NORTHROP TRIGA REACTOR

CONCRETE DISPOSITION REPORT

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ATTACHMENT A

NORTHROP TRIGA REACTOR CONCRETE DISPOSITION REPORT

The basis for seeking permission to ship and to bury the remaining concrete structure at a Los Angeles County dump site is summarized in this brief report.

The neutron activation of the concrete, due to its proximity to the TRIGA Reactor (Figure 1), is perceived to be a hazard. The neutron fluence created in the core of the reactor during the twenty two years operation of the reactor was 2.2×10^{19} n/cm^2. Figure 2 plots the neutron fluence versus distance from the core. The fraction of the time the reactor operated at different locations in the pool determined the magnitude of the exposure of various structural materials. The reactor operated at the exposure room position 45 percent of the operating period. The concrete at this location was exposed to the maximum neutron irradiation. Only the data related to the activation of concrete is presented in this report since all other activated materials, except for the concrete, were removed from the facility.

Table 1 lists the weight fraction of the elements of radiological interest in the concrete in the reactor structure, determined by measurements on concrete samples. The list is divided into two categories, those contributing to the natural background radioactivity and those contributing to the neutron induced radioactivity. The neutron induced radioactivity in the concrete at the surface before the removal of the activated layer is shown in Table 1.

Potassium-40, the uranium series, and the thorium series produce the background activity observed in normal, unirradiated concrete. Table 2 summarizes the radioactivity created by these naturally occurring radioisotopes.

Table 3 summarizes the neutron induced activation of the concrete in the exposure room. Figure 3 plots the neutron induced activity versus the depth from the surface of the concrete, in the exposure room. The observed scatter in the data is due to the variation in the neutron fluence at the different surface positions. The essential conclusion from these data is that the neutron induced radioactivity is below the natural background activity at depth greater than 20 inches below the original surface of the concrete.

The entire wall between the exposure room and the pool was removed, and the remaining walls, ceiling, and floor were removed to a depth of 24 inches or greater, and shipped to the Hanford Site for burial (Table 4).

The specific activity at the surface of the remaining concrete is 25 pCi/gm. The induced radioactivity falls off exponentially with depth, with a relaxation length of 4 inches. The induced activity is contained in a mass of 22 metric tons of concrete, with a total induced activity of 0.55 millicuries, created by 0.000011 millimoles of radioisotopes due to neutron capture (Table 5). The natural background radioactivity generated in the same mass of concrete is 0.64 millicuries, created by 8,820 millimoles of naturally occurring radioisotopes. The total mass of the concrete structure, approximately 1000 metric tons, generates 29 millicuries of radioactivity, created by 400,000 millimoles of naturally occurring radioistopes. The ratio of the neutron induced radioisotopes to the background radioisotopes in the concrete is approximately one part in forty billion. The total activity in the 1000 metric tons of concrete rubble is summarized in Table 5, and the fraction of the allowed limit for burial of this material, as specified in the State of California Title 17, Section 30288 and Appendix B, is also listed. Table 5 shows the radioactivity created by the neutrons in the concrete rubble is only two percent of the allowed level. The natural primordial radioactivity in the concrete rubble is approximately the same as the measured radioactivity in ordinary dirt (Table3), and is much less available since it is chemically bonded in the concrete.

The gamma activity, measured in the exposure room after the removal of the activated concrete,is 21.3 uR/hr. The activity measured by the detector when complelely surrounded by 2 inches of lead was zero. The activity measured by the same detector placed above and below a 2 inch layer of lead bricks (Table 7) show that the gamma activity for a flat surface of the same concrete would be 10.7 uR/hr. The gamma activity measured on concrete surfaces in buildings in the Northrop Complex that are completely isolated from the Reactor Facility is 11.6 uR/hr. The same level is measured on public thorughfares outside the Northrop Complex (Table 8). The calculated level from the molar content of the naturally present radioisotopes is 14.3 uR/hr (Table 2D).

The quantity of neutron induced radioactivity that will enter the soil after burial will be very low because the radioisotopes are chemically bonded in the concrete, and their lifetimes are relatively short. In contrast, a significant fraction of the uranium and thorium series radioisotope will escape because the concrete will decompose during the very long lifetime of the parent isotopes, and also because of the gaseous phase of the radon link in the decay series will allow some of the radioisotopes to diffuse from the concrete rubble. The maximum level of the neutron capture radioactivity eroded into the soil from the concrete after burial is approximately 0.2 microcurie. For the same erosion conditions, the primordial radioactivity eroded into the soil will start at 10 micrcuries and increase linearly with time until the concrete is completely decomposed (Tables 9-10, and Figure 4).

The eroded concrete rubble buried at the landfill site will be exposed to water infiltrated into the soil from natural rainfall. The radioisotopes from the eroded concrete will be dissolved in the water and transported into the soil and rock structure. An analysis of the specific activity of the groundwater, based on the geologic and hydrogeologic report and the climatological report , is given in Table 11 and the dilution of the radioactivity versus time is tabulated in Table 12. The neutron induced radioactivity introduced into the groundwater at the site is negligible compared to the natural primordial radioactivity, and, in any event, will be completely contained within the site due to : the low permeability of the sandstone (75 ft/yr) and siltstone (0.05 ft/yr) formation ; the construction of leachate barriers in the canyons ; and the large area of the landfill site (1365 acres) that precludes any of the induced radioactivity leaving the site during the relatively short lifetime of these neutron induced radioisotopes (Figure 5).

In summary, the concrete can be safely transported to, and buried at a local dump site because the radioisotopes produced by the neutronsin the concrete structure are negligible (one part in forty billion) of the naturally occurring radioisotopes, and this small fraction of neutron produced radioisotopes will remain chemically bonded in the concrete rubble during their relatively short lifetimes.

TABLE 1

RADIOISOTOPE TABLE FOR CONCRETE
IN THE NORTHROP FACILITY

RADIO ISOTOPE (XA)	PARENT ISOTOPE (YB)	CONTROLLING LIFETIME (YEARS) (TA)	PARENT ISOTOPIC ABUNDANCE (PERCENT) (GB)	PARENT CONCRETE ABUNDANCE (PERCENT) (JECON)	SPECIFIC SURFACE ACTIVITY (pCi/gm) (AAERCON)
ACTIVATION - NEUTRON CAPTURE					
FE55	FE54	3.90	5.82	10.2000	7000
CO60	CO59	7.60	100.00	0.0070	800
NI63	NI62	144.44	3.66	0.0015	1
ZN65	ZN64	0.97	48.89	0.0020	1
EU152	EU151	19.62	47.82	0.0005	2900
EU154	EU153	12.70	52.18	0.0005	240
ACTIVATION - PRIMORDIAL					
K40	K40	1.81 E 9	0.01	2.4 E -8	17.00
RA226	U238	6.51 E 9	99.27	1.1 E -8	0.37
TH228	TH232	2.03 E 10	100.00	6.4 E -8	0.70
TH232	TH232	2.03 E 10	100.00	6.4 E -8	0.70

NOTE

Summary of data from final report.

AAERCON = KA*10000*AU*JECON*10000*LLER/100

KA	:		TABLE 3.1.3C
AU	=	1.28 Ci/gm	TABLE 3.1.3C
JECON	:		TABLE 3.1.3B
LLER	=	0.01 percent	TABLE 3.1.3F

TABLE 2A

NATURAL BACKGROUND ACTIVITY IN CONCRETE

POTASSIUM-40

Nuclear Decay Reactions

K-40 = Ca-40 + beta + 1.3 MeV (89 percent)
K-40 = Ar-40 + El.C.+ 1.5 MeV (11 percent)

$T_{1/2}$ = 1.26 x 10^9 years

Specific Activity

A_t = 17 pCi/gm - Total measured activity of K-40

A_b = 15 pCi/gm - Beta activity, 89 percent of A_t.
A_g = 2 pCi/gm - Gamma activity, 11 percent of A_t.

URANIUM SERIES

Nuclear Decay Reactions

U-238 --------> Pb-206 + 8 alphas + 6 betas + approx. 8 gammas/xrays

$T_{1/2}$	=	4.5 x 10^9 years	
D-Mass	=	51.7 MeV	Rest mass difference, see Bib-3.1.5.
D-alpha	=	42.9 MeV	Kinetic energy, see Bib-6.4.1.
D-beta	=	5.7 MeV	See Bib-6.4.1.
D-recoil	=	0.8 MeV	Momentum conservation nuclear recoils
D-part.	=	49.4 MeV	Sum of particle kinetic energies
D-gamma	=	51.7 - 49.4 = 2.3 MeV	Difference of above
E_a	=	42.9/8	= 5.4 MeV per alpha
E_b	=	5.7/6	= 0.8 MeV per beta
E_g	=	2.3/8	= 0.3 MeV per gamma

Specific Activity

A_1 = 0.37 pCi/gm Measured Ra-226 activity - 1 alpha decay

A_a = 8x0.37 = 3.0 pCi/gm for the 8 alpha decays
A_b = 6x0.37 = 2.2 pCi/gm for the 6 beta decays
A_g = 8x0.37 = 3.0 pCi/gm for the 8 gamma decays

A_t = A_a+A_b+A_g= 8.2 pCi/gm for all decay processes

TABLE 2B

NATURAL BACKGROUND ACTIVITY IN CONCRETE

THORIUM SERIES

Nuclear Reactions

Th-232 --------> Pb-208 + 6 alphas + 4 betas + approx. 6 gammas/xrays

$T_{1/2}$	=	1.41×10^{10} years
D-Mass	=	42.7 MeV Rest mass difference, see Bib-1.3.5.
D-alpha	=	35.8 MeV Kinetic energy, see Bib-6.4.1.
D-beta	=	3.2 MeV See Bib-6.4.1
D-recoil	=	0.6 MeV Momentum conservation, nuclear recoils
D-part.	=	39.6 MeV Sum of the particle energies
D-gamma	=	42.7 - 39.6 = 3.1 MeV Difference of above
E_a	=	35.8/6 = 6.0 MeV per alpha
E_b	=	3.2/4 = 0.8 MeV per beta
E_g	=	3.1/6 = 0.5 MeV per gamma

Specific Activity

Al	=	0.7 pCi/gm Measured Th-232 single alpha decay.
A_a	=	6x0.7 = 4.2 pCi/gm for the 6 alpha decays
A_b	=	4x0.7 = 2.8 pCi/gm for the 4 beta decays
A_g	=	6x0.7 = 4.2 pCi/gm for the 6 gamma decays
A_t	=	$A_a+A_b+A_g$ = 11.2 pCi/gm for all decay products

