Attachment A

Waste Front Radius and Pressure Front Calculations

A. Waste Front Radius Calculation

The maximum daily wastewater flow is 765,000 gallons.

The calculation assumes the injection of an equal volume split between two wells.

The closest spaced injection wells, IW 1 and IW3, were selected for the calculations (Figure B2, Appendix B).

The injection zone includes early Eocene sand sequences, located at the estimated depth interval of 4,700 to 5,600 feet bgs.

Per injection well	Q (gallons per day): 765,000/2=382,500
	Net H (ft): 500
	Porosity: 25.0%

Calculations based on Warner & Lehr (1977), *eqns 3-10, 3-1 1*

$r=\{V/(pi*h*phi)^{*0.5}$

$r^2=r+2.3*(D*r)*^{0.5}$

Where: r = radial distance of wastewater front from well

r^2 = radial distance of wastewater front from well with dispersion

V =cumulative wastewater injection in cubic feet

pi = 3.1416

h = net reservoir thickness

phi = average effective porosity

D =dispersion coefficient; 3 for sandstone

The data in Table A1 was used to the construct of contour map of waste front radii (Figure A2, Attachment A).

Note: The range of porosity for sandstones in the San Joaquin basin, is reportedly 20% to 35%. A porosity of 25% has been assumed for the injection zone sandstone sequences located between 4,750 and 5,590 feet bgs at the PEC site.

B. Pressure Front Calculation

Injection Zone: Early Eocene Sand

Injection Wells IW 1 and IW 3

Calculations based on Warner & Lehr (1977): eqn 3.9a

Delta P = {(162.6*Q*Uw)l(k*h)}{log(k*t)/(phi*Uw*Ct*r^2)-3.23}

Where: Delta P = psi reservoir pressure change at radius r (R) and time t (years).
Q = injection rate, (BPD)
Uw = injectate viscosity, centipoise
k = reservoir permeability
h = net thickness, R
t = injection time, years
phi = reselvoir porosity. %.
Ct = reservoir compressibility, psi $^{-1}$
r = radius of interest, ft.

Apply
Q (BPD): 9,107 per well
Porosity: 25.0%
Uw (w): I
k (md): 500
h (ft.): 500
t (years): 30
Ct: 5.90E-06

