Title: *GEOCHEMICAL CHARACTERIZATION OF GEOLOGICALLY COMPLEX MOUNTAIN FRONT AQUIFERS: Placitas, New Mexico*

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Key Topics: Placitas, Las Huertas Creek, Albuquerque Basin, Mountain zone, Mesozoic ramp, geochemistry, hydrogeology, fault-controlled ground-water flow, recharge, potentiometric surface, aquifers, ground-water flow barriers

Summary:

- "Infiltration of surface water from Las Huertas Creek was identified as the single most important source of recharge and Las Huertas Canyon and the north slope of the Sandia Mountains were identified as locations where direst infiltration of precipitation to the Madera Formation is also a significant source of recharge" (p. 71).
- Faults: Rincon, San Francisco, Placitas
    - North of the junction of the northeast trending Placitas fault with the northeast trending Rincon fault are numerous bedding-plane faults with recemented fault breccias (up to 5m thick) (p. 11).
    - "Faults can act as either barriers or conduits to ground-water depending on fault displacement, lithology, three dimensional fault geometry, subsidiary structures, and fluid-rock interactions (Caine et al., 1996)" (p. 12).
    - "Throughout the study area, contrasting lithologies are juxtaposed by rotated fault blocks and individual permeable layers are split into discontinuous and widely separated aquifers" (p. 14).
        - Figure 5. Generalized geology of the study area (Connell et al., 1995) (p. 88)
- Hydrogeology: surface and subsurface systems
    - The <u>Mountain zone</u> (high transmissivity, low storativity, and localized fault-controlled ground-water flow), the <u>Mesozoic ramp</u> (highly variable ground-water quality, supply, and characteristics caused by heterogeneous lithology, hydraulically isolated aquifers, small aquifers, and faults that act as barriers and preferential pathways), and the

Albuquerque Basin (relatively homogeneous aquifer of Tertiary and Quaternary basin fill sediments). (p. 14)

    - Figure 7. Hydrogeologic zones of the Placitas study area. (p.90)

  - 3 major drainage basins: Las Huertas Creek, Arroyo Agua Sarca, and Arroyo San Francisco). "In Placitas, the springs and streams contribute to the complexity of the ground-water system by discharging ground water from one aquifer and redistributing it across faults and relatively impermeable formations to recharges otherwise isolated aquifers" (17).

    - Figure 8. Surface water drainages and springs (p.91)

  - A generalized potentiometric surface was developed by NMBMMR by Johnson (1999) figure 9, using 59 domestic wells, 27 springs and artesian wells, 61 well records (OSE), and 20 water level records (USGS database). (17)

    - Figure 9. Potentiometric Surface (p. 92)

- Results:

  - Precipitation Data

  - Ground and Surface Water Data

    - Temperature, Dissolved Oxygen, Total Dissolved Solids, Major Ions, Trace Elements, Ground-water Dating, and Stable Isotopes

- Discussion: Subzones (8 total): ground water flow paths, discontinuities, etc based on geochemistry

    - Figure 42. Aquifer Sub Zones (p. 125)

  - Mountain zone:

    - Las Huertas Canyon: Madera Formation ground-water flow "is characterized by localized and discrete flow paths, along high-permeability faults and fractures" (p. 44) which "permit both direct infiltration of precipitation and infiltration of surface water to contribute recharge to discrete parts of the aquifer" (p. 45).

    - Figure 43. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from Cuchilla Lupe and upper Las Huertas Canyon (p. 126)

    - Cuchilla de San Francisco: south to north flow pathways and east to west ground-water flow barriers (p. 48). "The Madera Formation is the major water transmitting geologic unit in this sub-zone" (p. 48). The San Francisco fault moves water in the Madera Formation parallel to the fault and this is facilitated by increased transmissivity from south to north.

- Figure 46. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from Cuchilla de San Francisco (p. 129)

o Mesozoic Ramp:

  - Northeast basin: “compartmentalization of aquifers, separation of ground-water flow paths,… ground-water flow across the San Francisco fault is limited to discrete locations: the highly fractured junction of the San Francisco fault and the Placitas fault zone, and the termination of the Madera Formation north of Cuchilla de San Francisco.” (p. 51)

    - Figure 49. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the northeastern part of the basin (p. 132)

  - Central Mesozoic ramp: “a complex set of discontinuous sandstone, siltstone, and limestone aquifers that are both isolated and connected by a complex fault network, and isolated by interbedded shale aquitards” (54). Recharged ground water from the Madera Formation in the Sandia Mountains follows high permeability sedimentary units and faults and then mixes with older ground water.

    - Figure 52. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the central part of the Mesozoic ramp (p. 135)

  - Eastern Mesozoic ramp: Exploited aquifers in this sub-zone are the Jurassic Morrison and Cretaceous Dakota, Hosta-Dalton, and Point Lookout Formations (p.54). “Relatively continuous Jurassic and more compartmentalized Cretaceous sandstone aquifers” (p. 57). Interbedded shale and mudstone aquitards isolate aquifers in the Cretaceous sandstone from recharge. Reinfiltration of the Placitas springs and interaquifer flows from the Madera Formation recharge the well-connected aquifers (p. 57).

    - Figure 55. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the eastern part of the Mesozoic ramp (p. 138)

  - Western Mesozoic ramp: Exploited aquifers in this sub-zone are the Jurassic Morrison and Cretaceous Dakota, Hosta-Dalton, Point Lookout Formations, and some portions of the Lower Menefee Formation and Lower Mancos Shale (p.

59). "…Arroyo Agua Sarca is a significant source of recharge but it is infrequent" (p. 60). "Contrasting ridges and troughs in the potentiometric surface (Figure 9) suggest that impediments to ground-water flow and 'permeability windows' exist along the Placitas fault zone and Caballo fault" (p. 60). Ground water "exists in a system of northeast dipping and relatively continuous aquifers that are isolated by interbedded shale and mudstone aquitards" (p. 61). Recharge occurs only near Arroyo Agua Sarca and there is limited interaquifer flow (p. 61).

    - Figure 61. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the western part of the Mesozoic ramp (p. 144)

- Basin Zone:

    - North-central basin: Water bearing units are the Lower and Upper Santa Fe Formation basin-fill sediments (p. 57). The Santa Fe Group aquifer is recharged primarily from infiltration of surface water from Las Huertas Creek and Arroyo de Ojo del Orno, however infiltration seems to be limited to a short reach down stream of the "basin-bounding faults" (p. 59).

        - Figure 58. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the north-central part of the basin (p. 141)

    - West basin: Water bearing unit is the Upper Santa Fe Formation (p. 61). "…recharge at the higher elevation basin margin and discharge in the low elevation parts of the basin…" (p. 63). Recharge is from infiltration of Las Huertas Creek and minor recharge from Arroyo Agua Sarca (p.63).

        - Figure 64. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the western part of the basin (p. 147)

- Summary of regional hydrogeology: Las Huertas Creek redistributes water from the Sandia Mountains (precipitation) to the Santa Fe Group aquifers in the Albuquerque Basin through infiltration (p. 64). "Consistent recharge to the basin-fill aquifers appears to be limited to a short reach immediately down stream of the basin-bounding faults" within the north-central basin sub-zone

    - **Figure 67. Regional hydrogeology of the Placitas study area (p. 150).**

Useful Figures:

References:

Caine, J.S., J.P. Evans, and C.B. Forster (1996) Fault zone architecture and permeability structure. *Geology.* **24**, no. 11, p. 1025-1028.