TABLE 2C

NATURAL BACKGROUND ACTIVITY IN CONCRETE

SUMMARY OF BACKGROUND ACTIVITY DATA

SOURCE OF RADIATION	SPECIFIC ACTIVITY OF THE VARIOUS PROCESSES				ENERGY OF GAMMAS
	ALPHA	BETA	GAMMA	SUBTOTALS	
	(-------------pCi/gm			--------------------)	(MeV)
K-40	---	15	2	17	1.5
Uranium series	3.0	2.2	3.0	8.2	0.3
Thorium series	4.2	2.8	4.2	11.2	0.5
Subtotals	7.2	20.0	9.2	36.4	0.7

TABLE 2D

NATURAL BACKGROUND ACTIVITY IN CONCRETE

GAMMA BACKGROUND RADIATION LEVEL EXTERNAL TO CONCRETE

Energy Density Conversion Factor in Uniformly Activated Material

K_d = 2.13 (uR/hr) / (pCi/gm) / MeV

Specific Energy Deposition from Uniformly Activated Material

ITEM	UNITS	PER PARTICLE			TOTAL
		ALPHA	BETA	GAMMA	
E_x	MeV/particle	5.7	1.2	0.7	
A_x	pCi/gm	7.2	20.0	9.2	36.4
D_{1x}	(pCi-MeV)/gm	41.0	24.0	6.4	71.4
D_{2x}	uR/hr (=K_dxD_{1x})	87.3	51.1	13.6	152.1
D_{sx}	uR/hr (=D_{2t})				152.1
BU (ul,E_g)				2.1	
D_{1g}	uR/hr (=BUxD_{2g})			28.6	
D_{ft}	uR/hr (=0.5xD_{st})				76.0
D_{fg}	uR/hr (=0.5xD_{1g})			14.3	

NOTE

E_x, A_x, from previous table
D_{1x} = (E_x x A_x) is specific energy source, expressed in pCi-MeV/gm.
D_{2x} = (K_d x D_{1x}) is specific energy density , expressed in uR/hr.
D_{sx} = D_{2t} is specific energy deposited in test material placed in a small cavity in the uniformly activated material.
BU : is buildup factor for gamma radiation for 1 relaxation depth and for gamma energy, E_g (see Bib-6.4.1).
D_{1g} = (BU x D_{2g}) is specific energy deposited in test material placed in a large cavity, greater than range of charged particles from surface. D_{ft} = (0.5 x D_{st}) is energy deposited in test material placed near a surface of uniformly activated material (2pi geometry).
D_{fg} = (0.5 x D_{1g}) is energy deposited in test material placed beyond the range of the charged particles from a flat surface (2pi geom.).

TABLE 2E

NATURAL BACKGROUND SURFACE ACTIVITY FROM CONCRETE

ALPHA SURFACE ACTIVITY

A_{sa} = $K_a \times A_a$ dpm/100cm^2 Surface activity from alphas

R = 0.005 gm/cm^2 Range of 5.7 MeV alphas
X = 0.5 Depth of emission factor
O = 0.5 steradian Effective solid angle factor
K_d = 222 (dpm/100cm^2)/(pCi/gm) Conversion factor

K_a = $R \times X \times O \times K_d$ = 0.28 (dpm/100cm^2)/(pCi/gm)

A_a = 7.2 pCi/gm Specific activity of alphas

A_{sa} = 2.0 dpm/100cm^2 Surface activity from alphas

BETA SURFACE ACTIVITY

A_{sb} = $K_b \times A_b$ dpm/100cm^2 Surface activity from betas

R = 0.25 gm/cm^2 Mean range of betas
X = 0.125 Depth of emission factor
O = 0.5 steradian Effective solid angle factor

K_b = $R \times X \times O \times K_d$ = 14 (dpm/100cm^2)/(pCi/gm)

A_b = 20.0 pCi/gm Specific activity of betas

A_{sb} = 280 dpm/100cm^2 Surface activity from betas

GAMMA SURFACE ACTIVITY

R = 12 gm/cm^2 Mean range of gammas
XO = 0.083 gm/cm^2 Effective attenuation, depth, solid angle factor

K_g = $R \times XO \times K_d$ = 222 (dpm/100cm^2)/(pCi/gm)

A_g = 9.2 pCi/gm Specific activity of gammas

A_{sg} = 2000 dpm/100cm^2 Surface activity from gammas

BETA-GAMMA SURFACE ACTIVITY

$A_{sbg} = A_{sb} + A_{sg}$ = 2300 dpm/100cm^2

TABLE 2F

NATURAL BACKGROUND RADON COMPONENT

NUCLEAR REACTIONS

U238 ----> Rn222 + 4 ALPHAS + 2 BETAS + 4 GAMMAS
Rn222 ---> Pb206 + 4 ALPHAS + 2 BETAS + 4 GAMMAS

Th232 ---> Rn220 + 3 ALPHAS + 2 BETAS + 3 GAMMAS
Rn220 ---> Pb208 + 3 ALPHAS + 2 BETAS + 3 GAMMAS

K40 -----> Ca40 0.89 BETAS
K40 -----> Ar40 0.11 GAMMAS

The Radon isotope splits the Uranium series and the Thorium series into two approximately equal decay components. Since Radon is a noble gas,it will tend to diffuse out of the surface of the concrete, and therefor will reduce the surface activity of the concrete if the surface is exposed. Since Rn222 has a halflife of 3.82 days, and Rn220 a halflife of 55.6 seconds, the diffusion time is relatively short. The halflife of the remaining decay products are all very short except for Pb210, which is 22 years.

SPECIFIC ACTIVITY

The Radon component represent 50 percent of the alphas, 12 percent of the betas, and 25 percent of the gammas.

CATEGORY	PARTICLE				
	ALPHA	BETA	GAMMA	SUBTOTALS	
RADON INDEPENDENT	3.6	17.6	6.9	28.1	pCi/gm
RADON DEPENDENT	3.6	2.4	2.3	8.3	pCi/gm
TOTALS	7.2	20.0	9.2	36.4	pCi/gm

SURFACE ACTIVITY

CATEGORY	PARTICLE				
	ALPHA	BETA	GAMMA	SUBTOTLAL	
At 1 cm (w/o Rn)	1	250	1500	1750	$dpm/100cm^2$
At 1 cm (with Rn)	2	280	2000	2300	$dpm/100cm^2$
At 1 m (w/o Rn)			10.2	10.2	uR/hr
At 1 m (with Rn)			14.3	14.3	uR/hr
In cavity (w/o Rn)			21.4	21.4	uR/hr
In cavity (with Rn)			28.6	28.6	uR/hr

TABLE 3

SUMMARY OF CONCRETE AND SOIL SAMPLE MEASUREMENTS

NEUTRON INDUCED ACTIVATION IN CONCRETE OF EXPOSURE ROOM

DEPTH (INCHES)	FE-55	CO-60	EU-152	EU-154	TOTAL
	pCi/gm				
0-3	7060	796	2870	234	10960
17	1300	2.92	5.0	0.6	1307
20	73.5	2.74	8.2	0	84.4
24	(13)	(2.5)	(8.8)	(0.7)	(25.0)
29	1.86	0.36	1.25	0	3.5

NATURAL BACKGROUND ACTIVITY IN NORMAL CONCRETE

LOCATION	K-40	RA-226	TH228	TH232	U235
	pCi/gm				
EXP.RM.	14.4				
EXP.RM.	14.0				
EXP.RM.	18.6	0.38			0.041
POOL	18.6	0.31			
POOL	17.9	0.46			
POOL	14.6				
OUT.WALL	20.0	0.32	0.73	0.64	
AVERAGE	16.9	0.37	0.73	0.64	0.041

NATURAL BACKGROUND ACTIVITY IN SOIL

BELOW EXP.RM	16.1	0.42			0.038
BELOW EXP.RM	18.3	0.35			0.047
AVERAGE	17.2	0.38			0.042

NOTE Blanks in table indicate that particular isotope was not analyzed, and does not necessarily mean that the isotope was not present in the material.

Data at 24 inches is interpolated from actual measurements.

TABLE 4

RADIOACTIVE WASTE SHIPMENTS

SHIP. No.	DATE	WEIGHT (lbs)	VOLUME (ft^3)	NUMBER BINS	ACTIVITY (mCi)	MAJOR CONTRIBUTORS
1	7/15	43810	672	7LSA	211	CONC.REB.WOOD
2	7/17	43400	672	7LSA	168	CONC.REB.WOOD
3	7/19	44080	768	8LSA	142	CONC.REB.WOOD
4	7/31	44930	576	6LSA	22	CONC.REB.WOOD H3(sealed) (21.4Ci source) Ra226foils(84uCi)
5	8/8	44470	576	6LSA	204	CONC.REBAR Ra226foils(66uCi)
6	8/15	43210	480	5LSA	293	CONC.REBAR
7	8/22	39880	536	5LSA 5DRUMS HT.EXCH'R	228	CONC.REBAR
TOTALS		303780 (138 MT)	4280	44LSA 5DRUMS HT.EXCH'R	1268	CONCRETE REBAR WOOD

ESTIMATES OF MATERIAL COMPOSITION

LOCATION	MATERIAL	VOLUME (m^3)	DENSITY (MT/m^3)	MASS (MT)
EXPOSURE ROOM	CONCRETE	40	2.7	110
EXPOSURE ROOM	REBAR	2.5	7.9	20
EZPOSURE ROOM	WOOD	8	0.5	4
BEAM PORTS	B.P.,CONC.	2	2.7	4
TOTAL		52.5	2.7	138

TABLE 5A

CONCRETE RUBBLE
BURIAL AT LANDFILL SITE
NEUTRON GENERATED RADIOACTIVITY IN CONCRETE

RADIO ISOTOPE BASE	RADIO ACTIVITY (1000 MT)	ALLOWED ACTIVITY (EACH BUR)	ALLOWED ACTIVITY (PER YEAR)	FRACTION ALLOWED LIMIT (PER YEAR)
	uCi	uCi	uCi	percent
FE55	286	100,000	1,200,000	0.02
CO60	50	1,000	12,000	0.42
EU152	194	1,000	12,000	1.62
EU154	15	1,000	12,000	0.12
TOTAL	546	-------	------	2.18

NOTE

1) The radiactivities listed in the table are the measured values given in Table 3.

2) The neutron produced radioactivity in the concrete rubble is only 2.2 percent of the allowed burial limits.

