs and Hem, 1964). The tuff is mostly ash-flow debris, but it contains also a few beds of ash-fall pumice at the base and at the top. Near the vicinity of the Los Alamos County sanitary landfill, the Tshirege Member is more intensely welded and typically, has a low porosity (28 percent)(Griggs and Hem, 1964). The Tshirege Member is approximately 1.4 million years old and ranges in thickness from 30 to 305 m (100-1000 ft). The Tshirege Member is approximately 107 m (350 ft) thick in the vicinity of the landfill. This low-permeable and relatively non-porous medium can effectively impede the migration of leachate to ground water.

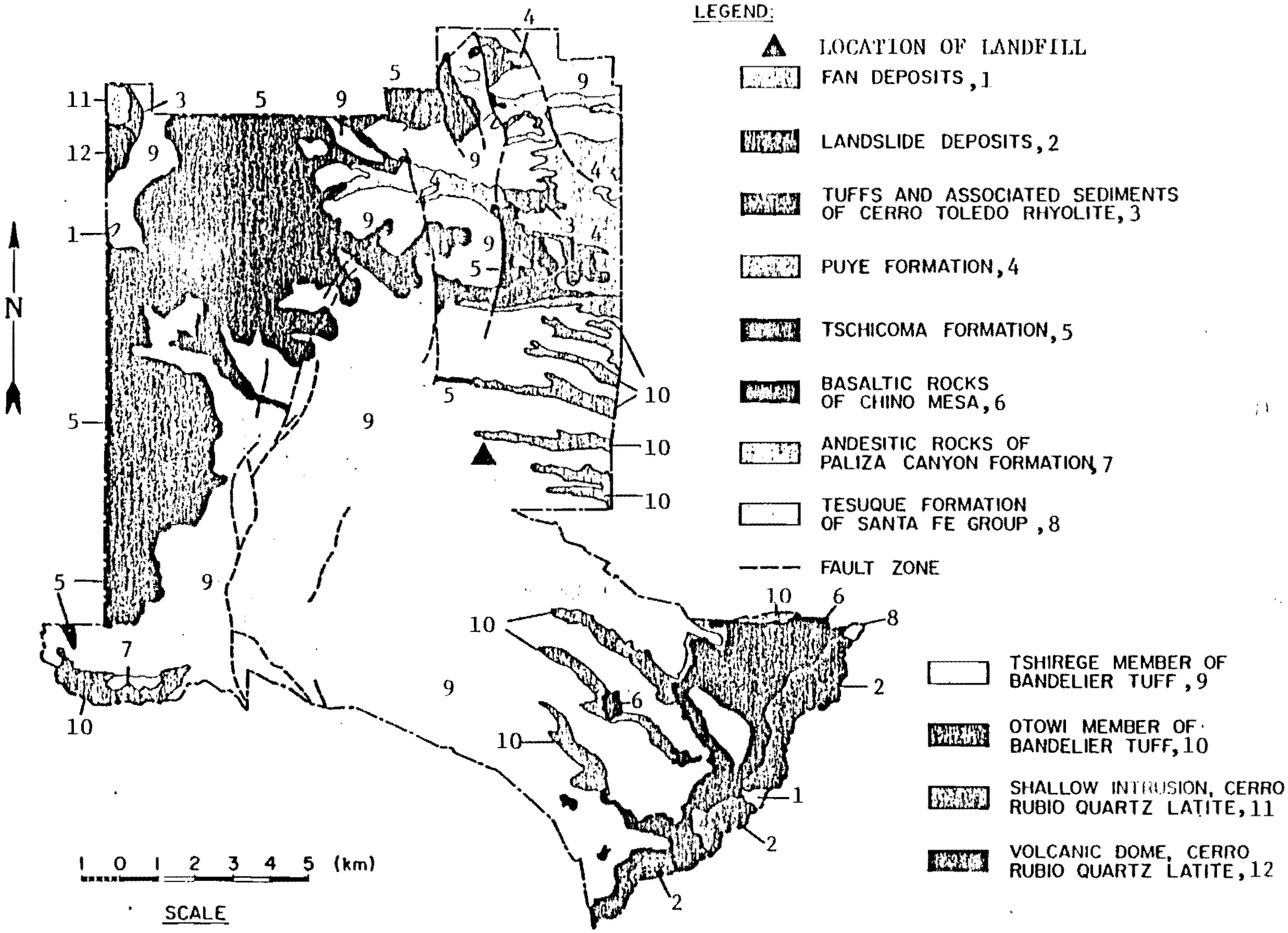

Figure 3. Geology of Los Alamos County(modified from Nyhan and others,1978).