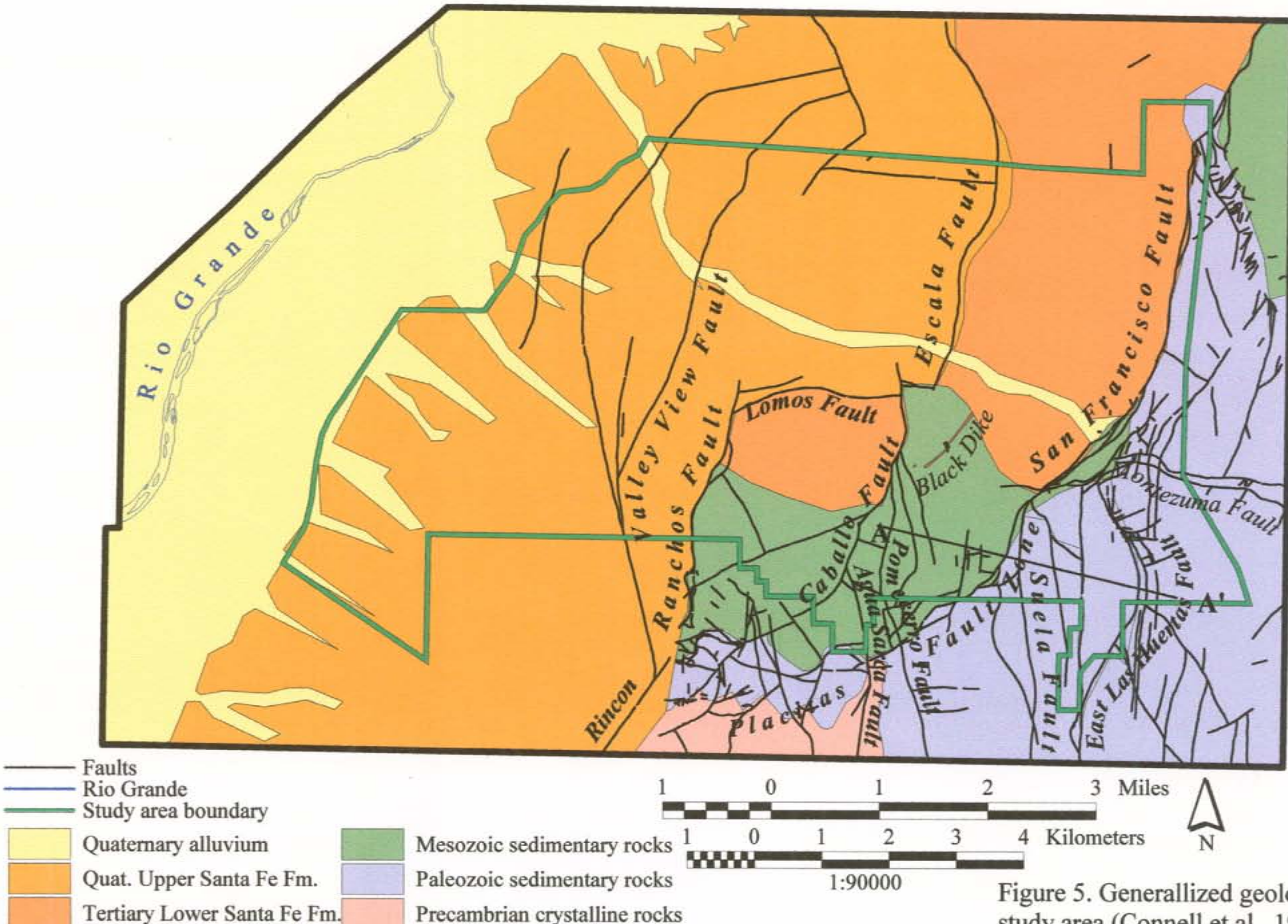
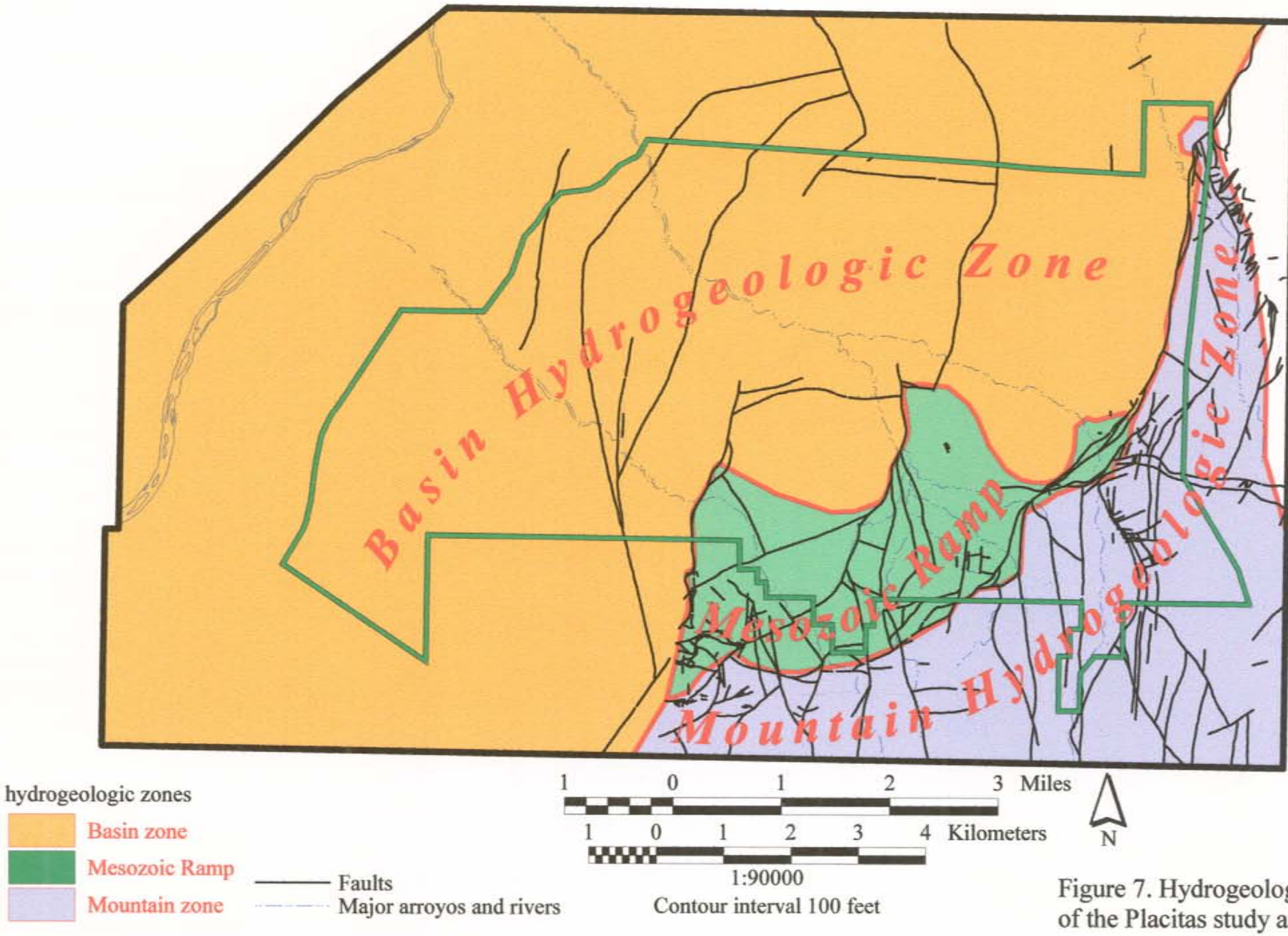


Figure 5. Generallized geology of the study area (Connell et al., 1995).