TABLE 5B

CONCRETE RUBBLE
BURIAL AT LANDFILL SITE
NATURAL PRIMORDIAL RADIOACTIVITY
IN CONCRETE, SOIL, AND GROUNDWATER

RADIO ISOTOPE BASE	RADIO ACTIVITY (1000 MT)	ALLOWED ACTIVITY (EACH BUR)	ALLOWED ACTIVITY (PER YEAR)	FRACTION ALLOWED LIMIT (PER YEAR)
	uCi			percent
NATURAL PRIMORDIAL ACTIVITY IN CONCRETE				
K40	17,000	100	1,200	1417
THORIUM	690	50,000	600,000	0.12
URANIUM	410	50,000	600,000	0.07
TOTAL	19,000	-------	-------	1417.19
NATURAL PRIMORDIAL ACTIVITY IN SOIL				
K40	17,200	100	1,200	1430
THORIUM	not measured			
URANIUM	410	50,000	600,000	0.07
TOTAL	17,610	-------	-------	1430.07

NOTE

1) The radiactivities listed in the table are the measured values given in Table 3.

2) The natural primordial radioactivity in the concrete rubble is less than the natural primordial activity measured in ordinary dirt, and is much less available since it is chemically bonded in the concrete. Therefor it is less hazardous than ordinary dirt.

TABLE 6

RADIOACTIVITY AND MOLES OF RADIOISOTOPES IN CONCRETE FOR DISPOSAL

RADIO ISOTOPE (XA)	CONTROLLING LIFETIME (YEARS) (TAX)	SURFACE RADIO ACTIVITY (uCi) (AXNM)	22 MET.TONS RADIOACTIVE MOLES (uMoles) (NXNM)	REMAINING RADIO ACTIVITY (ucuries) (AXNM)	1000 MET.TONS RADIOACTIVE MOLES (uMoles) (NXNM)
NEUTRON CAPTURE RADIOISOTOPES					
FE55	3.9	286	0.002	0	0
CO60	7.6	55	0.001	0	0
EU152	19.6	194	0.007	0	0
EU152	12.7	15	0.001	0	0
SUBTOTAL		550	0.011	0	0
PRIMORDIAL RADIOISOTOPES		(AXBM)	(NXBM)	(AXBM)	(NXBM)
K40	1.81 E 9	374	1310000	17000	60000000
URSER	6.51 E 9	114	1440000	5200	66000000
THSER	2.03 E 10	154	6060000	7000	66000000
SUBTOTAL		642	8820000	29200	401000000
TOTAL		1192	8820000	29200	401000000

AXNM = KN*AXN*M — Neutron capture activity in concrete.

AXBM = KN*AXB*M — Natural background alpha and beta activity.

KN = 1.94 E -6 — uMoles/uCi/year - Conversion factor

AXN : — Specific activity from neutron capture at the surface of the remaining concrete.

AXB : — Specific activity from natural primordial radioactivity in the concrete.

NXNM = AXNM*TAX — Number neutron capture radioisotope nuclei.

NXBM = AXBM*TAX — Number primordial radioisotope nuclei.

TAX : — Mean lifetime of radioisotope

TABLE 7

EXPERIMENTAL DATA FOR CAVITY DOSE RATE

EXPERIMENT

A Ludlum low level gamma scintilator, with a 1 inch diameter by 1 inch long sodium iodide detector was placed in the center of the exposure room. It measured 21.3 uR/hr activity. A 2 inch thick by 8 inch wide by 16 inch long layer of lead was placed below the detector, with the center of the detector at approximately 1.4 inches above the center of the surface. The meter read 14 uR/hr. The detector was placed below the layer of lead at approximately 1.9 inches below the surface. The meter read 15.5 uR/hr. The meter read zero when completely surrounded with a 2 inch layer of lead.

ANALYSIS

UPPER HEMISHERE

AU = 14 uR/hr
SU = 2 pi + 8 x ARCSIN (1.4 / (1.4^2 + (4^2 + 8^2))$^{.5}$)
SU = 6.28 + 1.23 = 7.5 Steradians
ASU= AU/SU = 1.87 uR/(hr-ster)

LOWER HEMISPHERE

AL = 15.5 uR/hr
SL = 2 pi + 8 x ARCSIN (1.9 / (1.9^2 + (4^2 + 8^2))$^{.5}$)
SL = 6.28 + 1.65 = 7.93 Steradians
ASL= AL/SL = 1.95 uR/(hr-ster)

AVERAGE ACTIVITY

ASA= (ASU + ASL) / 2 = 1.89 uR/(hr-ster)

AT = 4 pi x ASA = 23.7 uR/hr (calculated)
AM = 21.3 uR/hr (measured)

The minor discrepancy between the calculated and measured total activity indicates the actual solid angles for the upper and lower measurements were slightly larger than calculated.

BACKGROUND FLAT SURFACE ACTIVITY

AC = AM / 2 = 10.7 uR/hr (Calculated for 2 pi geometry)
AC = 14.3 uR/hr (Calculate from specific activities, Table 2D)
AM = 11.6 uR/hr (Measured background - see Table 7)

The agreement indicates the concrete in the exposure room is at background level.

TABLE 8

BACKGROUND SURVEY MEASUREMENTS
AT UNRESTRICTED AREAS

MEASUREMENT NO.	LOCATION	GAMMAS AT 1 METER (GR) (uR/hr)	BETA-GAMMAS AT <1 CM (BG) (dpm/100cm2)	ALPHAS AT < 1 CM (A) (dpm/100cm2)
1	BKGD-GATE15 AREA	12	1612	0
1	BKGD-GATE15 AREA	12	1612	0
2	BKGD-BLDG-3-55	12	1612	0
3	BKGD-BLDG-3-55	11	1612	0
4	BKGD-BLDG-3-55	9	1612	0
5	BKGD-BLDG-3-55	11	1612	0
6	BKGD-BLDG-3-55	12	3224	0
7	BKGD-BLDG-3-10	12	1612	0
8	BKGD-BLDG-3-10	12	1612	0
9	BKGD-BLDG-3-10	11	1612	0
10	BKGD-BLDG-3-61	12	1612	0
11	BKGD-BLDG-3-61	11	1612	0
12	BKGD-BLDG-3-61	12	1612	0
13	BKGD-BLDG-3-7	9	1612	0
14	BKGD-BLDG-3-7	11	1612	0
15	BKGD-BLDG-3-7	11	1612	0
16	BKGD-PARKLOT-747	12	1612	0
17	BKGD-PARKLOT-747	12	1612	0
18	BKGD-PARKLOT-747	12	1612	0
19	BKGD-BLDG-1-153	12	1612	0
20	BKGD-BLDG-1-153	12	1612	0
21	BKGD-WINTUNLOT-1-76	12	1612	0
22	BKGD-WINTUNLOT-1-76	12	1612	0
23	BKGD-TRANSWHOUSE	12	1612	0
24	BKGD-TRANSWHOUSE	12	1612	0
24	BKGD-TRANSWHOUSE	12	1612	0
25	BKGD-PRAIRIE-NORTHROP	12	3224	0
26	BKGD-PRAIRIE-EL SEGUNDO	12	1612	0
27	BKGD-NORTHROP-CRENSHAW	12	1612	0
27	BKGD-NORTHROP-CRENSHAW	12	1612	0
	AVERAGE (30 READINGS)	11.6	1720	0
	STANDARD DEVIATION	0.8	410	0
	MAX.LIKELYHOOD DOSE RATE	12.7	2140	0

TABLE 9

RADIOACTIVITY IN SOIL
DUE TO EROSION OF CONCRETE AFTER BURIAL

EROSION OF NEUTRON ACTIVATED SURFACE

The dimensions of the exposure room, after the removal of 24 inches of the activated concrete, was 4.2 x 4.2 x 4.8 meters. The remaining activity had a mean depth of 10 cm. The total mass of concrete remaining in the concrete structure was approximately 1000 metric tons. The rate at which activity is eroded into the soil can be estimated for a specific erosion rates of the concrete, K, and for a specific sizes of the concrete rubble, LR. The analysis is for an erosion rates of 1 mm/100yrs, and for rubble with a uniform mass distribution from 1 cm cubes to 1 meter cubes.

EROSION OF NEUTRON ACTIVATED SURFACE

SN =	106	m^2	Exposure room surface area - no window wall.
K =	0.00001	m/yr	Erosion rate.
RC =	2.7	MT/m^3	Density of concrete
AX =			Specific activity of radioisotope X at time of burial - Table 3.
AX0	= K x SN x RC x AX		Activity of radioisotope, X, at time of burial, for 1 years erosion.
TAX	=		Mean life of radioisotope, X - Table 1.
AXT	= AX0 x T x EXP(T/TAX)		Activity of eroded radioisotope, X, in soil after T years burial - Table 10.
ANT	= SUM (AXT)		Total radioactivity from neutron capture radioisotopes eroded into the soil after T years of burial - Table 10.

EROSION OF PRIMORDIAL ACTIVATED SURFACES

RL =	0.01	m	Smallest size cubic concrete rubble.
RH =	1	m	Largest size cubic concrete rubble.
M =	1000		Total concrete mass.
AX0= K x M x AX x LOG(RH/RL) / (RH-RL)			Activity at burial - see above.
AXT and ABT			As described above.

The eroded activity of the neutron-capture radioisotopes and primordial background isotopes are tabulated in Table 10, for various burial times. The total eroded radioactivities for the neutron-capture radioisotopes and the primordial radioisotopes, and their logarithmic value, are listed in Table 10. These data are plotted in figure 3.1.7.

TABLE 10

RADIOACTIVITY IN SOIL FROM CONCRETE ERODED AFTER BURIAL

RADIO ISOTOPE (XA)	FIRST YEAR (AX1)	FOURTH YEAR (AX4)	SIXTEENTH YEAR (AX16)	SIXTY-FOURTH YEAR (AX64)	128TH YEAR (AX128)
	RADIOACTIVITY FROM ERODED CONCRETE — uCi				
NEUTRON CAPTURE					
FE55	0.029	0.05	0.01	0.00	0.000
CO60	0.006	0.02	0.01	0.00	0.000
EU152	0.024	0.08	0.18	0.06	0.005
EU154	0.002	0.01	0.01	0.00	0.000
Total	0.061	0.16	0.21	0.06	0.005
PRIMORDIAL					
K40	3.954	15.82	63.26	253.04	506.047
TH232	2.605	10.42	41.68	166.71	333.397
U238	1.935	7.74	30.96	123.83	247.648
Total	8.494	33.98	135.90	543.58	1087.092

SUMMARY OF TOTALS

TIME AFTER BUR. YRS (T)	RADIOACTIVITY: NEUTRON ACTIV. uCi (ANT)	RADIOACTIVITY: PRIMOR ACTIV uCi (ABT)	LOG RADIOACTIVITY: TIME (LT)	LOG RADIOACTIVITY: NEUT. ACTIV LOG + 3 LOG(ANT)	LOG RADIOACTIVITY: PRIM.ACTIV LOG + 3 LOG(ABT)
1	0.061	8.5	0.000	1.733	3.969
4	0.160	34.0	0.628	2.170	4.597
16	0.210	135.9	1.256	2.293	5.225
64	0.060	543.6	1.884	1.726	5.853
128	0.005	1087.1	2.198	0.600	6.167

TABLE 11

RAINFALL INFILTRATION DILUTION OF RADIOACTIVITY, ERODED CONCRETE AFTER BURIAL

The radioisotopes released from the eroded concrete are diluted by the rainfall infiltrating the landfill site. The dilution by the direct flow of permeating water through the concrete rubble is estimated from the known average annual rainfall of 0.40 meters (13 inches) and an assumed infiltration factor of 50 percent. The concrete rubble is assumed to cover 1000 square meters. The dilution for the rainfall over the total area of the site is based on a site area of 5,520,000 square meters (1365 acres).