Hydrologic Conditions

Santa Fe Group - Main Aquifer

The depth to ground water in the Santa Fe Group is approximately 305 meters (1000 ft) below the landfill site (Figure 4). This depth was obtained by extrapolation of potentiometric contours on Figure 4 to the north, assuming that a uniform hydraulic gradient is prevalent. The depth below land surface to the top of the zone of saturation becomes Figure 3 progressively greater westward in the Los Alamos area, because the top of the saturated zone slopes upward to the west more gently than the slope of the land surface (Griggs and Hem, 1964). Beds of silt and sand and thin beds of conglomerate compose the main aquifer of the Santa Fe Group in the Los Alamos area (Griggs and Hem, 1964). All these beds found below the altitude of the Rio Grande are saturated. The elevation of the Rio Grande varies from 1615 to 1676 meters (5300 to 5500 ft) above mean sea level. Ground-water flow in the Los Alamos area is generally toward the east and southeast (Figure 4). The upper zone of saturation slopes upward to the east and to the west from the Rio Grande and ground water flow feeds the river (Purtymun and Adams, 1980; Griggs and Hem, 1964).

The permeability of the materials comprising the Santa Fe Group is not uniform, and the more permeable beds that yield water to wells are imperfectly connected. As a result, the pressure head in the unit varies with vertical and lateral distances (Griggs and Hem, 1964).

Bandelier Tuff

Perched bodies of groundwater are contained in the Bandelier Tuff, but these bodies are small and yield water slowly to wells (Purtymun and Adams, 1980; Griggs and Hem, 1964). These perched bodies are not a reliable source of water to wells.

The base of Tshirege Member of the Bandelier Tuff is approximately 183 meters (600 ft), above the main water table, but contains local bodies of perched-ground water (Griggs and Hem, 1964). Four springs emerge from perched zones at high altitudes 2895 meters (9500 ft) on the eastern slopes of the Sierra de los Valles located approximately 8 kilometers (5 miles) west of the Los Alamos County sanitary landfill. The existance of perched bodies of ground water in the Tshirege Member should be verified by field-hydrologic studies in the vicinity of the Los Alamos County sanitary landfill.

The hydraulic conductivity (unsaturated-flow conditions) for the Tshirege Member has recently been determined by Abeele and others (1981). Hydraulic conductivities (unsaturated-flow conditions) range from 1.1×10^{-9} to 1.2×10^{-8}m/sec, for average moisture contents (10 percent) and moisture content at field capacity, respectively. These low hydraulic conductivities will impede migration of TCE through the Tshirege Member. These hydraulic conductivities should be representative of conditions found at the landfill, since the Tshirege Member at this location is densely welded and fracture permeability is probably insignificant.

Physical and Structural Controls of Hazardous Waste Migration

In order to accurately determine the geologic and hydrologic controls of migration pathways of TCE at the Los Alamos County sanitary landfill, two important factors must also be considered. First, there is significant lateral variability within the Bandelier Tuff