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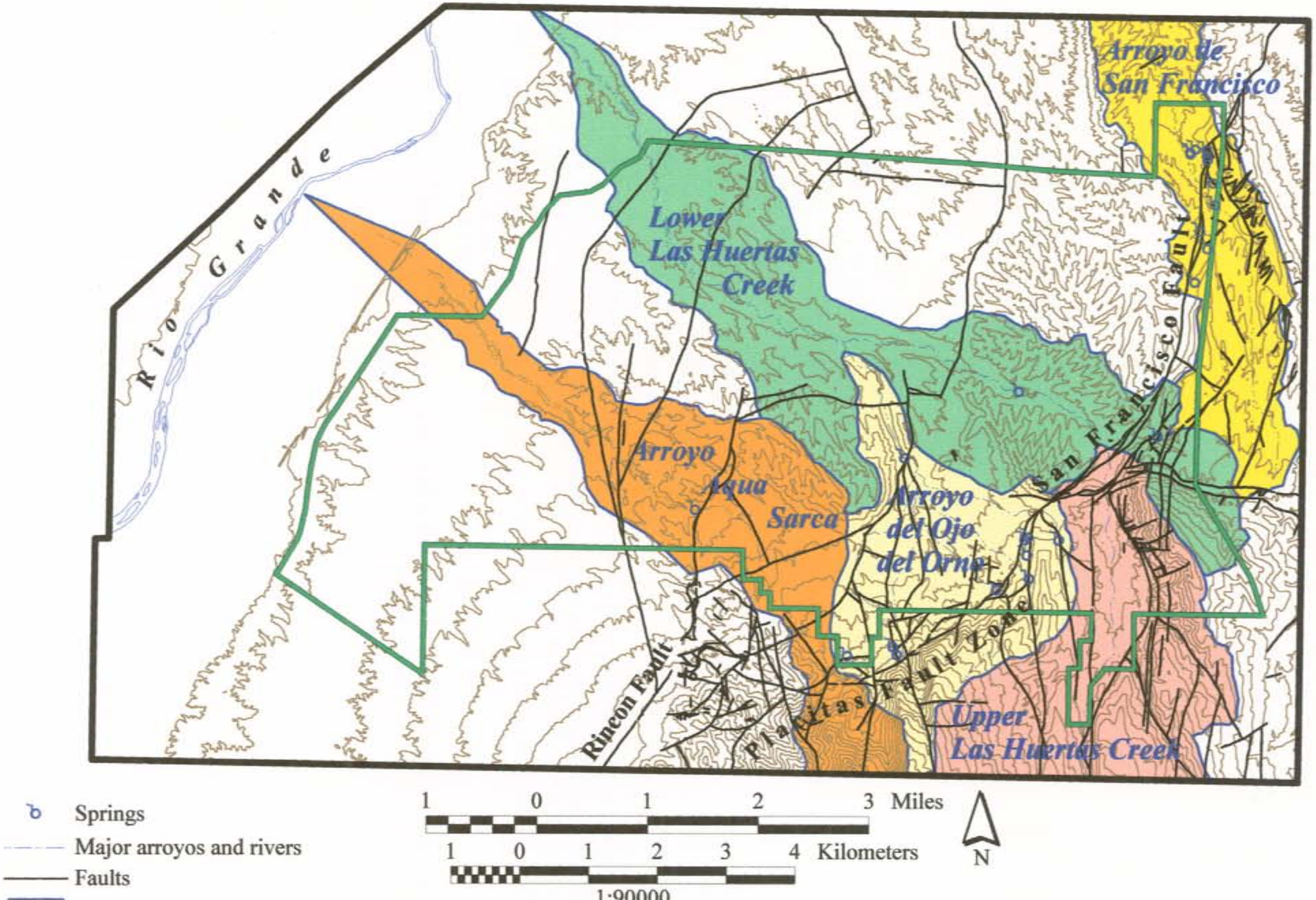

Figure 8. Surface water drainages and springs.