SL	= 1000 m^2	Area of rubble
RF	= 0.4 m	Annual rainfall (13 inches)
I	= 0.5	Infiltration factor
VL	= SL*RF*I = 200 m^3	Annual direct dilution volume of water
VLT	= VL*T	Total direct dilution at year T
ANT	:	Total neutron induced eroded R/A at T
ABT	:	Total primordial R/A at year T
ANLT	= ANT/VLT	Direct specific neutron induced activity
ABLT	= ABT/VLT	Direct specific primordial activity
VS	= SS*RF*I = 1,105,000 m^3	Annual site dilution water
VST	= VS*T	Total site dilution at year T
ANST	= ANT/VST	Site specific neutron induced activity
ABST	= ABT/VST	Site specific primordial activity
AGST	= 12300 pCi/m^3	Specific activity in ground water due to potassium-40, for 14 mg/l of elemental potassium (Bib 3.1.10). There may be other activities in groundwater, but not measured.

NOTE Data tabulated in Table 12.

TABLE 12

RAINFALL INFILTRATION DILUTION OF ERODED CONCRETE RADIOACTIVITY

TIME	TOTAL ACTIVITY		TOTAL WATER VOLUME		LOCAL SPECIFIC ACTIV.		SITE SPECIFIC ACTIVITY		
	NEUT.	PRIM.	LOCAL	SITE	NEUT.	PRIM.	NEUT.	PRIM.	GRD W.
yr	uCi		1000 m^3		pCi/m^3				
(T)	(ANT)	(ABT)	(VLT)	(VST)	(ANLT)	(ABLT)	(ANST)	(ABST)	(AGST)
1	0.061	8.5	0.2	1000	305	42000	0.06	8	12300
4	0.160	34	0.8	4000	200	42000	0.04	8	12300
16	0.210	136	3.2	16000	66	42000	0.01	8	12300
64	0.060	544	12.8	64000	5	42000	0.001	8	12300
256	0.005	1090	25.6	128000	0.2	42000	0.0000	8	12300

ANT : Data from Table 10
ABT : Data from Table 10
VLT : Data from Table 11
VST : Data from Table 11
ANLT = ANT/VLT
ABLT = ABT/VLT
ANST = ANT/VST
ABST = ABT/VST
AGST : Data from Table 11

NOTE The radioactivity, produced by neutrons, that is dissolved in the groundwater at the site is negligible compared to the other radioactivity in the water, and this neutron generated radioactivity will decay before the groundwater leaves the site.

FIGURE 1

NORTHROP REACTOR FACILITY

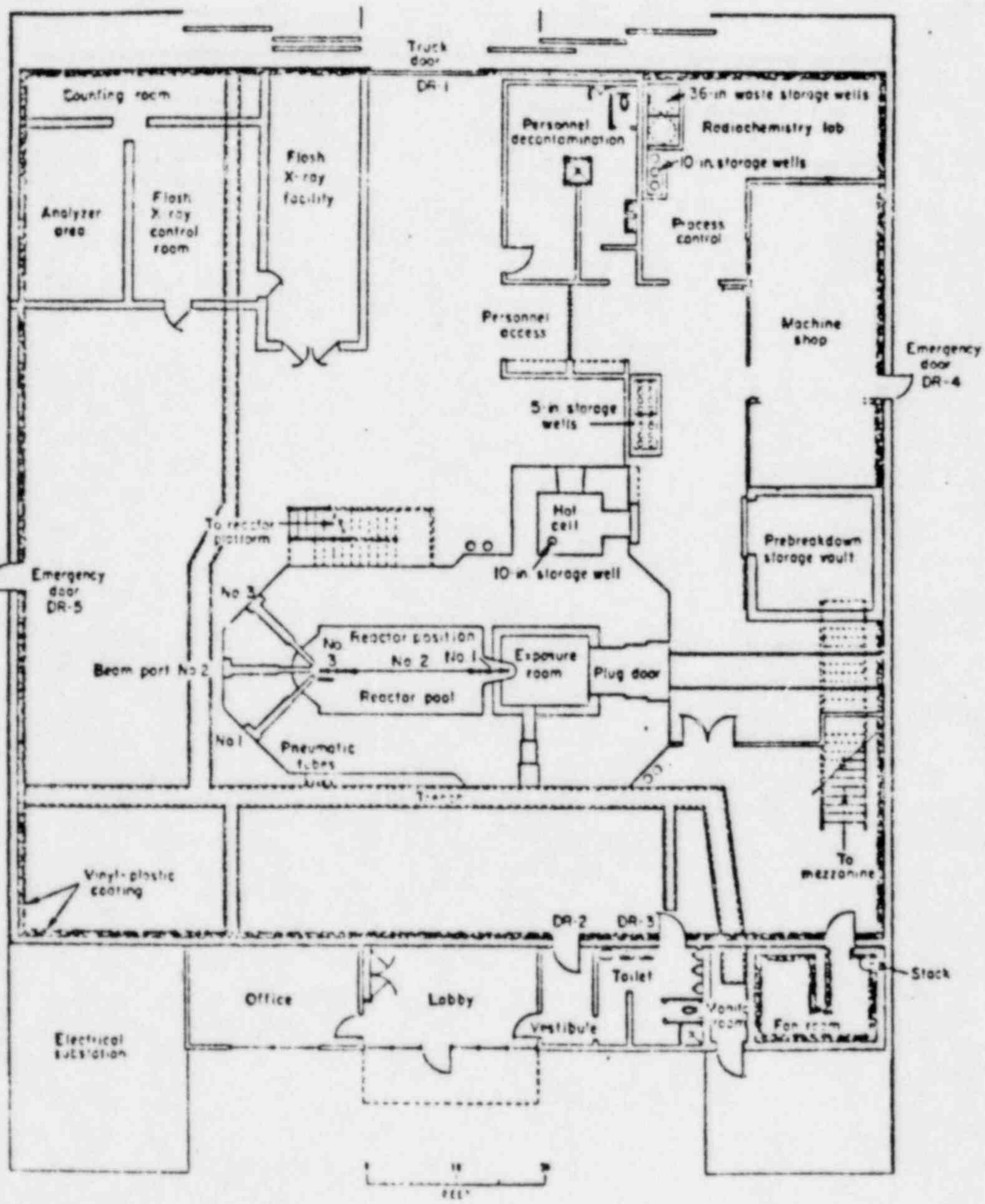
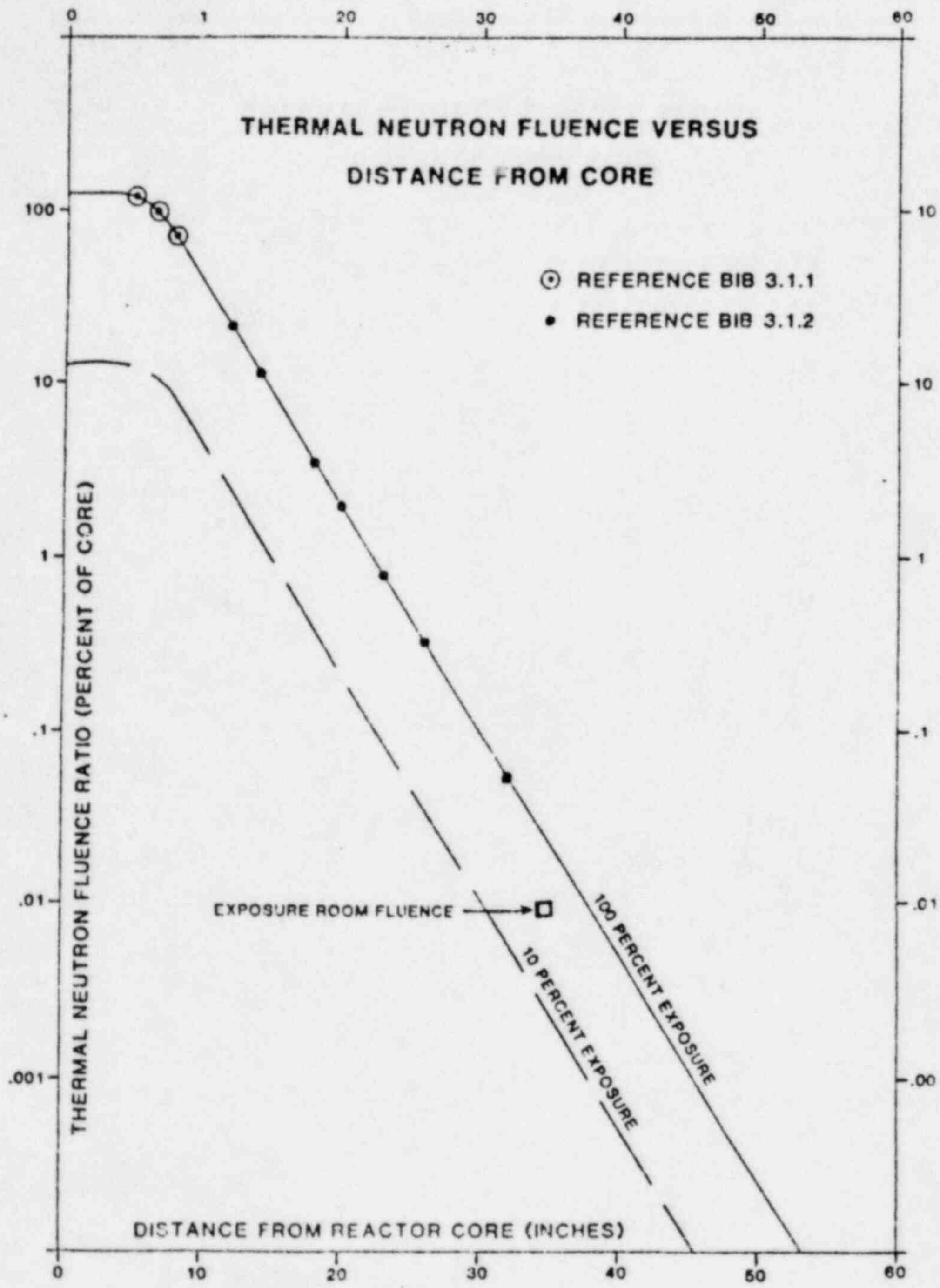
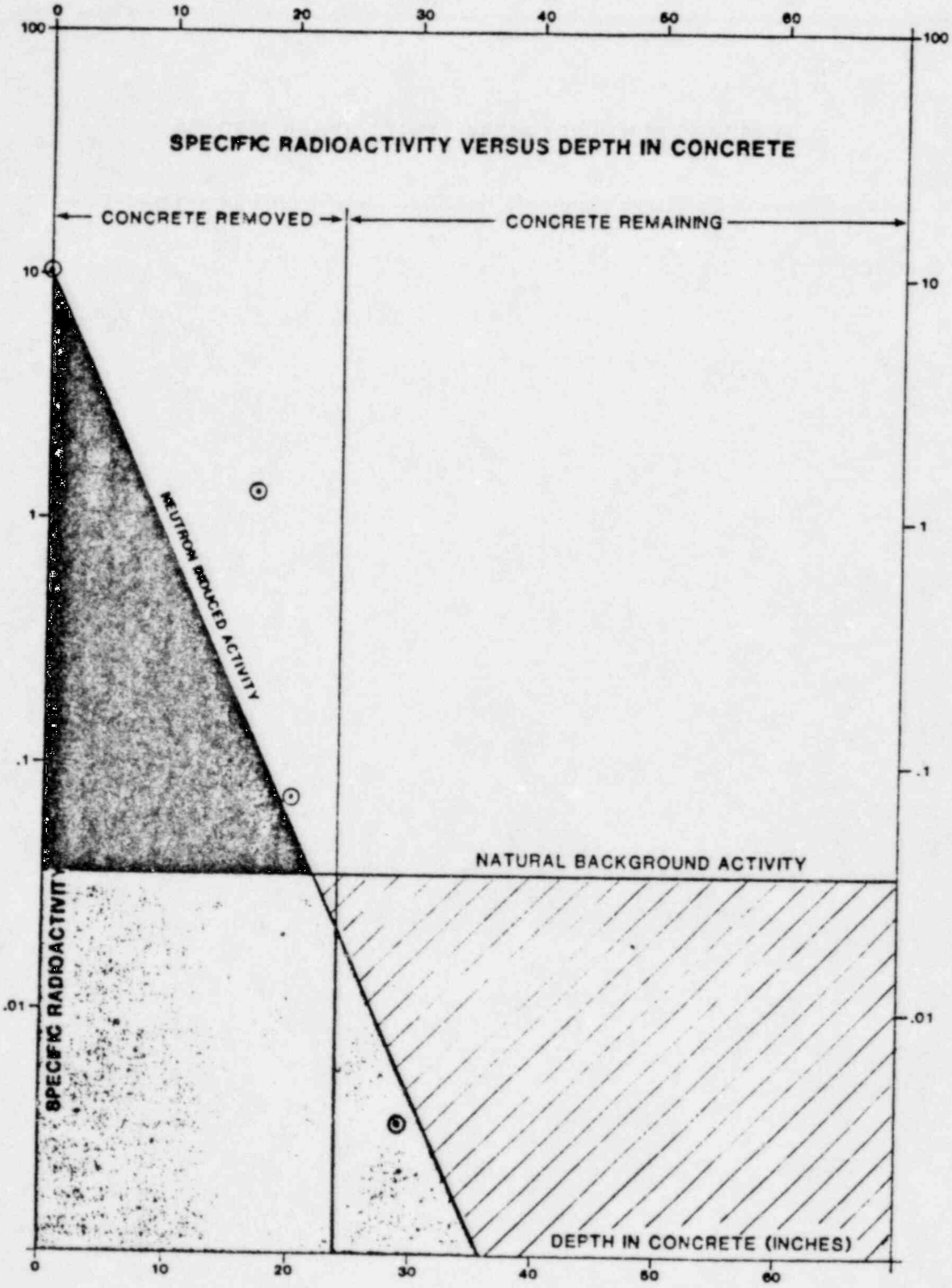


