Ground-Water Quality in the Palo Verde Slopes Community, Rio Hondo Basin, Lincoln County, New Mexico

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Dennis McQuillan, Gary Beatty, and Jack King
New Mexico Environment Department

Abstract

Septic tank effluents have contaminated ground water with nitrate in a subdivision built over a bedrock fault zone. Fractured bedrock is a well-established criterion for aquifer vulnerability. Five of 33 wells tested contained nitrate-N at 5 mg/L or above, and 2 wells had nitrate-N exceeding the health standard of 10 mg/L. The nitrogen loading rate for the residential density in this study area is nearly equal to what is allowed by state regulations, yet ground-water contamination in excess of the nitrate standard has occurred. This suggests that the minimum lot size regulation of 0.75 acre/lot may not protect ground water in all cases. Computer models had predicted that septic systems installed on lots sized at 0.75 acre or larger could contaminate ground water in some areas, but this is the first study in New Mexico to verify those simulations with actual field data.

Introduction

Ground-water contamination from on-site septic systems is a widespread problem in New Mexico (McQuillan, 2004). Septic tank effluents have contaminated more water supply wells, and more acre-feet of ground water, than all other sources in the state combined. The New Mexico Environment Department is conducting hydrogeologic investigations throughout the state to identify and map ground-water resources impacted by on-site systems. Palo Verde Slopes was platted as a subdivision in 1958, and was developed with on-site wells and septic systems. Prior to sub-development, the land had not been used for irrigated agriculture. Platted lots range from 0.2 to 1.42 acres, with an average lot size of 0.48 acre. Not all lots have been developed, and some have been combined to make larger homesteads. The subdivision consists of 86 acres with 102 residences, so the actual residential density is 86acres/102 residences = 0.84 acre/residence.

Tourism, ranching and irrigated agriculture are important components of the Lincoln County economy. Ground water is an important resource in the region, and withdrawals are increasing to meet the demands of increased tourism and new residential developments.

Physical Setting

Palo Verde Slopes is located within the floodplain and on a slope rising south of the Rio Ruidoso. The valley has been incised by the river into sandstones, siltstones and dolomites of the Permian Yeso Formation, which is overlain locally by deposits of river alluvium and slope colluvium in the study area. Outcrops of Yeso are exposed in the region, and underlie the Permian San Andres Formation, which crops out at higher elevations above the valley. The Yeso has been displaced by a fault that trends parallel to and south of the Rio, and runs through the study area (Figure 1).

Ground water occurs in the Yeso and in river alluvium. The regional direction of alluvial ground-water flow is to the east (Donohoe, 2004, Mourant, 1963). Water level elevations in the Yeso, based on depths to water reported in well logs filed with the Office of the State Engineer, are shown in Figure 2. The direction of ground-water flow within the Yeso is not well defined, but appears to be generally from the valley slope towards the inner valley. Hydraulic gradients between the Yeso and alluvium have not been established. Most wells in the study area are completed in the Yeso. Sandstone, limestone and dolomite are the most common water-bearing materials reported in area well logs. Reported well depths range from 48 to 325 feet, with depths to ground water ranging from 12 to 237 feet. Ground water is shallowest in the floodplain and deepens upslope to the south. A hydrograph for an alluvial well near the study area (Figure 3) shows an overall water-level decline of about four feet since 1956. Well logs suggest that ground water occurs largely under unconfined conditions in the study area.

Well records report yields ranging from 5 to 200 gallons per minute (gpm) with an average of 46 gpm. In the Roswell Basin, east of the study area, the Yeso is a low permeability formation that acts as the basal confining layer for the artesian San Andres aquifer. Reported well yields, however, suggest that the Yeso has significant hydraulic conductivity in the study area. This is most likely the result of fracture porosity associated with faulting.

Methods

Historical data from Water Fairs and public water system monitoring were assembled and reviewed, along with published ground-water quality information from the U.S. Geological Survey and other sources. Thirty-three water supply wells were tested throughout the community of 102 residences. Homeowners granting permission for sampling were interviewed as to the well depth and age, number of people using the well as a source of drinking water, well driller, and distance from well to septic system. If a water treatment system had been installed, water was sampled prior to treatment. Field measurements of conductivity, and temperature were conducted on-site using a YSI Model 85 meter. Wellhead coordinates were determined with a Garmin Etrex GPS unit. One-liter samples of well water were collected in a plastic container for additional off-site analysis of specific constituents. A HACH Model DR 890 colorimeter was used to determine nitrate-N, iron and fluoride. The instrument was calibrated on a daily basis with de-ionized water and factory prepared standard solutions. In addition to the

colorimeter analyses, four samples were sent to the State Laboratory in Albuquerque for analysis of general chemistry including anions/cations. Samples were not filtered through a 0.45 um membrane, but were acidified with sulfuric acid to pH <2 for nitrogen-species aliquots sent to the Scientific Laboratory Division (SLD) of the N.M. Department of Health in Albuquerque. Homeowners were provided with a written report of test results for their well water, along with a bilingual information sheet explaining the significance of the parameters that were analyzed. In order to protect homeowner confidentiality and property rights, NMED does not publicly disclose the names and addresses for samples collected during community surveys such as this.