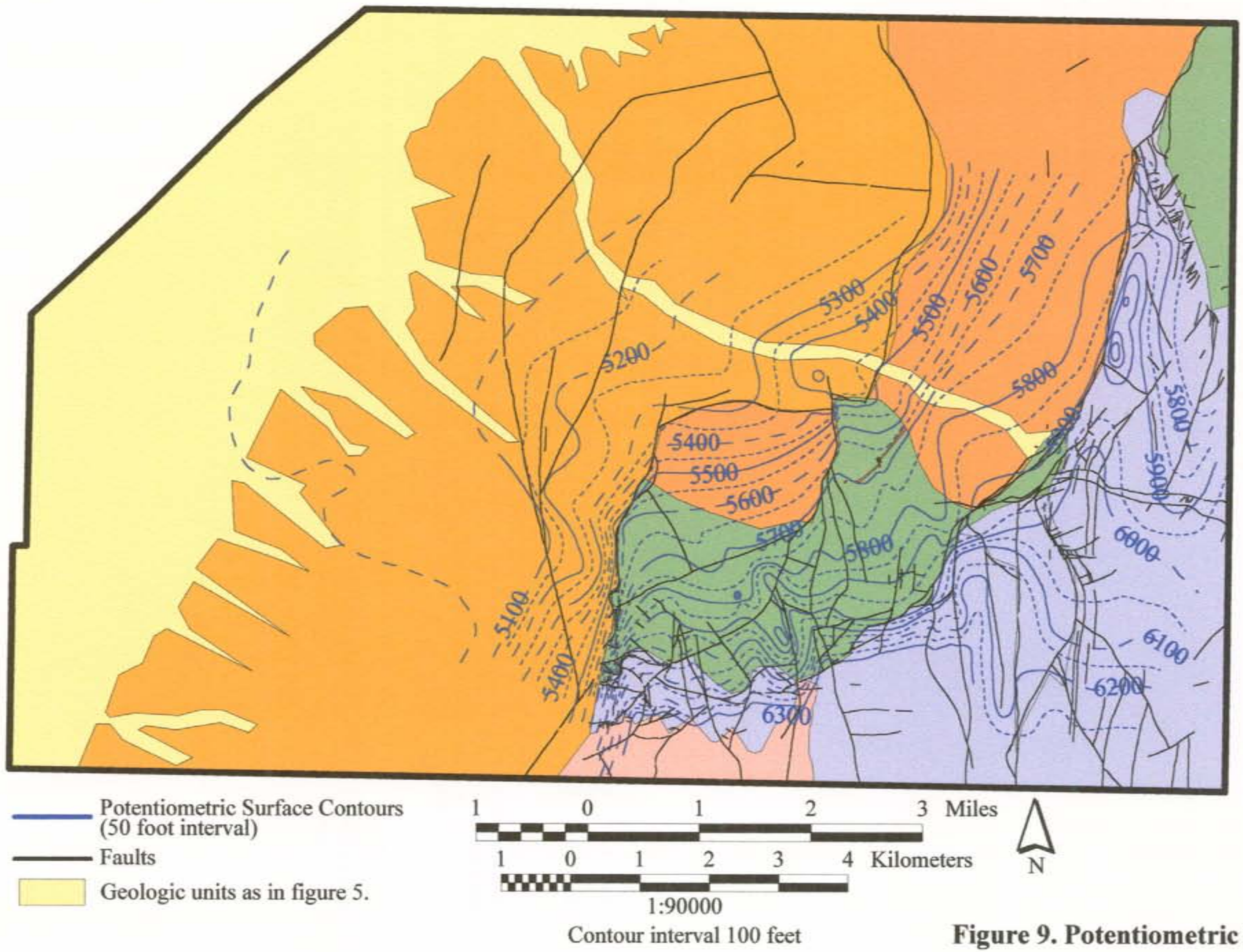

Figure 9. Potentiometric Surface

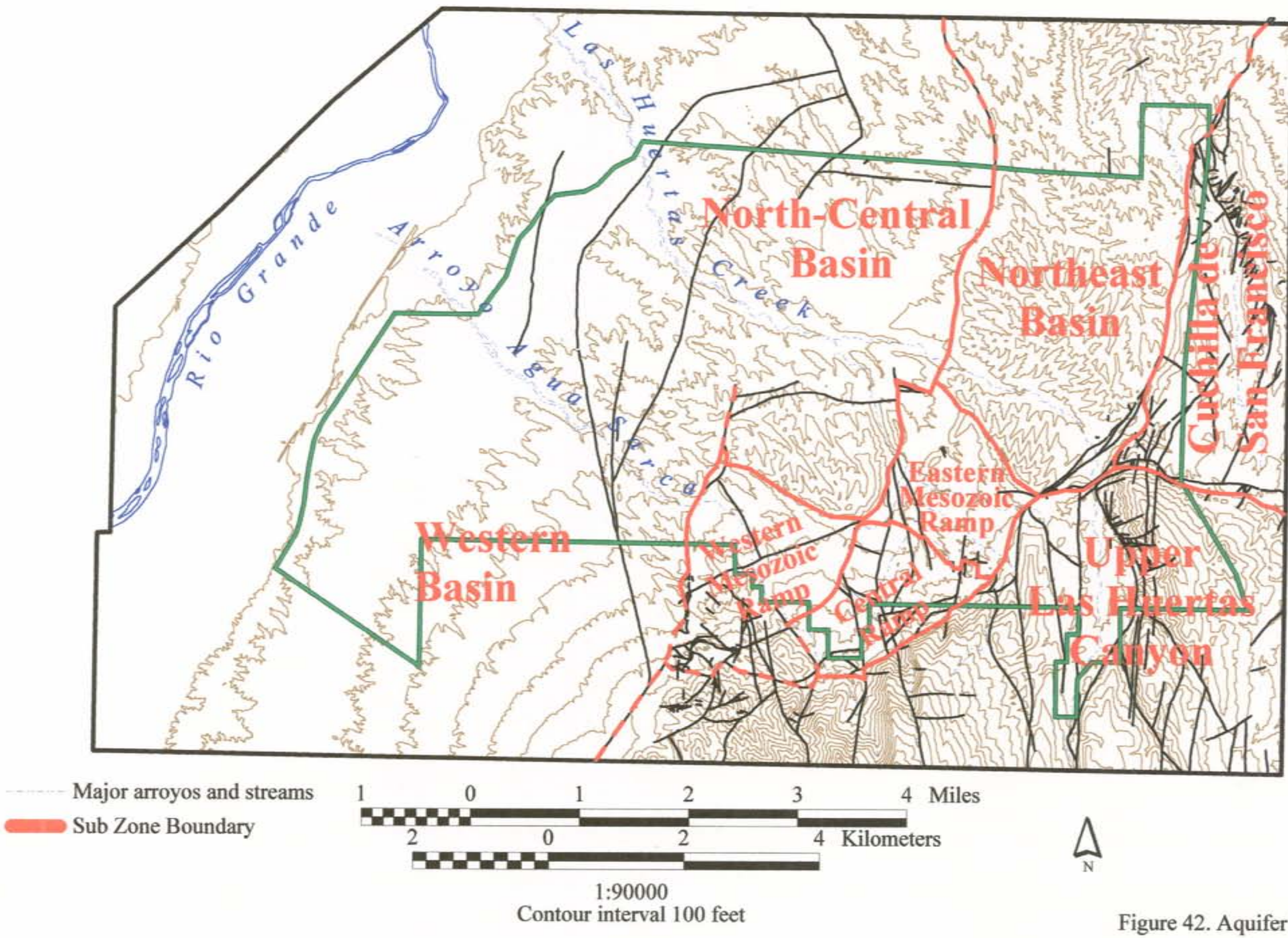

Figure 42. Aquifer Sub Zones

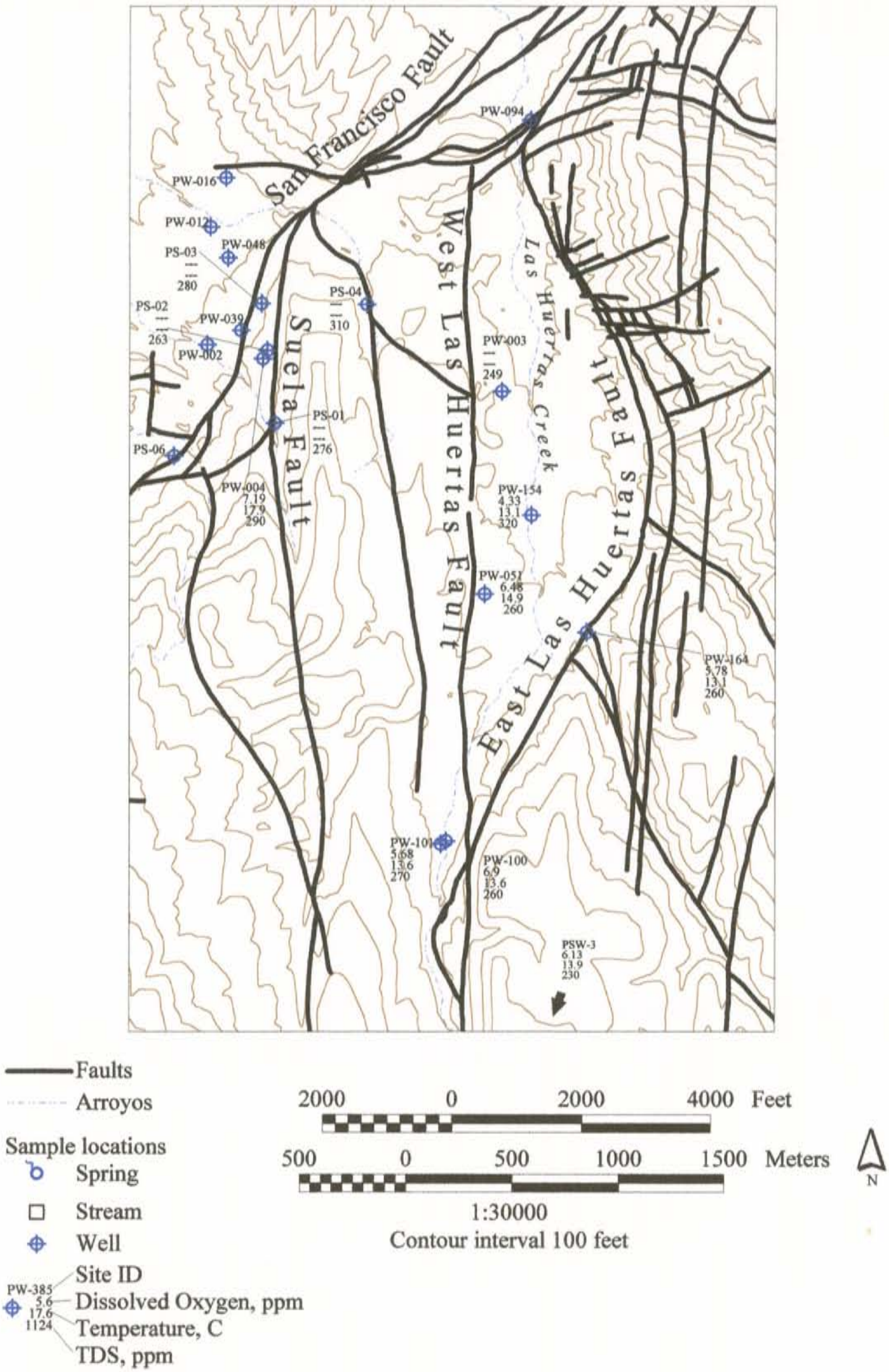

Figure 43. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from Cuchilla Lupe and upper Las Huertas Canyon.

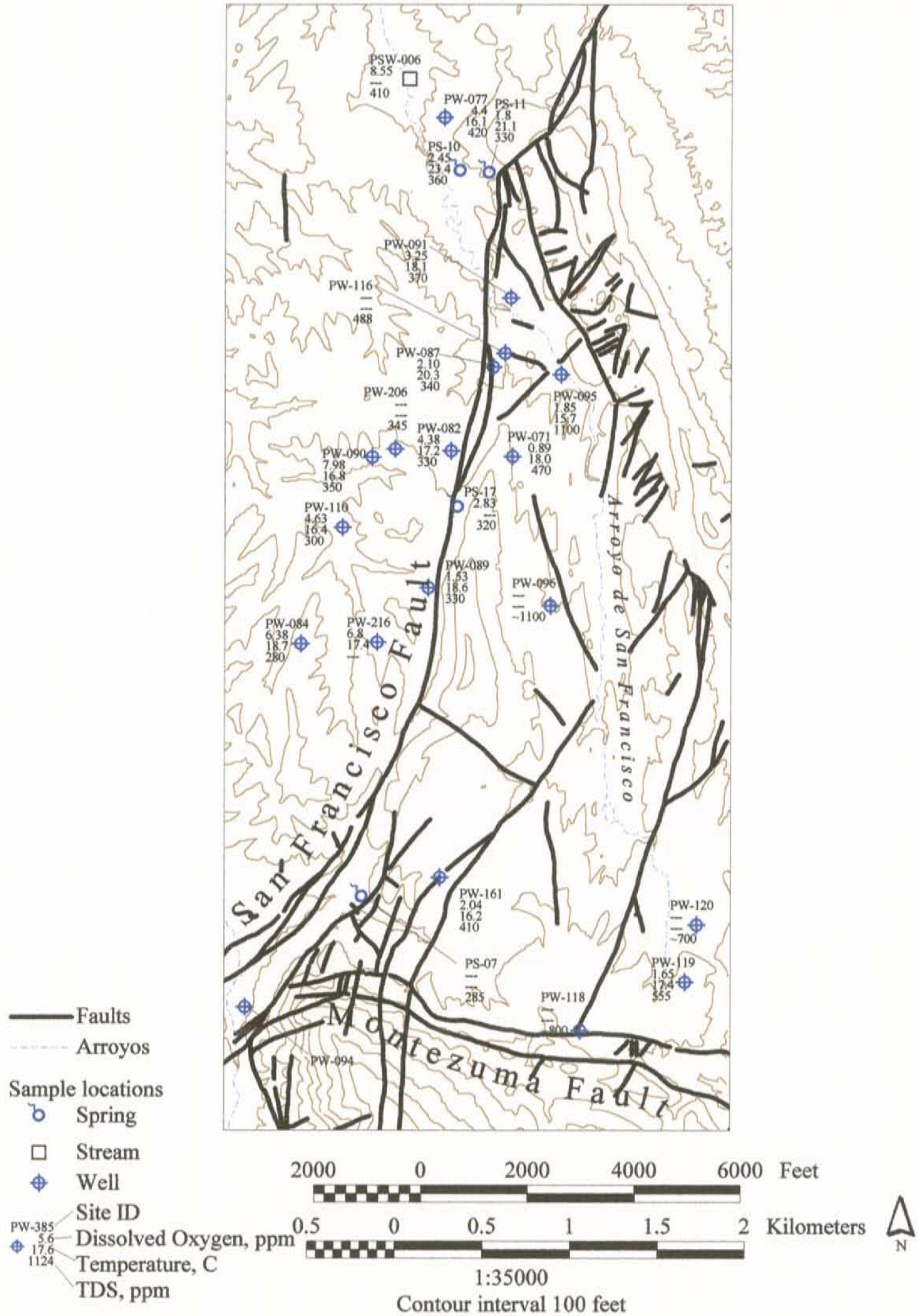

Figure 46. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from near Cuchilla de San Francisco.