FIGURE 2



THERMAL NEUTRON FLUENCE VERSUS
DISTANCE FROM CORE
REFERENCE BIB 3.1.1
REFERENCE BIB 3.1.2
EXPOSURE ROOM FLUENCE
100 PERCENT EXPOSURE
10 PERCENT EXPOSURE
THERMAL NEUTRON FLUENCE RATIO (PERCENT OF CORE)
DISTANCE FROM REACTOR CORE (INCHES)
100
10
1
.1
.01
.001
0
10
20
30
40
50
60

FIGURE 3



SPECIFIC RADIOACTIVITY VERSUS DEPTH IN CONCRETE
CONCRETE REMOVED
CONCRETE REMAINING
NEUTRON INDUCED ACTIVITY
NATURAL BACKGROUND ACTIVITY
SPECIFIC RADIOACTIVITY
DEPTH IN CONCRETE (INCHES)
0
10
20
30
40
50
60
100
10
1
.1
.01

FIGURE 4

ERODED BURIED CONCRETE

The radioactivity created by neutron capture is always small compared to the natural primordial radioactivity eroded from the concrete, and also is small compared to the natural radioactivity already present in the soil.

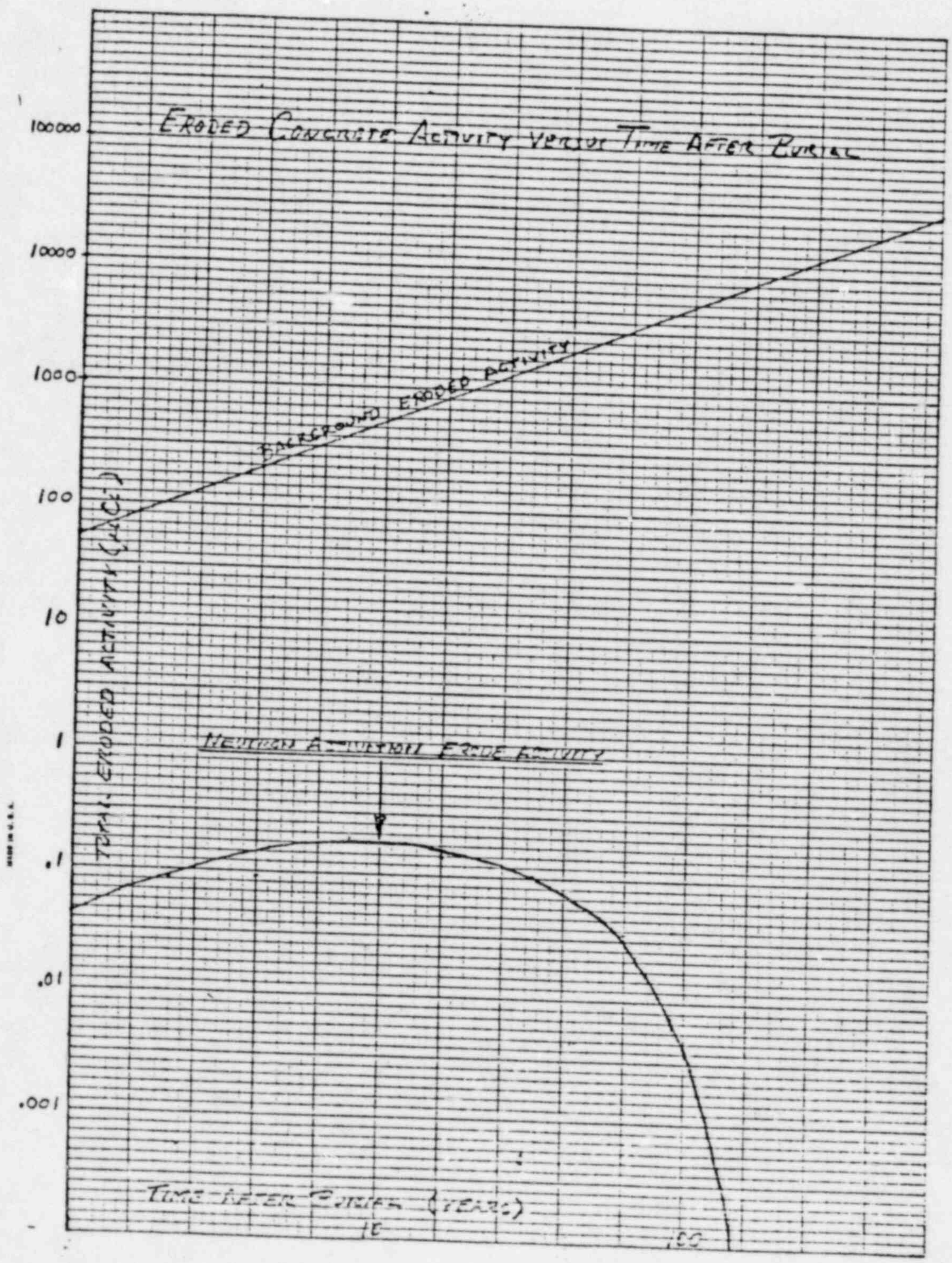
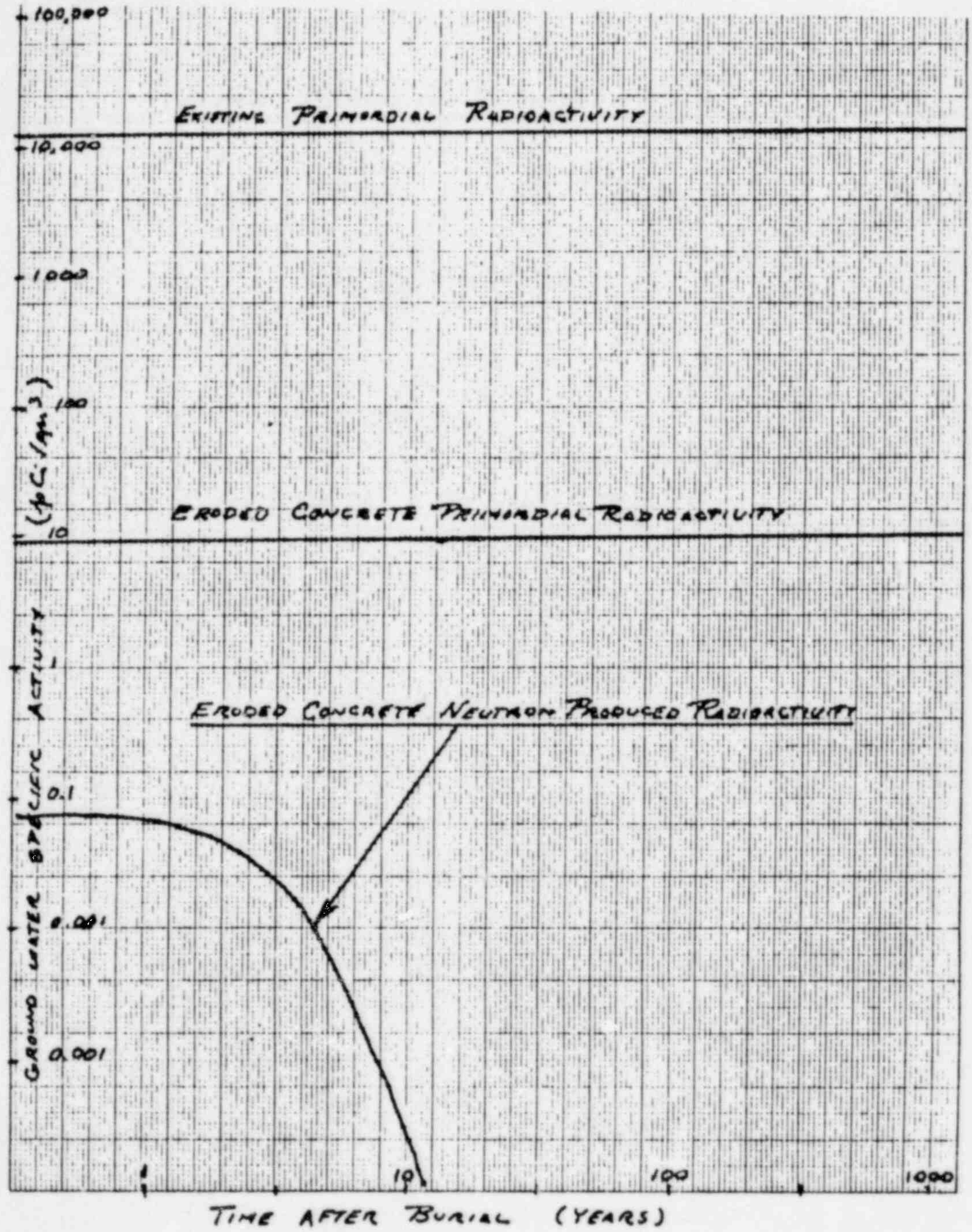