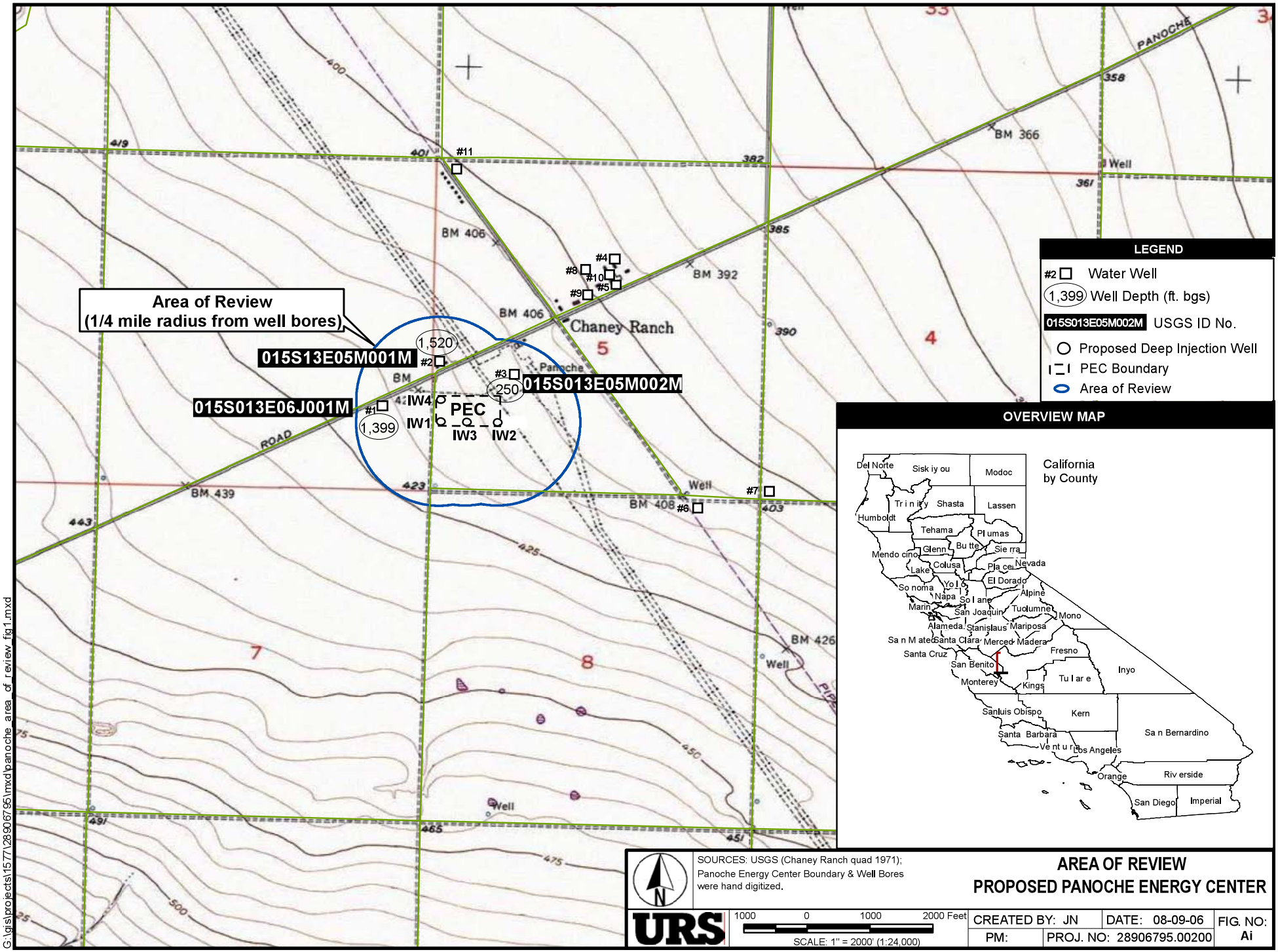
Table A2 Pressure Front Data

Radius* (feet)	Delta P, psi One well	Delta P, psi ** Two wells
4,000	20.84	44.0
3,500	21.52	45.3
3,000	22.32	47.0
2,500	23.26	49.0
2,000	24.40	51.5
1,500	25.89	54.6
1,000	27.97	55.5
750	29.46	58.0
500	31.54	62.0
250	35.11	67.4
100	39.83	75.0
1	63.53	90.0

*Radius centered between injection wells IW 1 and IW 3.
**Pressure measured at a point perpendicular to a line joining wells IW 1 and IW 3.

TABLE A1. Waste Front Radius Data

Time (years)	Injection Volume (cu ft.)	Cumulative Volume (cu ft.)	Waste Radius (ft) with no dispersion	Waste Radius (ft) with dispersion	Wastefront Rate with Dispersion (ft/yr)
1	37347543	37347543	308	378	378
2	37347543	74695086	436	519	260
3	37347543	112042629	534	626	209
4	37347543	149390172	617	716	179
5	37347543	186737715	690	794	159
6	37347543	224085258	755	865	144
7	37347543	261432801	816	930	133
8	37347543	298780344	872	990	124
9	37347543	336127887	925	1046	116
10	37347543	373475430	975	1100	110
11	37347543	410822973	1023	1150	105
12	37347543	448170516	1068	1199	100
13	37347543	485518059	1112	1245	96
14	37347543	522865602	1154	1289	92
15	37347543	560213145	1194	1332	89
16	37347543	597560688	1234	1373	86
17	37347543	634908231	1272	1414	83
18	37347543	672255774	1308	1452	81
19	37347543	709603317	1344	1490	78
20	37347543	746950860	1379	1527	76
21	37347543	784298403	1413	1563	74
22	37347543	821645946	1446	1598	73
23	37347543	858993489	1479	1632	71
24	37347543	896341032	1511	1666	69
25	37347543	933688575	1542	1698	68
26	37347543	971036118	1572	1730	67
27	37347543	1008383661	1602	1762	65
28	37347543	1045731204	1632	1793	64
29	37347543	1083078747	1661	1823	63
30	37347543	1120426290	1689	1853	62