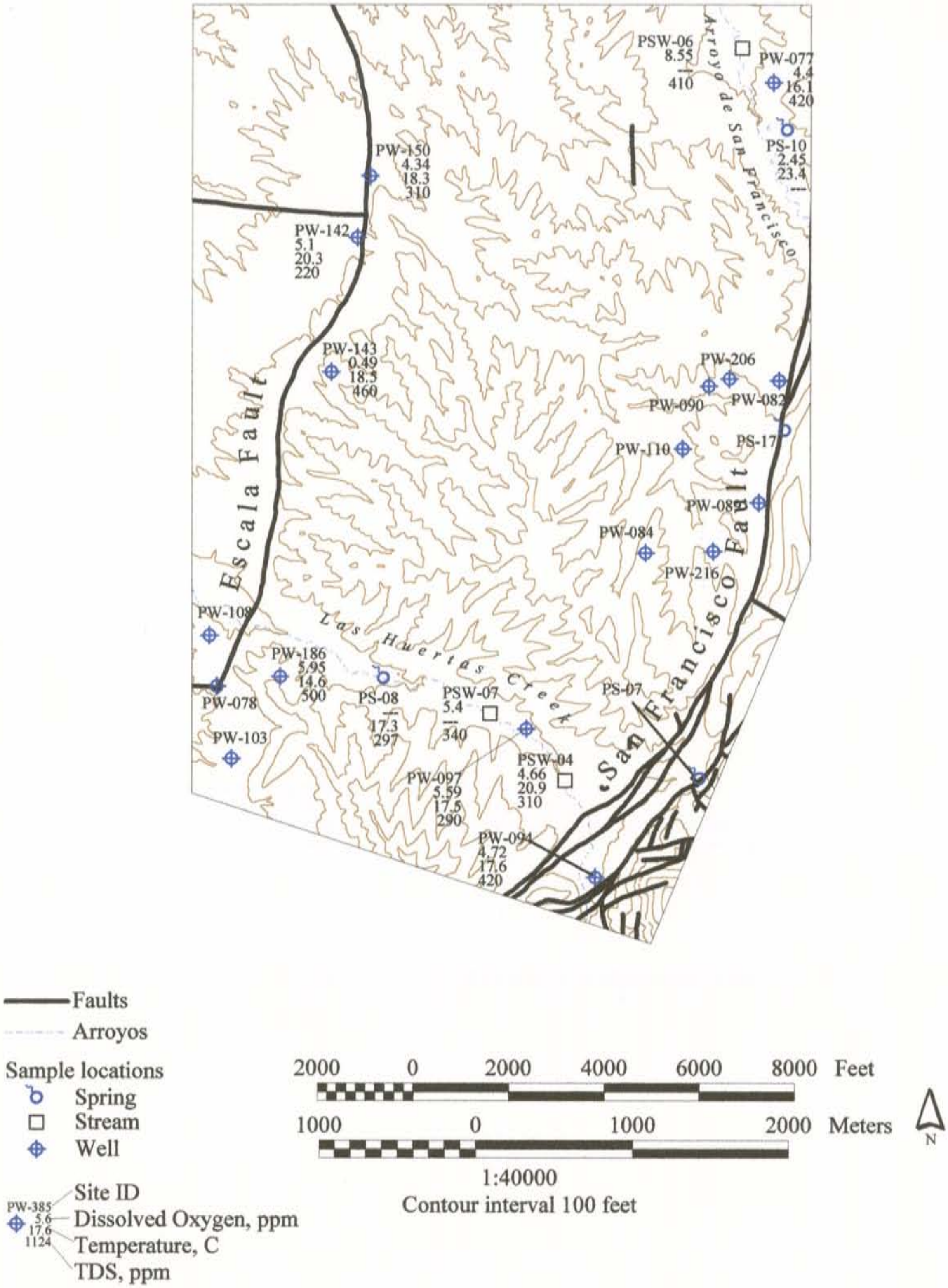

Figure 49. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the northeastern part of the basin.

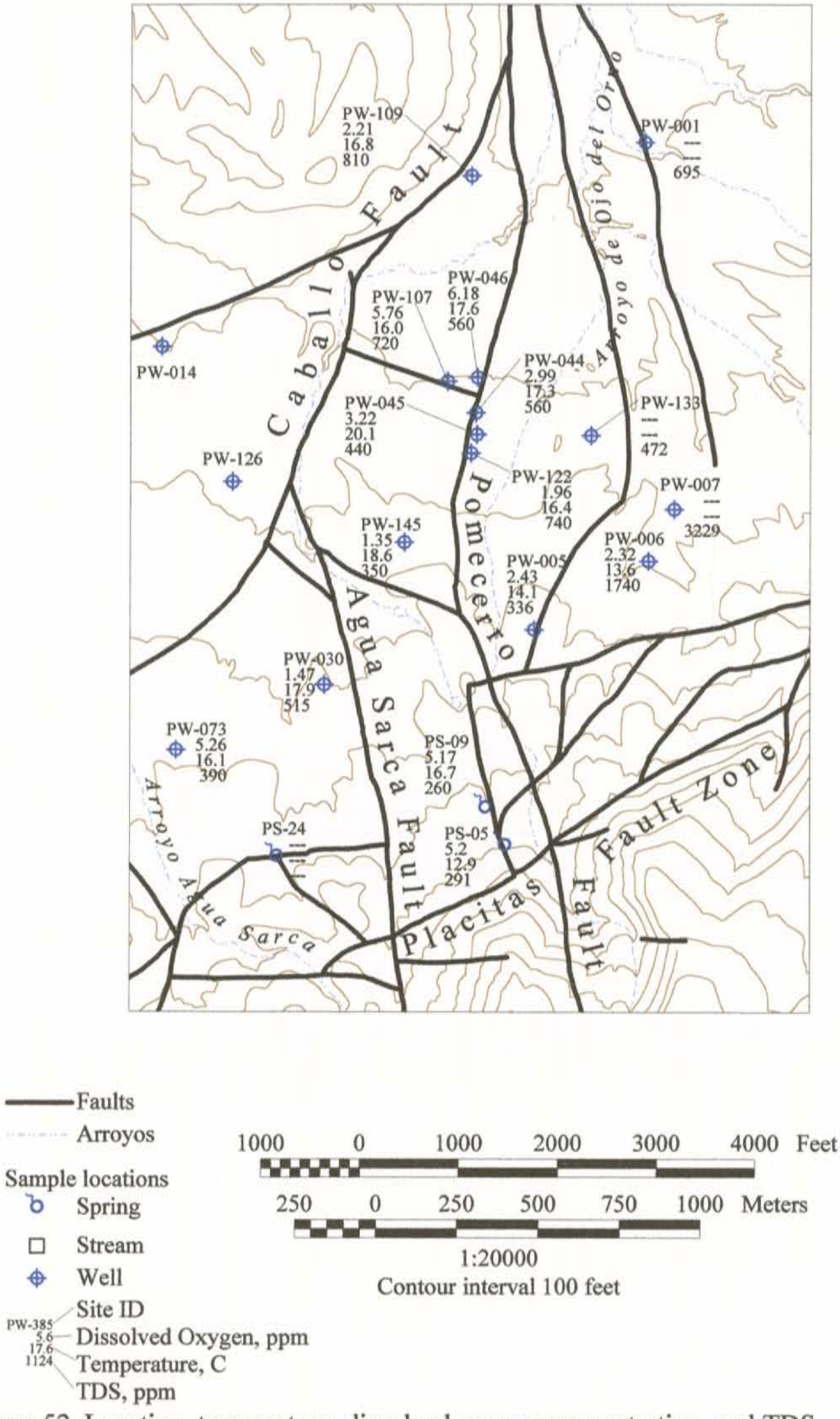

Figure 52. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the central part of the Mesozoic ramp.