FIGURE 5

GROUNDWATER RADIOACTIVITY

The radioactivity created by the neutron capture, that is dissolved in the groundwater by the infiltrating rainwater, is extremely small compared to the natural primordial activity already existing in the groundwater. This neutron produced radioactivity will completely disappear before the groundwater diffuses from the burial location to any off-site location



ATTACHMENT B

Excerpt from a geologic and hydrogeologic report on the Puente Hills Landfill by LeRoy Crandall and Associates.

3. Local Environment

A. General Description

The Puente Hills Landfill site is surrounded by various land uses. To the north, between the existing landfill operation and the Pomona Freeway, is a partially complete industrial park and a small residential development. Beyond the industrial park, at a distance of 1000 feet from the site boundary and north of the Pomona Freeway, is a condominium development known as Whittier Woods. North and east of the Whittier Woods development and north of the San Jose Creek diversion channel, is the community of Avocado Heights which is located within 1500 feet to 1 1/2 miles from this site. To the southwest of the site is the Rio Hondo College and the Rose Hills Memorial Park. Immediately west of the site is industrial land use within the City of Industry. Residential development abuts the property on the east in the Hacienda Heights community. North of the Pomona Freeway, east of the existing landfill operation and north of the 151 acre parcel, is the Wildwood Mobile Home Park. Exhibit IV-1 shows the landfill site and existing nearby land use.

B. Topography

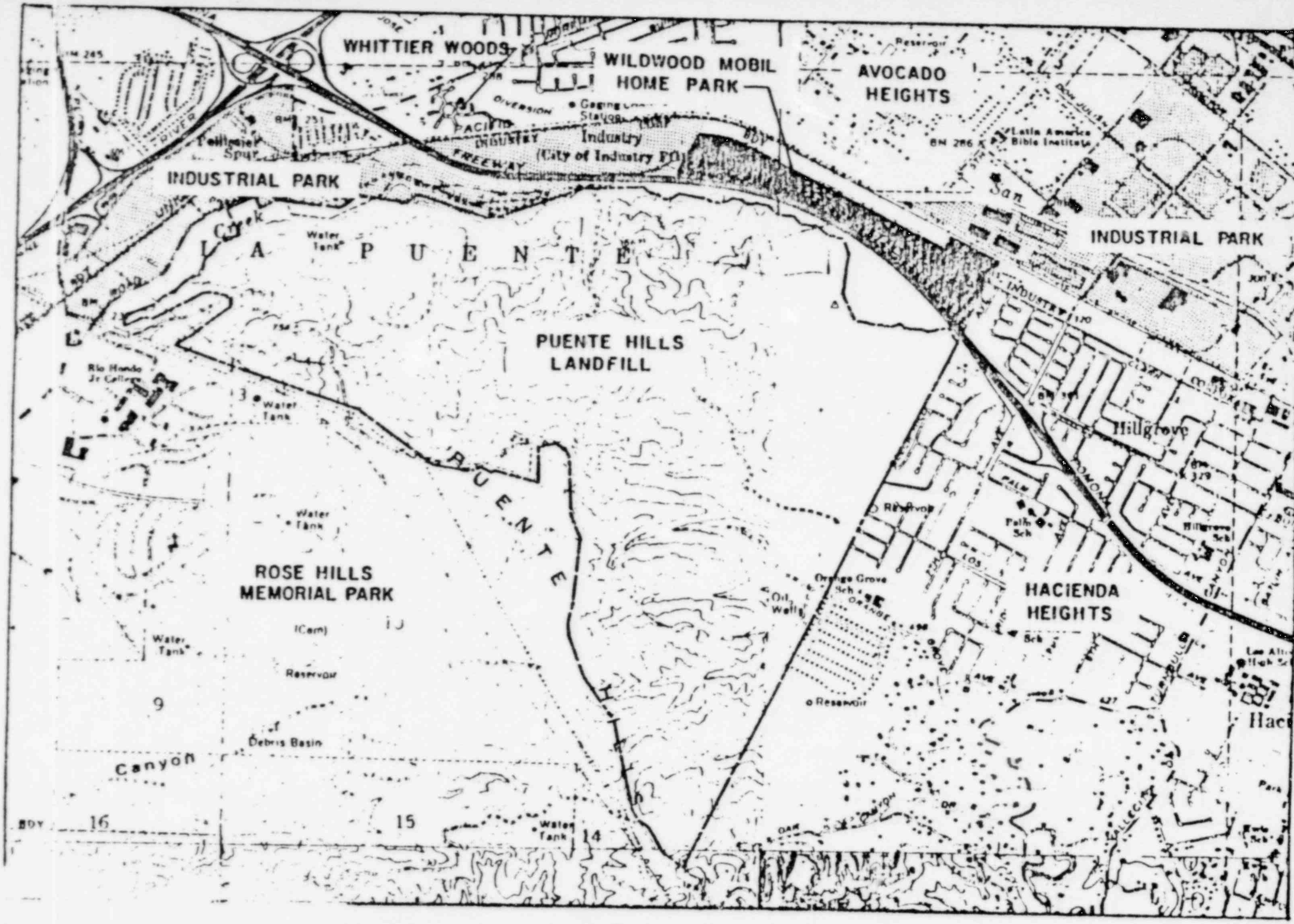
Environmental Setting. The Puente Hills Landfill site is located within a northwest trending arm of the western Puente Hills. The Puente Hills, in the project area, rise to modest elevations and overlook the San Gabriel Valley. Together with the San Jose Hills, the Puente Hills form a western extension of the Santa Ana Mountains.

The western Puente Hills, in the project area, are bounded on the north and east by the San Jose Creek floodplain, on the west by the Whittier Narrows flood control basin, dam, and recreation area, on the southwest by the San Gabriel River floodplain, and on the southeast by Turnbull Canyon.

Elevations on the property range from 226 feet above mean sea level at a stream channel near the Workman Mill Road entrance to nearly 1,245 feet at its southernmost point. The eastern side of the property contains six east-west trending, v-shaped canyons with intermittent stream channels. Vertical relief in these canyons is from 200 to 300 feet from canyon bottom to ridge top. South facing slopes have gradients from 30 to 45 degrees. Slopes facing north are noticeably less steep and have gradients from 20 to 30 degrees. In general, the four southernmost canyons are more rugged than the northernmost canyons, canyons 3 and 4. This is geologically significant in that the difference is due to the composition of the soil strata and their orientation. The northeastern side of the project area is characterized by three canyons, two of which terminate on the 151 acre parcel.

The westernmost portion of the project area is characterized by a wide plateau which has been created by the current landfill activities. The existing fill has been constructed on top of several small previous canyons and their ridges. Two prominent triangle shaped excavations with north facing 2 to 1 (horizontal length to vertical height) slopes are present where earthcutting has been necessary for the current landfill operations.

West of the present fill operations area are two southwesterly trending canyons. The northernmost canyon exits the property at a point northerly of the Rio Hondo College Police Training Facility and attains a maximum width of approximately 200 feet. The southernmost canyon (commonly referred to as Ecology Canyon) has developed a number of smaller tributaries and contains an unusual feature of steepened cliffs, some of which overhang. The lower portions of this canyon are richly vegetated and are a natural preserve for the Rio Hondo College under permit from the Districts. South of the site are the man-made slopes of Rose Hills Memorial Park and the wide stream channel of the Sycamore Canyon.