Results

Test results from this study are summarized in Table 1, and shown in Figures 4-7. Anion/cation data are presented in Table 2. Conductivities were all greater than the recommended aesthetic limit of 1000 uS (Figure 4). All waters are of the calcium-sulfate variety. Nitrate + nitrite (NO_3 + NO_2) concentrations were low (typically less than 1 mg/L as N) in the upslope study areas, but were generally higher in the mid to down-slope areas of the subdivision (Figure 5). Five samples had NO_3 + NO_2 greater than 5 mg/L as N, and two had levels greater than the health standard of 10. Iron was generally not detectable or low (Figure 6), with only one sample exceeding the aesthetic standard of 1 mg/L. Fluoride was detected in all samples, but at concentrations within the health standard of 2 mg/L (Figure 7).

Table 1. Summary of Palo Verde Slopes Well Water Quality.

Parameter	Low	High	Mean	Allowable or Recommended Standard
NO_3 + NO_2 mg/L-N	0.2	11.9	2.1	10
Chloride, mg/L	98	248	182	250
Conductivity, uS	1300	3800	2339	1000
Iron, mg/L	0.00	1.26	0.01	1
Fluoride, mg/L	0.1	1.6	0.6	2

Table 2. General Chemistry Data. Iron, fluoride, NO_3 + NO_2, conductivity and temperature were measured in the field. All other parameters were measured by SLD.

Parameter	Source	A4	A18	A20	A26
Calcium (mg/L)	SLD	360	484	505	191
Magnesium (mg/L)	SLD	98.8	119	132	55.4
Sodium (mg/L)	SLD	141	89	56.5	65.1
Potassium (mg/L)	SLD	<5	<5	<5	<5
Iron (mg/L)	Field	0.05	0.09	0.01	<0.01
Manganese (mg/L)	SLD	<0.05	<0.05	<0.05	<0.05
Total Hardness (mg/L)	SLD	1310	1700	1800	705
Alkalinity (mg/L)	SLD	200	164	147	169
Carbonate (mg/L)	SLD	0	0	0	0

Bicarbonate (mg/L)	SLD	244	210	180	206
Chloride (mg/L)	SLD	241	248	140	97.8
Sulfate (mg/L)	SLD	898	1620	1610	599
Fluoride (mg/L)	Field	1.0	1.3	1.5	0.8
NO3+NO2 (mg/L as N)	Field	11.9	1.6	0.3	1.2
Surfactants (mg/L)	SLD	<0.01	<0.01	<0.01	<0.01
Ion Balance	SLD	4.41	-7.5	-0.23	-0.48
Conductivity (us)	Field	2500	2720	2710	1300
Temperature (^oC)					
Total Dissolved Solids (mg/L)	SLD	2140	2870	2640	1220
pH (units)	SLD	7.78	8.06	8.09	7.86
Turbidity (NTU)	SLD	0.2	3.7	0.82	0.15
Color (units)	SLD	0	5	0	0
Odor (TON)	SLD	0	0	0	0

Discussion and Conclusions

Domestic water use adds dissolved minerals, reflected by conductivity increases, to sewage. One of the added constituents, ammonia, can oxidize to $NO_3 + NO_2$ in oxic soil and ground-water systems. Conductivity and $NO_3 + NO_2$, therefore, can be diagnostic indicators of septic tank contamination.

The high conductivities in the study area exceed the recommended aesthetic limit of 1000 uS for domestic consumption, but do not present a health hazard. These result from dissolution of gypsum (calcium sulfate) and other soluble minerals that occur in the Permian bedrock of the area.

The relatively high $NO_3 + NO_2$ levels in the mid to down-slope areas of the subdivision, we believe, result from percolating septic tank effluents. The spotty occurrence of elevated $NO_3 + NO_2$ also is consistent with a non-point source of contamination such as septic tanks. Fractured bedrock terrain, such as in the study area, provides less opportunity for natural attenuation of contaminants in septic tank effluent, than do porous inter-granular media such as soils. Fractured bedrock is a well-established criterion for aquifer vulnerability.