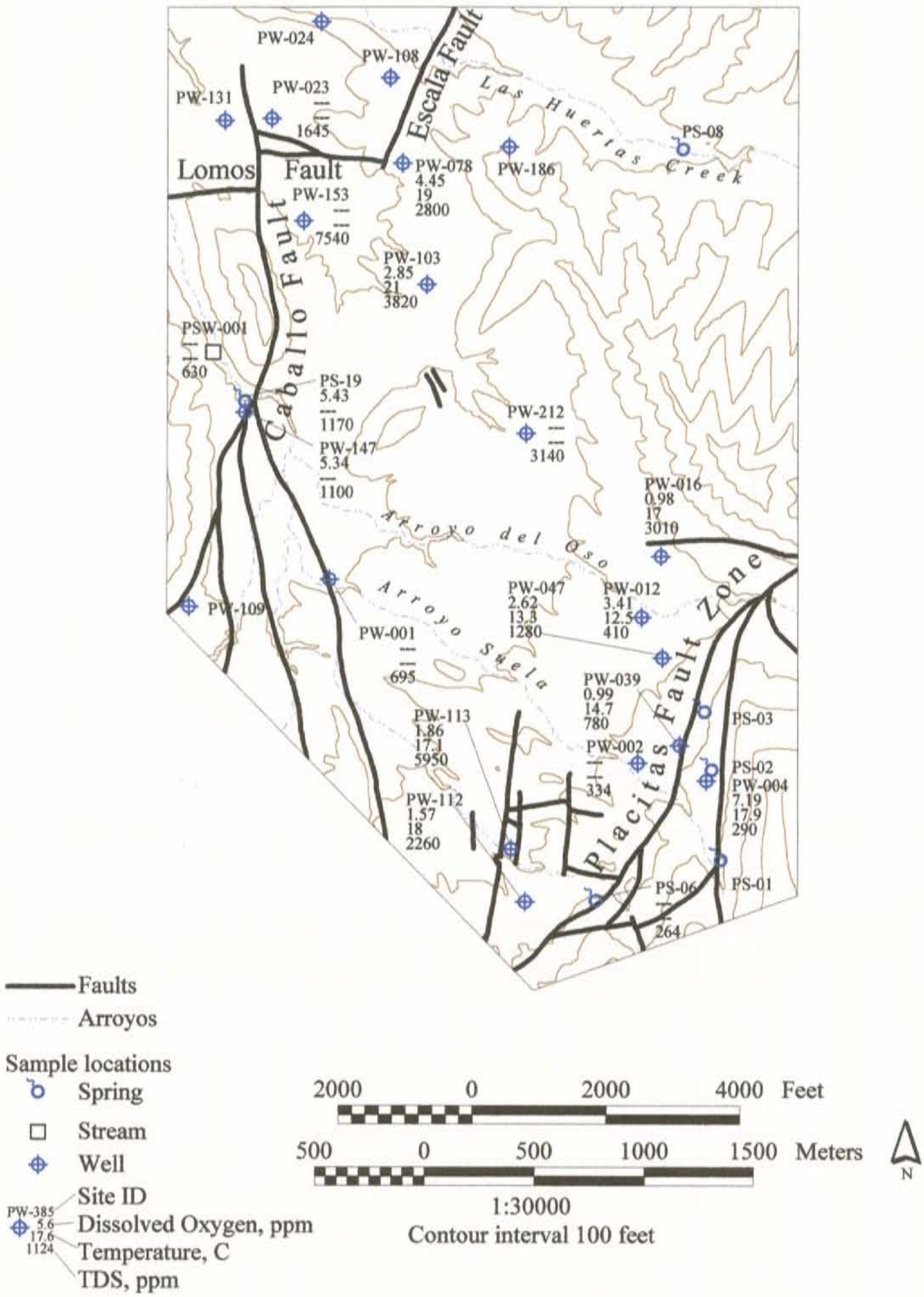

Figure 55. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the eastern part of the Mesozoic ramp.

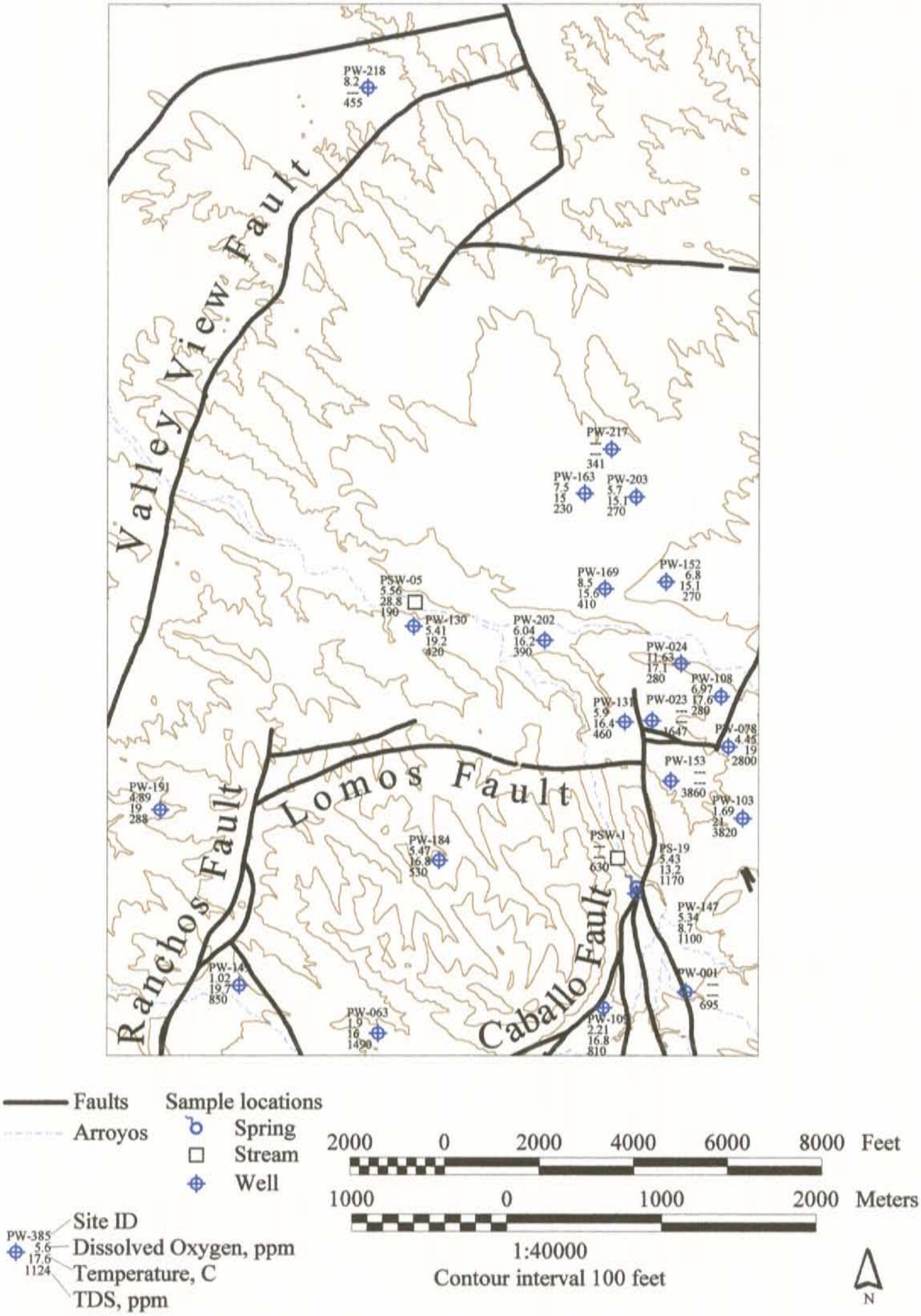

Figure 58. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the north-central part of the basin.