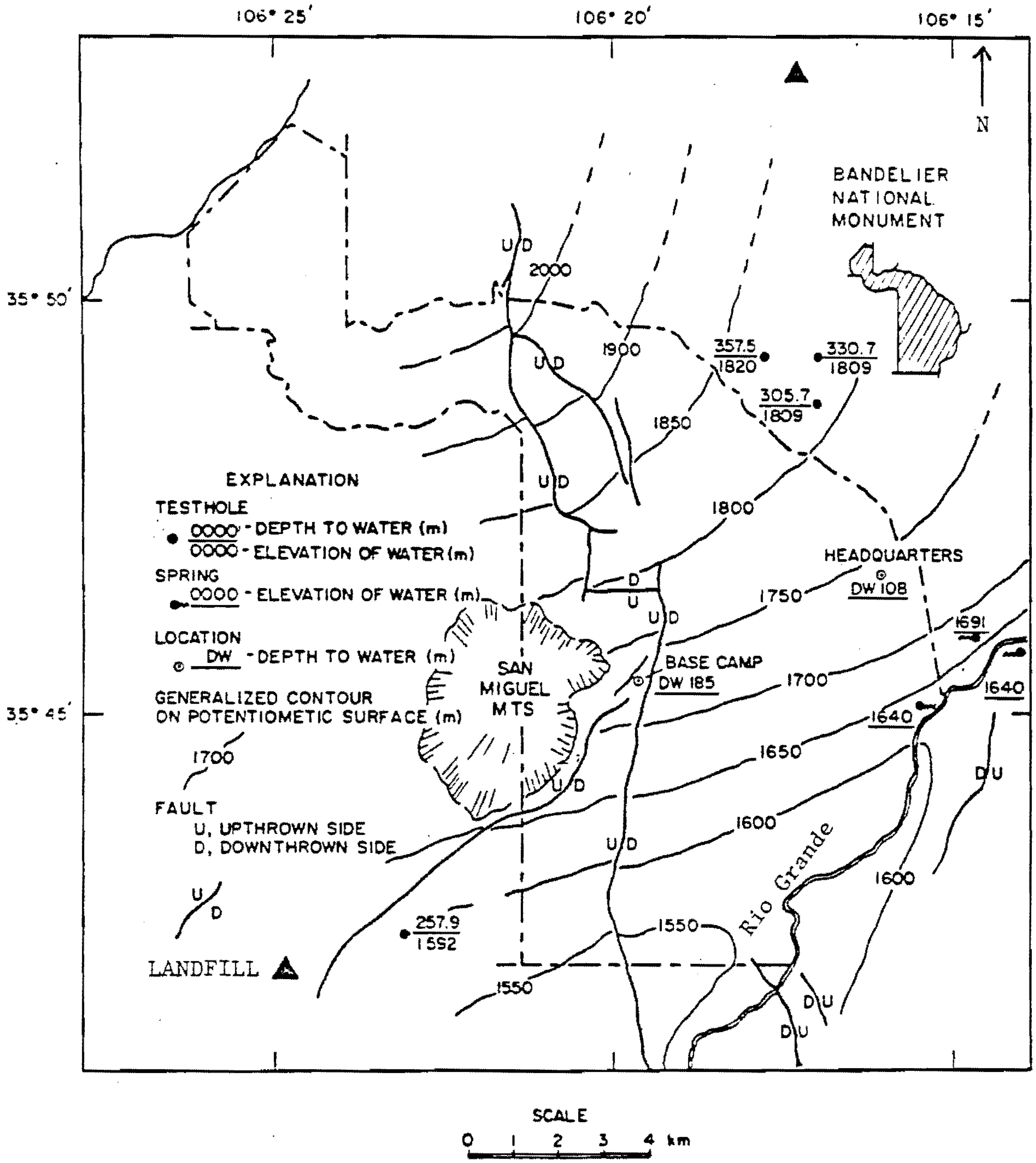

Figure 4. Generalized contours on the potentiometric surface of the Santa Fe Group(main aquifer)(after Purtymun and Adams,1980).

(Crowe and others, 1978) and a detailed evaluation of potential migration pathways is best directed at a site specific level, that is at the landfill site. Second, the value of possible migration pathways is minimal without site-specific hydrologic testing. However, recent hydrologic tests conducted by Abeele and others (1981) are probably applicable to conditions existing at the landfill. The hydrologic characteristics of the Tshirege Member will be controlled mainly by secondary features such as fractures, dissolution cavities and degree of welding (compaction of rock). For example, zones of maximum welding will tend to have the lowest water-filled porosity (10 percent); zones of partial to no welding will have higher porosity values (34.6 percent)(Crowe and others, 1978; Abeele and others, 1981). The Bandelier Tuff is strongly welded in the vicinity of the Los Alamos County sanitary landfill. Therefore, its water-filled porosity should be minimal (approximately 10 percent) and migration of TCE leachate should be negligible.

Zones of high-joint density (fracturing) in portions of the Bandelier Tuff may have a significant fracture permeability. The frequency of fracturing in the Bandelier Tuff is controlled by the rate of cooling of the volcanic rock and the presence of tectonic features such as faults, joints and other types of fractures. Typically, cooling joints are spatially related to welding zones in the Bandelier Tuff (Crowe and others, 1978). They occur as columnar joint sets (hexagonal in cross-section) that develop perpendicular to the base of the formation (cooling surface). These columnar joint sets may exhibit lateral variability in cooling joint geometry. Therefore, it is critical to determine the origin and geometry of joint sets within and adjacent to the Los Alamos County sanitary landfill.