Microbiological testing was not performed during this study. Fractured bedrock also provides a relatively high vulnerability to subsurface transport of, and contamination by, micro-organisms originating in sewage effluent. We recommend that Palo Verde residents have their well water tested for fecal coliform bacteria. Unlike testing for chemical constituents, NMED is unable to provide microbiological testing on-demand. NMED does, however, maintain a list of laboratories to certified to perform such testing, http://www.nmenv.state.nm.us/dwb/Certified_labs.html. The closest laboratory to Palo Verde is Diagnostic & Technology Center, Inc. in Alamogordo, 505-434-4944.

Residential Density Analysis

New Mexico regulations define minimum Lot Size (LS) as the acreage of the lot itself excluding roadways and easements. Assuming that roads comprise 15% of the area in a residential community, the Residential Density (RD) would be LS * 1.15 acres/residence. For an area developed with on-site systems, the Nitrogen Loading Rate (NLR) in lbsN/acre/yr can be calculated as follows:

$$\text{NLR}, \frac{\text{lbs N}}{\text{ac yr}} = \frac{\text{Q gal}}{\text{day-res}} * \frac{\text{365 day}}{\text{yr}} * \frac{\text{3.78 L}}{\text{gal}} * \frac{\text{C mg N}}{\text{L}} * \frac{\text{2.2 lbs}}{10^6 \text{ mg}} * \frac{\text{1 res}}{\text{RD ac}} \text{ where}$$

RD = LS * 1.15, acres/residence
C = total nitrogen concentration, mg N/L
Q = wastewater flow rate, gal/day/residence

New Mexico regulations allow for 375 gpd wastewater, assuming 60 mg/L total nitrogen, to be discharged on a 0.75 acre lot. The allowable NLR for nitrogen New Mexico, therefore, is:

$$375 * 365 * 3.78 * 60 * 2.2\text{x}10^{-6} / (0.75 * 1.15) = 79 \text{ lbs N/ac/yr}$$

The Palo Verde residential density is 86acres/102 residences = 0.84 acres/residence, which produces a NLR of 83 lbs N/ac/yr. Residential densities and NLRs also have been calculated for two sites in Albuquerque where septic tanks have contaminated ground water with nitrate: Sandia Heights (Thomson et al., 2004) and Barcelona (McQuillan et al., 1989). NLRs and maximum observed ground-water nitrate concentrations for these three sites are compared in Figure 8. Modeling simulations for sites in New Mexico and Utah (Geohydrology Associates, Inc. 1989; Lowe et al., 2000; Lowe et al., 2004; Wallace and Lowe, 1998a and 1998b) are also plotted in Figure 8 for comparison. These simulations predict higher ground-water nitrate levels than what has been observed in the three field studies, for NLRs up to 100-150 lbs N/ac/yr.

The NLR for the residential density in Palo Verde is nearly equal to what is allowed by current regulations, yet ground-water contamination in excess of the nitrate standard has occurred. This suggests that the current minimum lot size regulation of 0.75 acre/lot may not protect ground water in all cases, and it may be appropriate to impose more stringent standards in these situations.

Acknowledgments

Kara Hutchinson and Taylor McClain, student interns working for NMED, assisted with the fieldwork on this study. We are especially grateful to all Palo Verde residents who granted us permission to sample their wells.

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Figure 1. Geologic Map of Ruidoso, N.M. and Vicinity (From NMBGMR, 2003). Alluvial deposits are not shown. For explanations of geologic units other than the San Andres and Yeso, see NMBGMR, 2003.

☆ Study Area

Psa Permian San Andres Formation (limestone and dolomite with minor shale)
Py Permian Yeso Formation (sandstone, siltstone, anhydrite, gypsum and dolomite)
Fault or Fault zone
River