Area of Review
(1/4 mile radius from well bores)
015S13E05M001M
1,520
#2
015S013E05M002M
#3
250
015S013E06J001M
#1
1,399
IW4
IW1
PEC
IW3
IW2
#11
#4
#8
#10
#5
#9
#7
#6
BM 406
BM 392
BM 366
BM 439
BM 408
BM 426
Chaney Ranch
Panoche
PANOCHE
ROAD
Well
LEGEND
#2 Water Well
1,399 Well Depth (ft. bgs)
015S013E05M002M USGS ID No.
Proposed Deep Injection Well
PEC Boundary
Area of Review
OVERVIEW MAP
California
by County
Del Norte
Sisk iy ou
Modoc
Tri n ity
Shasta
Lassen
Humboldt
Tehama
Pl umas
Glenn
Bu tte
Sie rra
Mendo cino
Colusa
Pla ce
Nevada
Lake
El Dorado
So noma
Yo l
Napa
So l ane
Alpine
Marin
San Joaquin
Tuolumne
Mono
Alameda
Stanislaus
Mariposa
Sa n M ateo
Santa Clara
Merced
Madera
Santa Cruz
Fresno
San Benito
Monterey
Kings
Tu l ar e
Inyo
Sanluis Obispo
Kern
Santa Barbara
Sa n Bernardino
Ve nt u ra
Los Angeles
Orange
Riv erside
San Diego
Imperial
N
SOURCES: USGS (Chaney Ranch quad 1971);
Panoche Energy Center Boundary & Well Bores
were hand digitized.
URS
1000 0 1000 2000 Feet
SCALE: 1" = 2000' (1:24,000)
AREA OF REVIEW
PROPOSED PANOCHE ENERGY CENTER
CREATED BY: JN
DATE: 08-09-06
FIG. NO:
Ai
PM:
PROJ. NO: 28906795.00200
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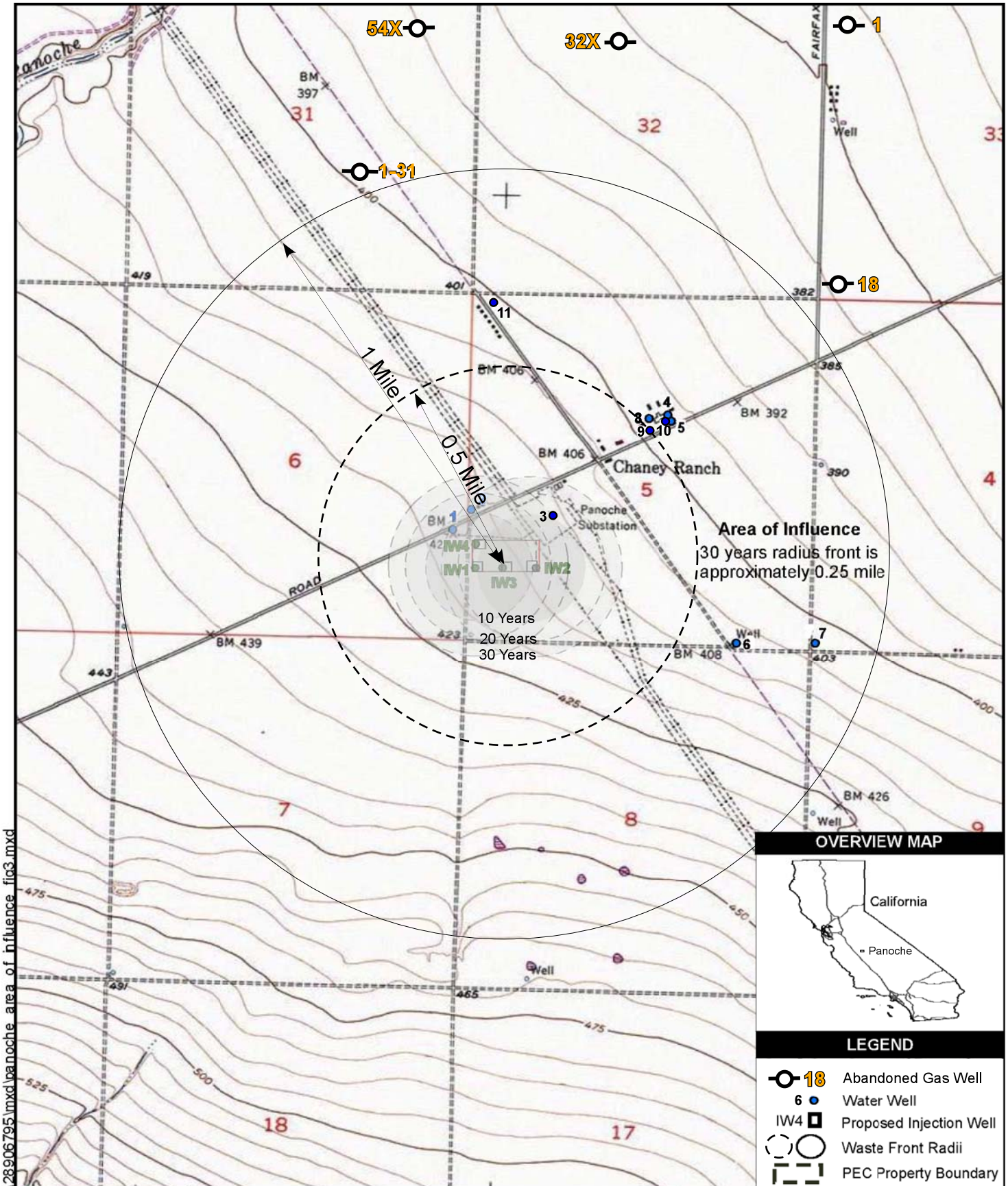

SOURCES: USGS (Chaney Ranch Quad 1971);
Well locations were hand digitized.