Migration Rate of TCE through the Bandelier Tuff

The equation describing the migration rate (conservative values used) of TCE relative to the migration rate of a chemically conservative specie (non-reactive ions such as Cl^- and SO_4^{2-}) migrating at the same rate as water is given by

(1) $$\frac{V}{V_{TCE}} \cong \frac{\rho}{n}(0.63)(Kow)(OC),$$ (Said, 1981)

where

ρ is the bulk density of the Bandelier Tuff (p = 1.84 gm/cm^3, Abeele and others, 1981);

n is the porosity (n= 0.28, Abeele and others, 1981);

Kow is the octanol-water partition coefficient (Kow for TCE = 357, Barbari and King, 1982);

OC is the organic carbon content (OC = 0.02, Abeele and others, 1981);

0.63 is a constant; and

V is the velocity of water (unsaturated-flow conditions) migrating through the Bandelier Tuff. V is given by

(2) $$V = \frac{-Ku}{\Theta}\overline{\nabla}\phi ,$$ (Dames and Moore, 1979), (2)

where

Θ is the volumetric moisture content (Θ = 0.22 at field capacity);

Ku is the hydraulic conductivity of the Bandelier Tuff (conservative value) at field capacity (Ku = 1.2×10^{-8}m/sec, Abeele and others, 1981); and

$\bar{\nabla}\phi$ is the gradient of the moisture potential ($\bar{\nabla}\phi$ = unity for vertical-unsaturated flow). Solving for V in equation (2),

$$V = \frac{1.2 \times 10^{-8}\text{m/sec}\,(1)}{0.22} = 5.45 \times 10^{-8}\text{m/sec.}$$

Now solving for V_{TCE} in equation (1)

$$\frac{5.45 \times 10^{-8}\text{m/sec}}{V_{TCE}} \cong \frac{1.84\ \text{gm/cm}^3\,(0.63)(357)(0.02)}{0.28}$$

$$V_{TCE} = 1.84 \times 10^{-9}\text{m/sec (0.06 m/yr).}$$

The actual migration rate of TCE should be much lower than this calculated value, because the moisture content of the Tshirege Member is less than field capacity. The unsaturated hydraulic conductivity is 1.1×10^{-9}m/sec for a moisture content of 10 percent, the average moisture content of the Tshirege Member. The migration rate of TCE, calculated by using the above method at a moisture content of 10 percent, is 3.72×10^{-10}m/sec (0.01 m/yr). This calculation assumes that fracture permeability is insignificant and that no other chemical compounds are mixed with TCE. The latter assumption is of prime importance because other chemical compounds mixed with TCE could effect the physical and chemical properties of TCE, such as solubility and volatility characteristics and decomposition products.

The Los Alamos County sanitary landfill appears to be suitable for accepting small quantities (as defined by the New Mexico Hazardous Waste Regulations) of TCE, provided that migration pathways, such as fracture and dissolution features, in the Tshirege Member are insignificant. If open (non-sealed) fractures are encountered upon excavation of soil at the landfill site, the following studies should be undertaken:

1) Site Specific Geologic - Stratigraphic Studies - Determine the presence (or absence) of fracture zones that could serve as conduits for leachate migration in and adjacent to the Los Alamos County sanitary landfill.

2) Field Hydrology Testing - It is important to determine how primary and secondary fractures in the Tshirege Member of Bandelier Tuff (host rock) control hydrologic transport rates of leachate migrating through the soil and Bandelier Tuff. However, recent hydrologic tests conducted by Abeele (1982) may indicate that the Tshirege Member is characterized by a very low hydraulic conductivity (unsaturated-flow conditions) at the site of the Los Alamos County sanitary landfill.

REFERENCES

Abeele, W.V., Wheeler, M.L. and Burton, B.W., 1981, Geohydrology of Bandelier Tuff. Los Alamos National Laboratory report LA-8962-Ms, 50p.

Barbari, T.A. and King, J.C., 1982, Equilibrium distribution coefficients for extraction of chlorinated hydrocarbons and aromatics from water into undecane: Environ. Sci. Technol. v. 16, p.624-627.

Birkeland, P.W., 1974, Pedology, weathering and geomorphological research: Oxford University Press, Inc., 285p.

Crowe, B.M., Linn, G.W.,Heiken, G. and Bevier, M.L., 1978, Stratigraphy of the Bandelier Tuff in the Pajarito Plateau. Applications to waste management. Los Alamos Scientific Laboratory report LA-7225-MS, 57p.

Dames and Moore, 1979, Generic methodology for assessment of radiation doses from groundwater migration of radionuclides in LWR wastes in shallow land buried trenches. Appendix B - Hydrogeologic charactertistics, 26p.