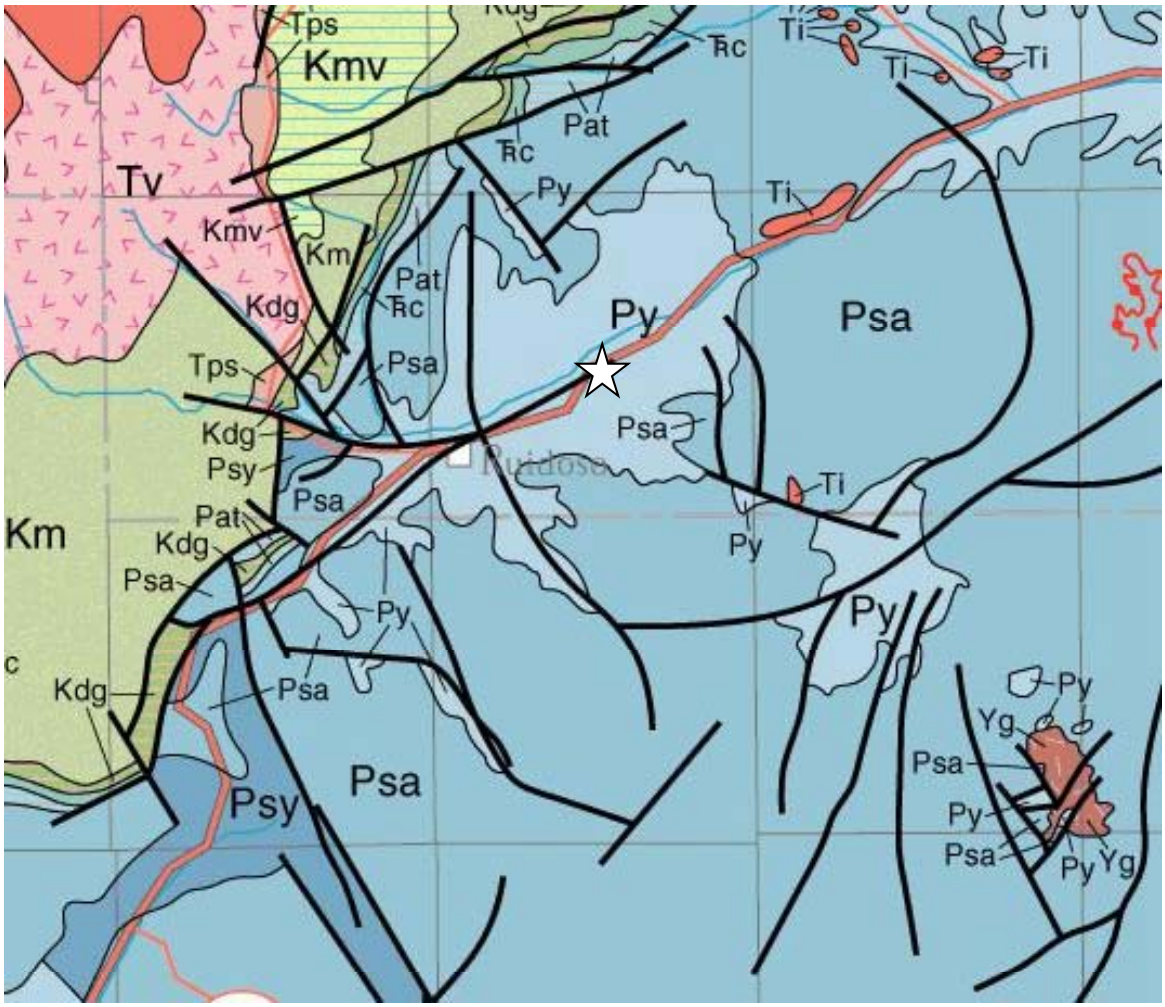


Figure 2. Water Level Elevations in the Yeso Formation.
Depths are given in feet. Elevations are in feet above mean sea level. TD is total depth of well.

Site ID	OSE Well #	Ground Elev.	Water Depth	Water Elev.	Well Depth	TD Elev.
010	H 01241	6278	65	6213	160	6118
018	H 01060	6282	124	6158	175	6107
027	H 01976	6342	234	6108	318	6024
006	H 00385	6243	58	6185	108	6135
012	H 00386	6380	50	6330	110	6270