PUENTE HILLS LANDFILL AND LOCAL ENVIRONMENT

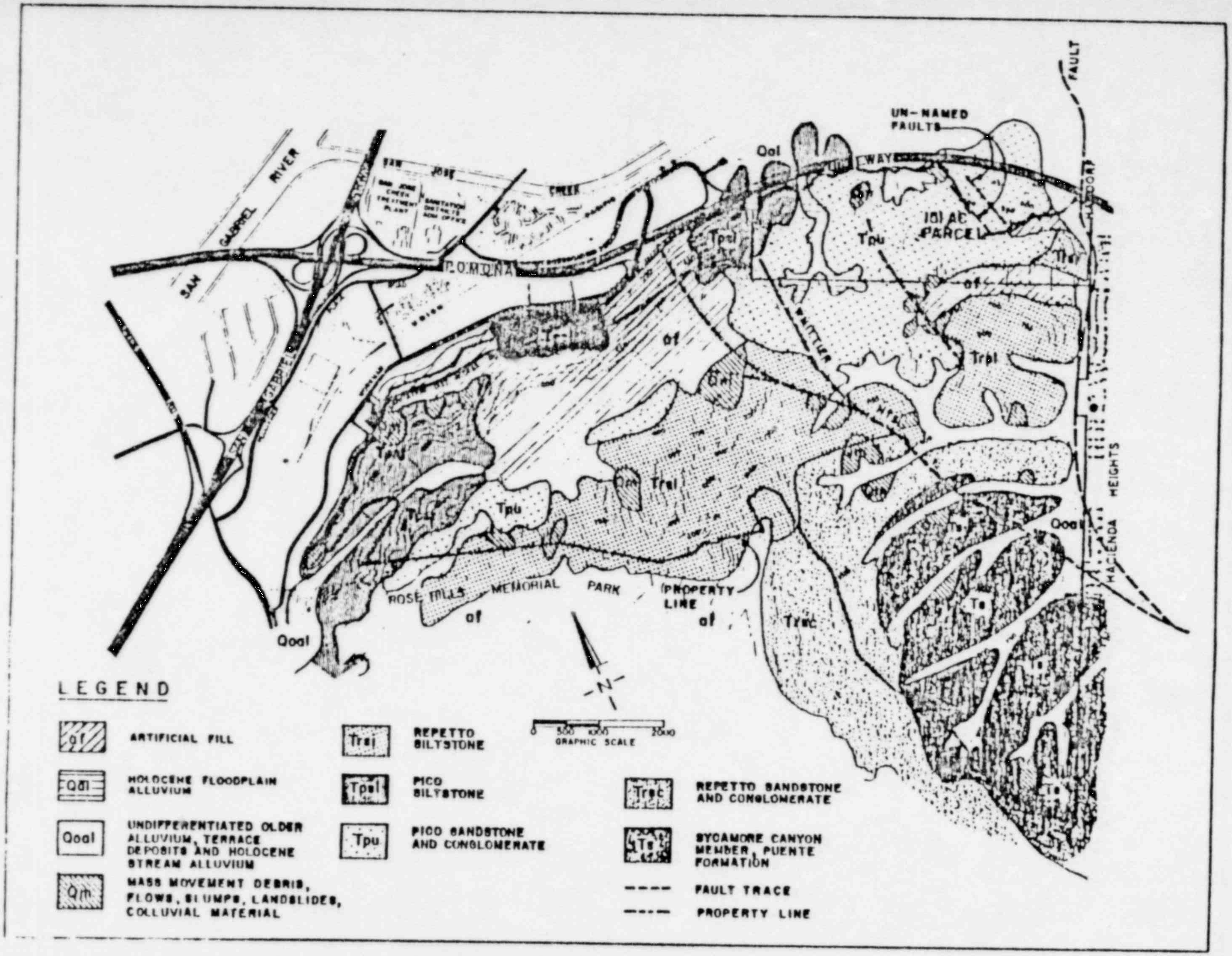
C. Geology and Soils

Environmental Setting. The following discussion on the geology and soils of the Puente Hills Landfill site is based upon a geologic and hydrogeologic investigation by LeRoy Crandall and Associates (1981). In the Puente Hills Landfill site, three bedrock formations made up of layers of different kinds of rocks are found. Four different types of surface soils are also found. The locations of the bedrock formations and surficial soils are shown in Exhibit IV-3.

Bedrock Formations. The three bedrock formations include the Puente, Repetto, and Pico Formations. The Puente Formation is mostly composed of sandstones and gravelly sandstone rocks and is found in the southern third of the property. The Repetto Formation is made up of mostly siltstone with some minor layers of sandstones and is found in the middle third of the property. The Pico Formation is composed of sandstones and siltstones and is found in the northern third of the property. The bedrock layers are exposed at the surface within the property and bend downward deep beneath the ground surface to the north, toward the San Gabriel Valley.

Surface Deposits. The four surficial deposits include older alluvial deposits, stream alluvium, mass movement debris (i.e. landslides, soil slumps, soil flows, etc.) and artificial fill. Alluvial materials are erosional soils that have been deposited from running water, rivers, or streams. The older alluvial deposits are made up of pebbles and gravel mixed with a filling of silty sand. The deposits are found on the eastern edge of the property at the mouths of the canyons. The stream alluvium is formed of pebbles and cobbles in a sand, silt, and clay filling. The stream alluvium is found in the bottom of canyons where storm waters have deposited erosional debris. Alluvial deposits in the bottoms of canyons are connected to alluvial deposits in the San Gabriel Valley. The San Gabriel Valley is an important aquifer system. For this reason, the construction of leachate barriers is necessary. The leachate barriers consist of impervious material constructed through the alluvial deposits and firmly keyed into bedrock. A leachate barrier system has already been designed and constructed for the existing landfill operation. Proposed leachate barriers in the eastern canyons are explained in Section 3-F of this Chapter. Artificial deposits are made up of different soil materials, bedrock fragments, and solid waste placed by man.

Faults. Several faults were found in the vicinity of the project and are discussed in greater detail in the report by Crandall and reports by the California Division of Mines and Geology and others.[2] Faults that are outside of the property boundaries are the Workman Hill Fault, Rowland Fault, and Whittier Fault. Faults that are found within the property boundaries include the Handorf Fault and the Whittier Heights Fault. The Handorf Fault, Rowland Fault and Workman Hill Fault are inactive.[3] An inactive fault is one which has had no recognized movement within the past 2-3 million years. The Whittier Fault is an active fault and is located 1.2 miles to the south. An active fault is one which has shown movement within the past 11,000 years.



GEOLOGY MAP OF PUENTE HILLS

An investigation of the Whittier Heights Fault determined this fault to be low potentially active.[4] A low potentially active fault is one which has shown movement from 1-3 million years ago. As indicated in Exhibit IV-3, the Whittier Heights Fault exits the property in the area of the existing leachate barrier where traces of the fault die out.

As a result of a request by the Citizens Advisory Committee, the Handorf Fault was reinvestigated by the consulting geologist. Additional research substantiated that the Handorf Fault is inactive.[5] Through recent communications with the Department of Water Resources and the Los Angeles County Flood Control District, it was found that the Handorf Fault did not affect groundwater levels in San Gabriel Valley alluvium as had been originally reported. The consultant's research concluded that the Handorf Fault is a subsurface feature identified by wildcat and exploratory wells and is buried by the alluvium of the San Gabriel Valley. The classification of faults by the consulting geologist is substantiated by the Fault Map of California by Jennings (1975).[6]

Seismicity. Seismicity can be defined as ".......the likelihood of an area being subject to natural earthquakes."[7] The consultant has reported a system of establishing the seismicity for the site based upon the estimated maximum probable earthquake magnitude from a 120 mile radius search of faults and a 62 mile radius search of earthquake epicenters. The maximum probable magnitude earthquake is the maximum that is "likely" to occur during a 100 year interval. It can only be regarded as a probable occurrence and not an assured event that will occur at a specific time. Crandall reports that for the Puente Hills Landfill site, the maximum probable magnitude earthquake over a 100 year recurrence would be 7.0 on the Richter Scale. Crandall found that the Puente Hills Landfill site could be subjected to earthquake vibrations as intense as any other location within the Los Angeles-Metropolitan area. It was found that the landfill site was not within a currently established Alquist-Priolo fault hazard zone. The Alquist-Priolo Special Studies Act of 1972 requires the State Geologist to delineate conservatively large special studies zones to emcompass all potentially and recently active traces of the San Andreas and other such faults that constitute a potential hazard to structures from surface faulting or fault creep.

A subject that was raised in the Citizens Advisory Committee meetings was the effect of large magnitude earthquakes on faults near the site. In response, the consultant has indicated that it is very unlikely that any of the faults on or near the site would be affected by movement along an active fault. In the case of the Whittier Fault, the nearest active fault, Crandall's research has shown that the majority of evidence for its activity is in the central and south-central portions of the fault, over 10 miles from the Puente Hills Landfill site. Also, the microseismic activity associated with the Whittier Fault is reported to be greater further to the south along the fault and appears to die out to the north near the Puente Hills area.

The Citizens Advisory Committee questioned whether or not refuse fill placement on or near the faults in the area would induce movement along those faults. In response, Crandall has indicated that the association of extremely heavy loads with microseismic activity is known to have occurred on very deep and large capacity water reservoirs which lie over active faults. It is clear

from that data that tremendously heavy loads, such as that from water reservoirs hundreds of feet deep, acting over many thousands of acres can produce microseismic activity deep below the surface on active faults underneath the reservoir. The consultant indicated that there is no evidence to indicate that any microseismic activity of the faults on or near the site will result from the placement of fill materials. During the extensive field investigations conducted in the area of the leachate barrier, no unusual surface or subsurface features were encountered in the immediate vicinity of the Whittier Heights Fault where it crosses the barrier alignment as a result of the existing placement of solid waste.

Another question raised during the Citizens Advisory Committee meetings was whether potential leachate from the proposed landfill could "lubricate" the low potentially active Whittier Heights Fault and cause it to move. Crandall has inspected the fault during field investigations and during construction inspection of the existing leachate barrier. Those inspections indicate that clay material is present in and along the fault. That clay material is sufficiently impermeable so as to preclude the movement of potential leachates along or across the fault. Crandall has indicated that there is no evidence that potential leachate could induce movement in the Whittier Heights Fault.

The Citizens Advisory Committee questioned whether landfill gas drilling could induce movement along the faults in the immediate area. Crandall indicates that there would be no significant effects of gas drilling on these faults, and that there is no evidence that inactive faults tend to move when forces such as drilling are applied to them. In this case, drilling would not even occur directly within the fault. Most gas well drilling would only occur within refuse fill and not in the underlying soil or bedrock formations.

Geologic Field Investigations. The field investigations included extensive field mapping, geophysical explorations, and a rock and soil bore hole sampling program. Geologic mapping investigated by the consultant covered a region over 100 square miles in size. The 1365 acre landfill site was subjected to five years of detailed study producing three maps and cluminating in three substantial volumes of data and findings. The geophysical exploration program involved 9570 linear feet of seismographic refraction investigations. The investigations searched over 200 feet beneath the surface over the site.

Landslides and soil movements were investigated. They were found to be located intermittently throughout the site (See Exhibit IV-3). Several seeps and intermittent springs were also found which result from rainfall infiltration into soil and alluvium on site. Cover soil excavations and placement of solid waste fill over these intermittent seeps and springs will largely remove them, since the rainfall will be diverted by the surface runoff drainage systems. The minor amount that is not intercepted could have the potential for contacting the waste material and produce leachate. A subdrain system will be made part of the leachate control systems which is discussed in Section F of this Chapter.

A total of 14 bedrock and soil sampling borings probed over 150 feet under the surface of the site. Laboratory tests taken on samples from rock and soil borings investigated many physical and chemical properties. Those physical and chemical properties tested included particle gradation, consolidation testing, rock shearing strength, moisture tests, expansion testing, compression testing,

permeability testing and excavation stability tests. The test data indicate that the bedrock siltstones are weathered and firm at the near surface but become hard at increasing depths. The bedrock sandstones contain some gravel and cobbles and are hard to very hard. Bedrock materials contain minor amounts of moisture and the siltstones can be expansive.