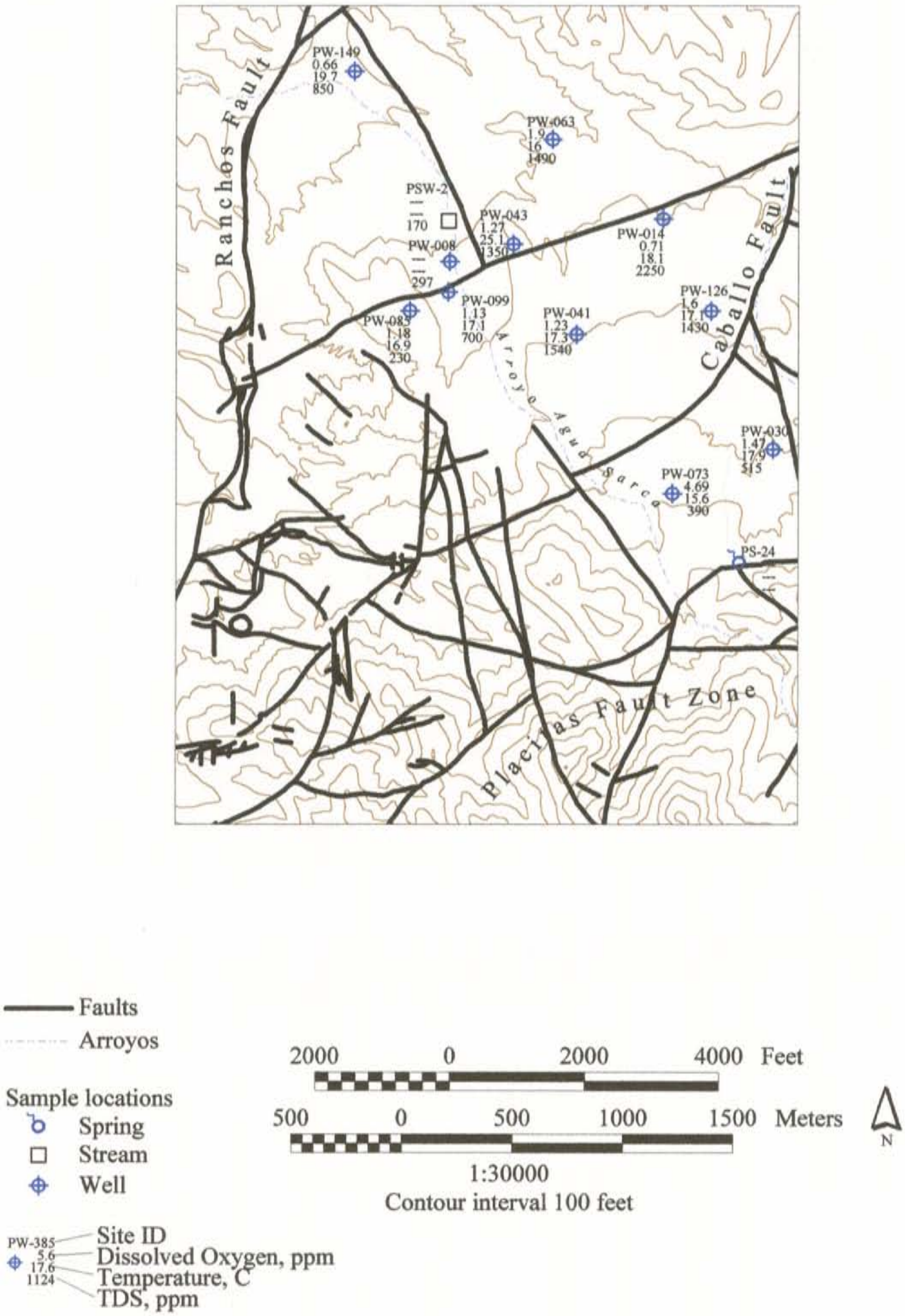

Figure 61. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the western part of the Mesozoic ramp.

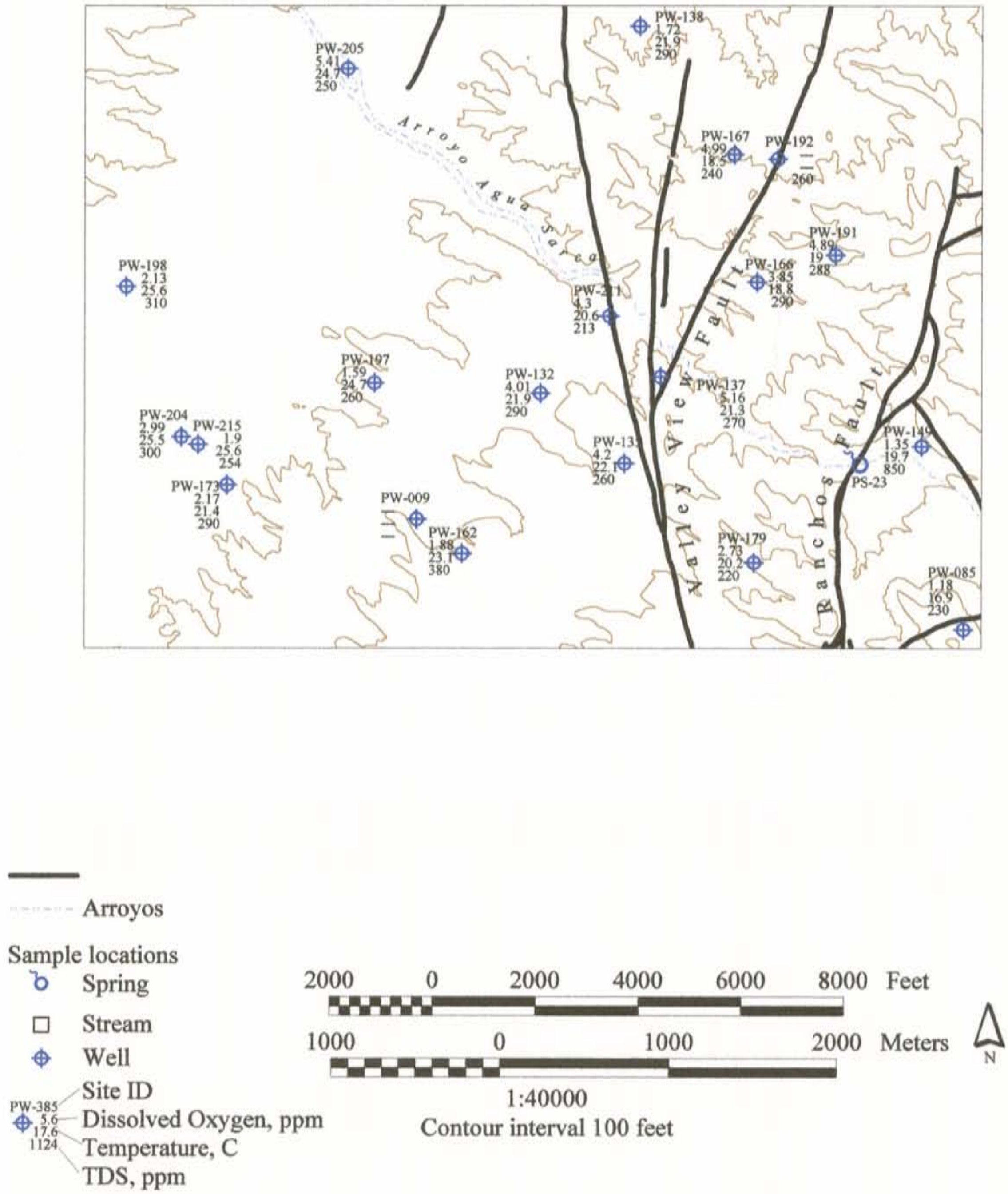

Figure 64. Location, temperature, dissolved oxygen concentration, and TDS concentration of ground-water samples collected from the western part of the basin.