Griggs, R. and Hem, J.D., 1964, Geology and ground-water resources of the Los Alamos area, New Mexico. U.S. Geol. Survey Water-Supply Paper 1753, 108p.

Nyhan, J.W., Harker, L.W., Calhoun, T.E. and Young, D.L., 1978, Soil survey of Los Alamos County, New Mexico. Los Alamos Scientific Laboratory report LA-6779-MS, 102p.

Purtymun, W.D. and Adams, H., 1980, Geohydrology of Bandelier National Monument, New Mexico. Los Alamos Scientific Laboratory report LA-8461-MS, 25p.

Said, A.S., 1981, Theory and mathematics of chromatography, A.H. Verlag, Inc. NY, p.121.

April 7, 1983

Addendum to Suitability of the Geologic and Hydrologic Conditions for the disposal of small quantities of 1,1,1 Trichloroethane at the Los Alamos County Sanitary Landfill:

Fractures and Fracture Permeability in the Bandelier Tuff

The migration of 1,1,1 Trichloroethane (TCE) through an open fracture, under unsaturated conditions, in the Bandelier Tuff in and adjacent to the Los Alamos County sanitary landfill is remote. The flow direction of TCE through the Bandelier Tuff (unsaturated conditions) will be vertical, under the influence of gravity, and not into a given fracture. It is likely that the fractures will be sealed and filled with fine-grain materials, such as clay minerals, that can efffectively adsorb the TCE. In addition, the fractures should be dry as the moisture content of the Bandelier Tuff is low (10 percent). The fractures may occupy less than 5 percent of the total volume of the Bandelier Tuff in and adjacent to the landfill.

HEALTH ENVIRONMENT department

STATE OF NEW MEXICO

ENVIRONMENTAL IMPROVEMENT DIVISION
P.O. Box 968, Santa Fe, New Mexico 87504-0968
(505) 984-0020
Russell F. Rhoades, MPH, Director

TONEY ANAYA
GOVERNOR

ROBERT McNEILL
SECRETARY

ROBERT L. LOVATO, M.A.P.A.
DEPUTY SECRETARY

JOSEPH F. JOHNSON
DEPUTY SECRETARY

MEMORANDUM

TO: Raymond Sisneros, Program Manager, PEM Section

THRU: Maxine S. Goad, Program Manager, Ground Water Section

THRU: Randy Hicks, Water Resource Specialist, Ground Water Section

FROM: Patrick Longmire, Geochemist, Ground Water Section

SUBJECT: Disposal of 1, 1, 1 trichloroethane in sanitary landfills in the Albuquerque area

DATE: April 25, 1983

Based on available data, the South Broadway, Los Angeles and Sandoval County sanitary landfills, located in the Albuquerque area, are not suitable for accepting 1, 1, 1 trichloroethane (TCE). However, these landfills could accept other materials that are insoluble and in solid form. Calculations describing the migration of TCE through the subsoils, assuming saturated-flow conditions (worst case) using best available data for each site, are included. Factors contributing to this analysis are:

1. The estimated depths to ground water at the South Broadway, Los Angeles, and Sandoval County sanitary landfills are 300, 110 and 350 feet, respectively (Bjorklund and Maxwell, 1961);

2. The soil and alluvial material found at each site are characterized by moderately permeable sand, gravel, silt and clay deposits, where the reported and estimated saturated hydraulic conductivities range from 6.51×10^{-6} to 2.17×10^{-5} m/sec; and

3. TCE is a soluble and volatile liquid capable of migrating through the subsoil, under unsaturated flow conditions, to the water table in a matter of 3 years or less at these three landfills sites. Conservative values for hydraulic conductivity, moisture content and porosity are used in migration-rate calculations. The Los Alamos County sanitary landfill is the nearest landfill site to the Albuquerque area that can safely contain TCE.

Migration Rate of TCE through Rio Grande Valley - Fill Material

The equation describing the migration rate (conservative values used) of TCE relative to the migration rate of a chemically conservative specie (non-reactive ions such as Cl^- and SO_4^{2-}) is given by:

$$(1) \quad \frac{V}{VTCE} = \frac{P\,(0.63)\,(Kow)\,(OC)}{n}, \qquad \text{(Said, 1981)}$$

where:

P is the bulk density of the alluvium (p = 1.72 gm/cm^3 at 35% porosity);
n is the porosity (assume n = 35%);
Kow is the octonal-water partition coefficient (Kow for TCE = 357, Barbari and King, 1982);
OC is the organic carbon content (assume OC = 0.02);
0.63 is a constant; and
V is the velocity of water (unsaturated-flow conditions) migrating through the alluvium. V is given by:

$$(2) \quad V = \frac{-K}{\theta} \nabla \phi, \qquad \text{(Dames and Moore, 1979)}$$

where:

θ is the volumetric moisture content (assume θ = 0.35 which is equal to the effective porosity);
K is the hydraulic conductivity of the alluvium; and
$\nabla \phi$ is the gradient of the moisture potential ($\nabla \phi$ = unity for vertical flow).