Permeability tests were performed on bedrock cores extracted in a natural state from the boring program. Permeability is the measure of how quickly water can move through bedrock and soil materials under the pressure exerted by standing water. The consultant selected core samples that best matched the bedrock and soil conditions at the landfill site. The results indicated that the siltstones could only allow fluid movement of about 2/100 to 7/100ths of a foot per year (1.9×10^{-8} to 6.8×10^{-8} cm/sec) or about 100,000 to 1,000,000 times slower than the alluvium in the canyon bottoms. The sandstones could only allow movement of about 75 feet per year or about 1000 times slower than the alluvium in the canyon bottoms.

As part of the drilling program a total of six monitoring wells were installed. Three of the wells were constructed in the canyon mouths through the alluvial deposits on the eastern boundaries of the site (See Exhibit IV-5). Three additional wells were established on the northern limit of the project area. One well was subsequently destroyed by the Crossroads Industrial Park development. The purpose of the monitoring wells was to provide sampling points at the subsurface drainage locations. These monitoring wells would detect the formation of any potential leachate. Groundwater samples are taken from these wells routinely, and water quality is analyzed. Groundwater results and the construction of leachate barriers are more fully discussed in Section 3-F of this Chapter.

The extensive findings of the geologic field investigations indicate that it is feasible to develop the 1365 acre site as a Class II landfill with limited non-hazardous liquid disposal. This finding is substantiated by the geologic field mapping and testing of the bedrock and soils that make up the site. Because of the way the bedrock and soil materials are shaped and fitted together above the San Gabriel Valley, the threat of groundwater pollution is limited to the alluvial materials in the canyon bottoms. The alluvial materials will be severed by leachate barriers as explained in Section 3-F of this Chapter. In support of this conclusion, Crandall found that the relatively impermeable siltstone of the Repetto Formation would separate potential leachate from usable groundwater in the San Gabriel Valley to the north.

As an additional portion of his work pertaining to the practicality of on-site excavations, Crandall found that bedrock and soil materials could be excavated utilizing ordinary heavy equipment as is currently available in the existing operation.

Abandoned Oil Wells. In the southeastern portion of the landfill property is a small inactive oil field identified as the North Whittier Heights Oil Field. Eleven wildcat or exploratory wells were drilled between 1915 and 1951. None of the wells produced oil or gas in commercial quantities. All wells in the project area were abandoned according to regulations that existed during the time of abandonment. Revisions in 1975 of the California Administrative Code will require re-abandonment of two of the eleven wells in accordance with new requirements. The Sanitation Districts will follow applicable requirements for abandonment of oil wells on the property.

F. Groundwater and Leachate Control

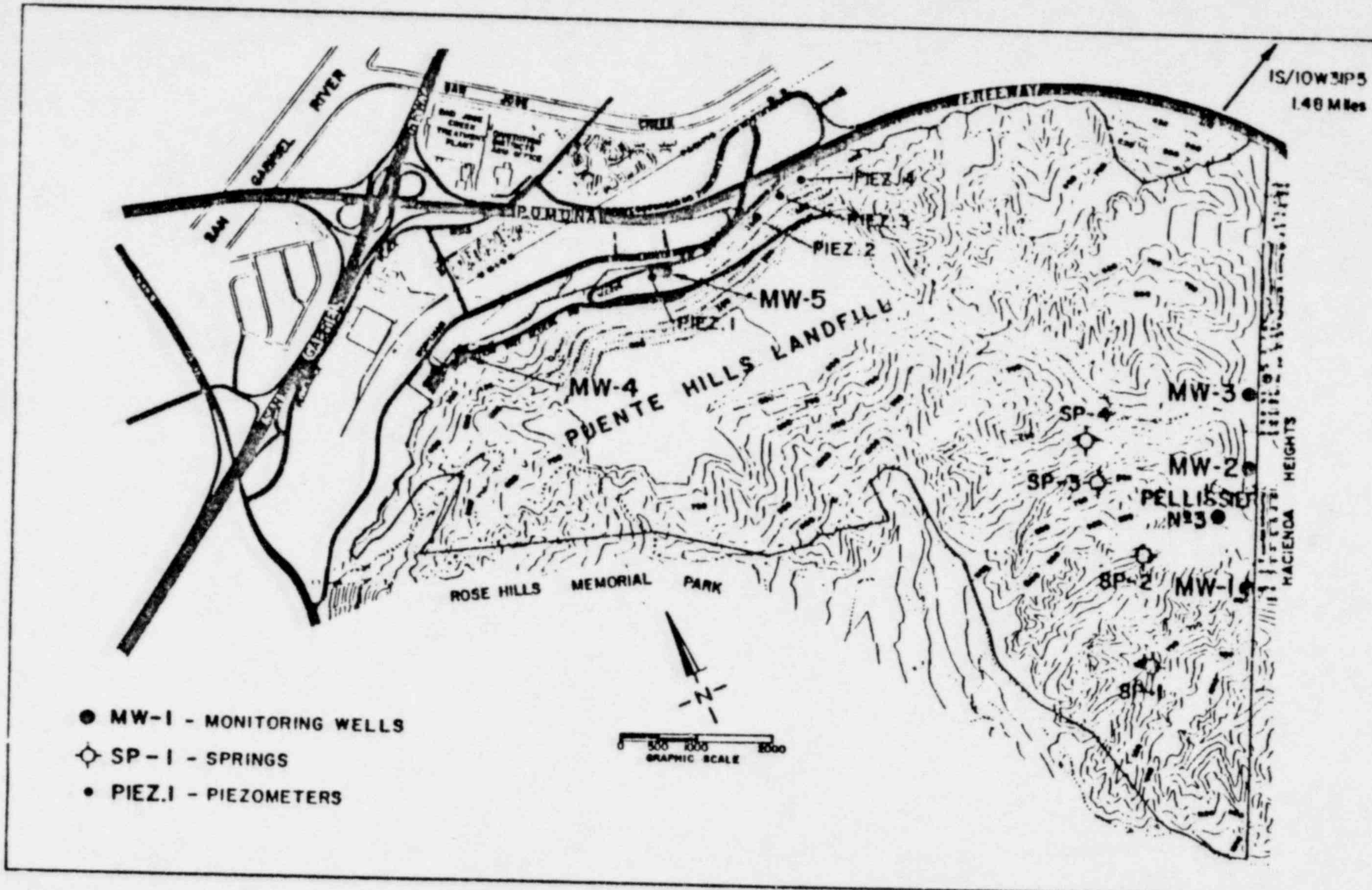
Environmental Setting. The landfill property is underlain by sedimentary rock of marine origin. This formation has relatively low permeability and does not contain groundwater. No water was detected during geologic investigations conducted from 1975 to 1978 in eight wells drilled up to 150 feet deep into the bedrock. Water was found in abandoned oil wells drilled several hundred feet into underlying bedrock formations. This water comes from great depths and does not constitute a part of any usable groundwater system.

Weathering processes have eroded the near surface and exposed rock on the property and deposited coarse alluvium onto the canyon bottoms. Precipitation seasonally recharges the alluvium with limited amounts of water. This water has formed a few small springs in the eastern canyons where the alluvium is very shallow. The water ultimately flows through the alluvium toward the San Gabriel Valley groundwater basin. This basin is a major aquifer and is situated to the east, north, and west of the landfill property.

The water from the oil wells contains relatively high amounts of sodium and bicarbonate. It has a poor quality characterized by a high level of dissolved solids. Water quality information from an oil well ("Pellissier No. 3") is listed in Table IV-3. This information is representative of the other oil wells abandoned on the Puente Hills site.

The water contained in the alluvium overlying the canyon bottoms has been monitored since 1975 using five wells installed during the geologic investigation. The locations of the monitoring wells are shown on Exhibit IV-5. The eastern wells are monitored quarterly and monitoring well 4 on the west is monitored monthly. Monitoring well 5 was destroyed in 1981 due to nearby construction activities. Four localized springs in the eastern canyons have also been monitored. Water quality information for the springs and monitoring wells is presented in Table IV-3. The water in the alluvium is uniformly poor in quality. This is due to the natural occurrence of mineral salts (e.g., sodium chloride, calcium sulfate and calcium carbonate) and organics in the marine formation. The salts contribute to the water's dissolved solids. The organics are residues from marine vegetation and are measured principally by the parameter "COD" (Chemical oxygen demand). These organics may also contribute to a small degree to the parameter "BOD" (Biochemical oxygen demand). The BOD measures the portion of the organics which is bio-degradable.

The water quality in the San Gabriel Valley Groundwater basin is diverse. The diversity results from the differing character of sediments within the basin, the range in sources for water recharge, and types of local land uses (e.g. industrial, agricultural, and residential). The water quality in a well situated in the basin upgradient and northeast of the property is illustrated in Table IV-3 (Well No. 1S/10W 31P5). This well is representative of others upgradient of the site. However, major parameters of water quality such as dissolved solids may vary by a factor of two at nearby wells. The water in the San Gabriel Valley Basin is characteristically "hard" but much superior to that found in the Puente Hills canyon alluvium. This is because sediments within the basin are by comparison extensively weathered and do not readily release salts



LOCATION OF WATER QUALITY MONITORING WELLS PIEZOMETERS AND SPRINGS

PUENTE HILLS GROUNDWATER SUMMARY

FIGURE IV-3

	EASTERN[1] CANYON WELLS	WESTERN AREA WELLS	PIEZOMETERS[3]	OIL WELL (PELLISSIER No. 3)	SPRINGS[4]	SAN GABRIEL VALLEY WELL (1S/10W-31P5)
pH	7.2	7.2	6.5	8.2	7.7	8.0
Calcium, mg/l	197	331	393	5.7	210	56
Magnesium, mg/l	137	148	161	7	143	14
Sodium, mg/l	237	210	230	724	116	58
Potassium, mg/l	8.5	13	20	4.4	6.9	2.4
Bicarbonate, mg/l	392	526	485	1,197	412	237
Sulfate, mg/l	857	933	719	73	868	86
Chloride, mg/l	103	257	348	403	82	25
Disssolved Solids, mg/l	1,986	2,541	2,530	2,306	1,619	376
Soluble COD,	15	91	103	N.R.[5]	N.R.	N.R.
Total BOD, mg/l	<1.4	<3.9	13	N.R.	N.R.	N.R.

1 Average of Monitoring Wells 1, 2, & 3
2 Average of Monitoring Wells 4 & 5
3 Average of Four Piezometers
4 Average of Four Springs (SP-1 through SP-4)
5 N.R. = Not Reported

All groundwater monitoring locations are shown on Exhibit IV-5.

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