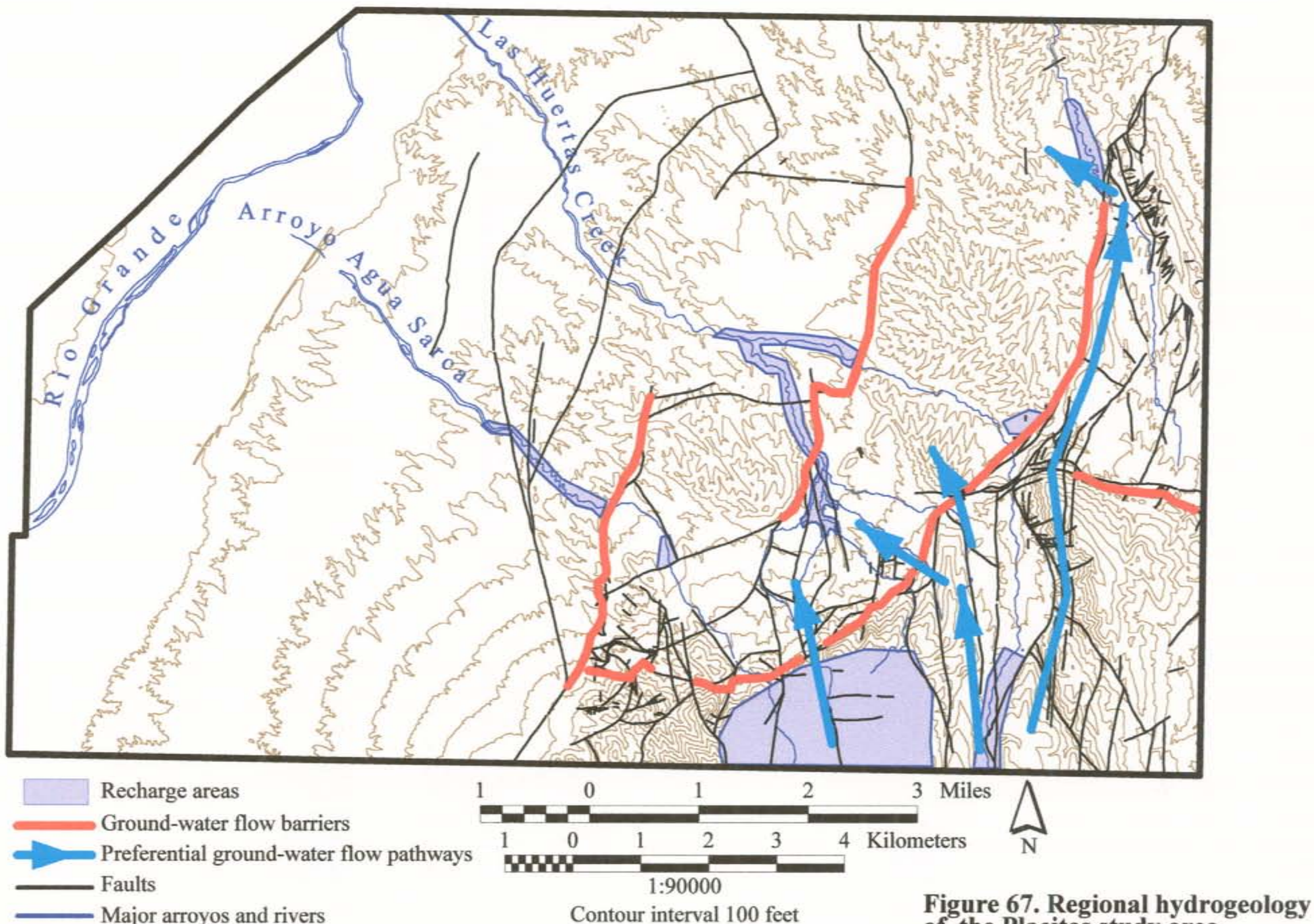

Figure 67. Regional hydrogeology of the Placitas study area.

Table 1. Stratigraphy of the Placitas study area (Connell et al., 1995).

Erathem	System/Series	Stratigraphic Unit	Thickness	Lithology
Cenozoic	Quaternary	Valley-fill and piedmont alluvium	<20m	Unconsolidated to moderately consolidated, sandy clay loam to poorly stratified sand, gravel and conglomerate.
	Tertiary	Upper Santa Fe Gr.	0-300m	Piedmont deposits of clast supported conglomerate and pebbly sandstone. Axial river deposits of coarse-grained channel sands, rare silt.
		Lower Santa Fe Gr.	0-210m	Well-cemented, clast supported conglomerate.
Mesozoic	Cretaceous	Menefee Fm.	250-560m	Sandstone, siltstone, shale and lignitic coal and ironstone lenses.
		Point Lookout Ss.	75m	Sandstone with limonitic sandstone lenses.
		Mancos Shale	440-490m	Shale with thick weakly cemented sandstone mid-section.
		Dakota Sandstone	22m	Massively bedded, well-cemented sandstone, thin black shale near top.
	Jurassic	Morrison Fm.	260m	Well-cemented friable sandstone, minor mudstone and siltstone.
		Todilto Fm.		Thinly laminated fetid limestone, upper unit of gypsum.
		Entrada Fm.	35m	Massively bedded, well-sorted, fine to medium grained eolian sandstone.
	Triassic	Petrified Forest Fm.	400-500m	Mudstone and very minor sandstone, Sandstone unit near top.
		Agua Zarca Fm.	25-130m	Conglomeratic sandstone, increasing mudstone near top.
		Moenkopi Fm.	20-25m	Micaceous sandstone
Paleozoic	Permian	San Andres Fm.	20-25m	Fine grained limestone.
		Glorieta Fm.	10m	Massively bedded sandstone.
		Yeso Fm.	165-210m	Thick-bedded friable sandstone, minor limestone, siltstone and gypsum near top of formation.
		Abo Fm.	230-330m	Thick red sandstone and mudstone sequences with minor limestone.
	Pennsylvanian	Madera Fm.	380-470m	Thickly bedded limestone with thin black shale. Upper member of limestone, sandstone, thick shale units.
		Sandia Fm.	59m	Thickly bedded, well cemented sandstone and limestone.
	Mississippian	Arroyo Peñasco Fm.	0-23m	Basal sandstone, conglomerate, mudstone, siltstone, and upper quartzite member.
Precambrian		Sandia Granite and Metamorphic rocks	Basement	Crystalline with weathered zone at top and along fractures and faults.

Table 8. Hydrogeologic sub-zones of the Placitas study area.

Sub-zone	Aquifer quality	Recharge potential	Water quality
1. Upper Las Huertas Canyon and Cuchilla Lupe	*good* high permeability aquifer conduit faults	*very good* Las Huertas Creek and direct infiltration of precipitation	*excellent* TDS < 320 ppm Ca/HCO_3
2a. Cuchilla de San Francisco	*good* high permeability aquifer conduit faults	*good* interaquifer flow	*excellent* TDS < 488 ppm $CaNa/HCO_3$
2b. San Francisco basin	*good to poor* permeable sandstone aquifers and mudstone aquitards conduit and barrier faults	*poor* interaquifer flow	*good to fair* TDS < 1100 ppm $NaMgCa/HCO_3SO_4$
3. Northeast basin	*excellent* high permeability sand, gravel, and conglomerate	*fair* interaquifer flow, Las Huertas Creek	*excellent* TDS < 500 ppm Ca/HCO_3 to $NaCa/SO_4HCO_3$
4. Central Mesozoic ramp	*good to poor* discontinuous sandstone and limestone aquifers, aquitards conduit and barrier faults	*good* interaquifer flow	*excellent to fair* TDS < 810 ppm Ca/HCO_3 to $CaMg/SO_4HCO_3$ and Na/HCO_3SO_4
5. East and North Mesozoic ramp	*good to poor* sandstone aquifers and shale and evaporite aquitards barrier faults	*poor* limited interaquifer flow, spring overflow	*excellent to very poor* TDS < 7540 ppm Ca/HCO_3 to $CaNa/SO_4$ to Na/SO_4
6. Central basin	*excellent* high permeability sand, gravel, and conglomerate barrier fault	*good* Las Huertas Creek, interaquifer flow	*excellent* TDS < 530 ppm Ca/HCO_3 to $CaMg/SO_4HCO_3$
7. West Mesozoic ramp	*good to poor* sandstone aquifers and shale aquitards barrier and conduit faults	*poor to good* interaquifer flow	*excellent to poor* TDS < 2250 ppm Ca/HCO_3, Ca/SO_4, Na/SO_4 and Na/HCO_3
8. West basin	*excellent* high permeability sand, gravel, and conglomerate	*good* Arroyo Agua Sarca, Las Huertas Creek	*excellent* TDS < 380 ppm $CaMg/HCO_3$ to $CaNaMg/HCO_3$ and to $CaNa/HCO_3Cl$

Table 12. Recharge amounts.

Recharge Area Name	Area [km²]	Winter Precipitation						Total Recharge	
		Min [cm]	Max [cm]	Range [cm]	Mean [cm]	Stdev [cm]	Total [m³/yr]	[m³/yr]	[Acre-ft/yr.]
Northern Rincon Ridge	1.9	3.2	4.2	1.0	3.6	.40	$6.9x10^4$	$8.4x10^4$	68
Canyon Agua Sarca	4.1	3.8	7.9	4.1	4.9	.98	$2.0x10^5$	$2.4x10^5$	200
Cuchilla de San Francisco	1.1	3.2	3.4	0.2	3.3	0.05	$3.6x10^4$	$4.3x10^4$	35
Sandia north slope	2.7	3.6	5.6	2.0	4.1	0.40	$1.1x10^5$	$1.3x10^5$	110
Las Huertas Canyon	45.6	2.9	15.7	12.8	9.2	4.11	$4.2x10^6$	$5.1x10^6$	4100
Totals (rounded)	55.3						$4.6x10^6$	$5.6x10^6$	4500