Site A

South Broadway Landfill

The hydraulic conductivity for Site A material is 2.17 x 10^{-5} m/sec (Hacker, 1977).
Using equation 2,

$$V = \frac{-K\nabla\phi}{\theta} = \frac{2.17 \times 10^{-5}\ \text{m/sec}\ (1)}{0.35} = 6.20 \times 10^{-5}\ \text{m/sec}.$$

Using equation 1,

$$\frac{6.20 \times 10^{-5}\ \text{m/sec}}{VTCE} = \frac{1.72\ \text{gm/cm}^3\ (0.63)\ (357)\ (0.02)}{0.35},$$

VTCE = 2.80 x 10^{-6} m/sec (88.45 m/yr).

The depth to ground water at Site A is 300 feet (91.44 m). The expected time for TCE to reach ground water (conservative values used), assuming no volatilization and biodegradation, is given by:

$$\frac{91.44 \text{ m}}{88.45 \text{ m/yr}} = 1.03 \text{ year.}$$

Site B

Los Angeles Landfill

The hydraulic conductivity for Site B material is 2.17×10^{-5} m/sec (Hacker, 1977). Using equation 2,

$$V = \frac{-K}{\theta}\nabla\phi = \frac{2.17 \times 10^{-5} \text{ m/sec (1)}}{0.35} = 6.20 \times 10^{-5} \text{ m/sec.}$$

Using equation 1,

$$\frac{6.20 \times 10^{-5} \text{ m/sec}}{\text{VTCE}} = \frac{1.72 \text{ gm/cm}^3 (0.63)(357)(0.02)}{0.35}$$

$$\text{VTCE} = 2.80 \times 10^{-6} \text{ m/sec (88.45 m/yr).}$$

The depth to ground water at Site B is 110 feet (33.53 meters). The expected time for TCE to reach ground water (conservative values used), assuming no volatilization and biodegradation, is given by:

$$\frac{33.53 \text{ m}}{88.45 \text{ m/yr}} = 0.38 \text{ year.}$$

Site C

Sandoval County Landfill

The hydraulic conductivity for Site C material is assumed to be 1×10^{-5} m/sec. Using equation 2,

$$V = \frac{-K}{\theta}\nabla\phi = \frac{1 \times 10^{-5} \text{ m/sec}}{0.35} = 2.86 \times 10^{-5} \text{ m/sec.}$$

Using equation 1,

$$\frac{2.86 \times 10^{-5} \text{ m/sec}}{\text{VTCE}} = \frac{1.72 \text{ gm/cm}^3 (0.63)(357)(0.02)}{0.35},$$

$$\text{VTCE} = 1.29 \times 10^{-6} \text{ m/sec (40.78 m/yr).}$$

The depth to ground water at Site C is 350 feet (106.67 meters). The expected time for TCE to reach ground water (conservative values used), assuming no volatilization and biodegradation, is given by:

$$\frac{106.67 \text{ m}}{40.78 \text{ m/yr}} = 2.62 \text{ years.}$$

REFERENCES

Barbari, T.A. and King, J.C., 1982, Equilibrium distribution coefficients for extraction of chlorinated hydrocarbons and aromatics from water into undecane: Environ. Sci. Technol. v. 16, pp. 624-627.

Bjorklund, L.J. and Maxwell, B.W., 1961, Availability of ground water in the Albuquerque area, Bernalillo and Sandoval Counties, New Mexico: New Mexico State Engineer Technical Report 21, 117p.

Dames and Moore, 1979, Generic methodology for assessment of radiation doses from ground water migration of radionuclides in LWR wastes in shallow land burial trenches. Appendix B - Hydrogeologic characteristics, 26p.

Hacker, L.W., 1977, Soil survey of Bernalillo County and parts of Sandoval and Valencia Counties, New Mexico - U.S. Soil Conservation Service 101p.

Said, A.S., 1981, Theory and mathematics of chromatography, A.H. Verlag, Inc. NY, p. 121.

PL:egr