WASTE FRONT MAP
PROPOSED PANOCHE ENERGY CENTER

URS

1000 0 1000 2000 Feet
SCALE: 1" = 2000' (1:24,000)

CREATED BY: DH	DATE: 08-16-06	FIG. NO:
PM:	PROJ. NO: 28906795.00200	A2

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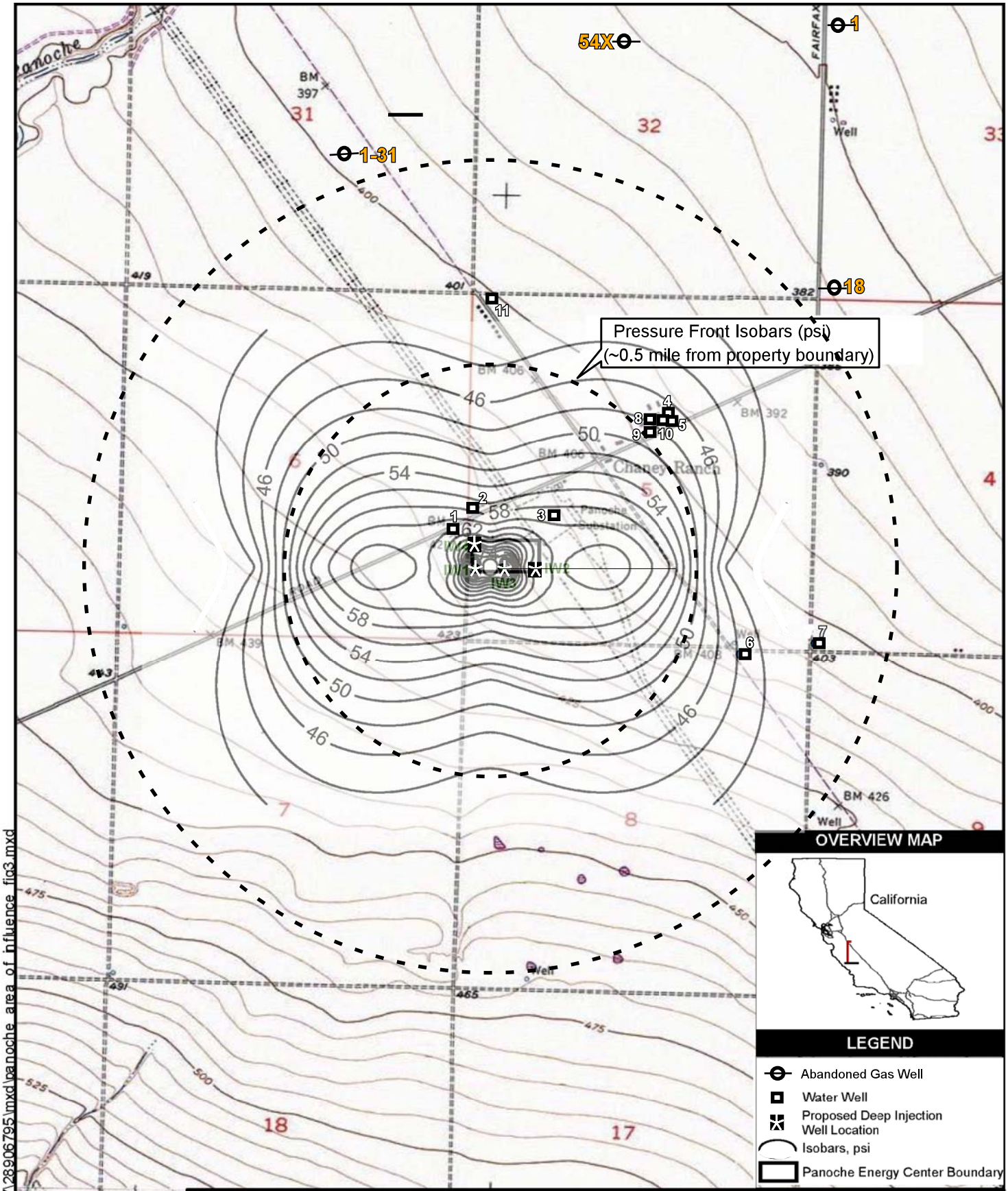

SOURCES: USGS (Chaney Ranch quad 1971); Well locations were hand digitized.

N

URS

1000 0 1000 2000 Feet

SCALE: 1" = 2000' (1:24,000)

PRESSURE FRONT MAP
PROPOSED PANOCHE ENERGY CENTER

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