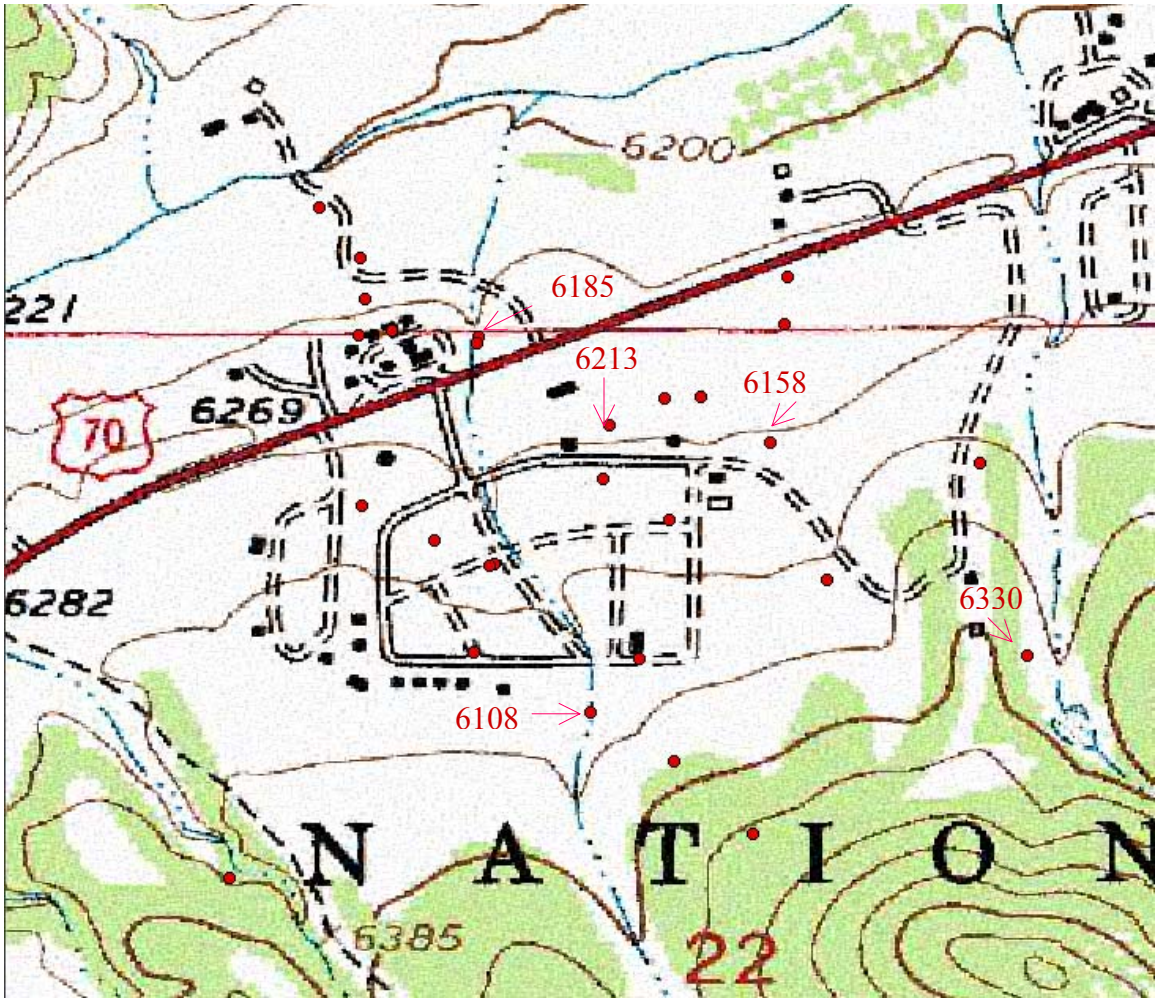


Figure 3. Hydrograph for well T11S R14E 15.432334 (from Donohoe, 2004).

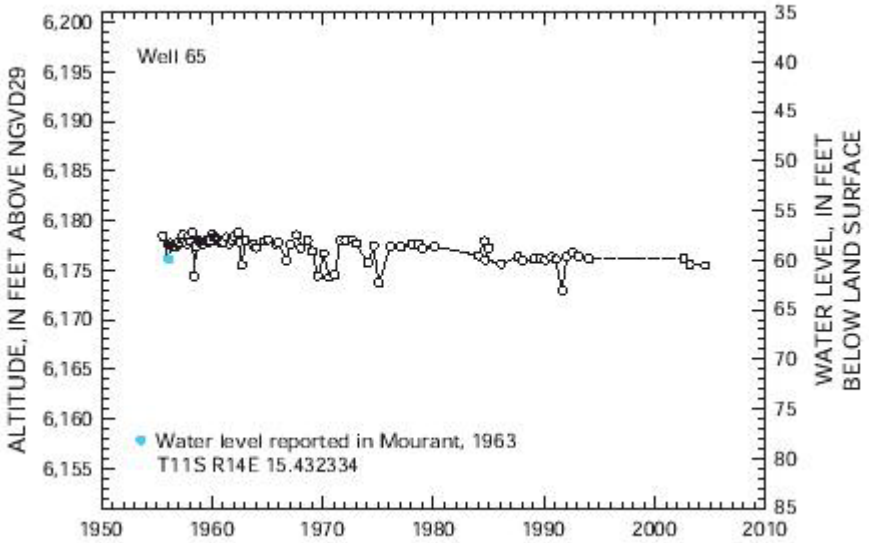


Figure 4. Conductivity (uS).

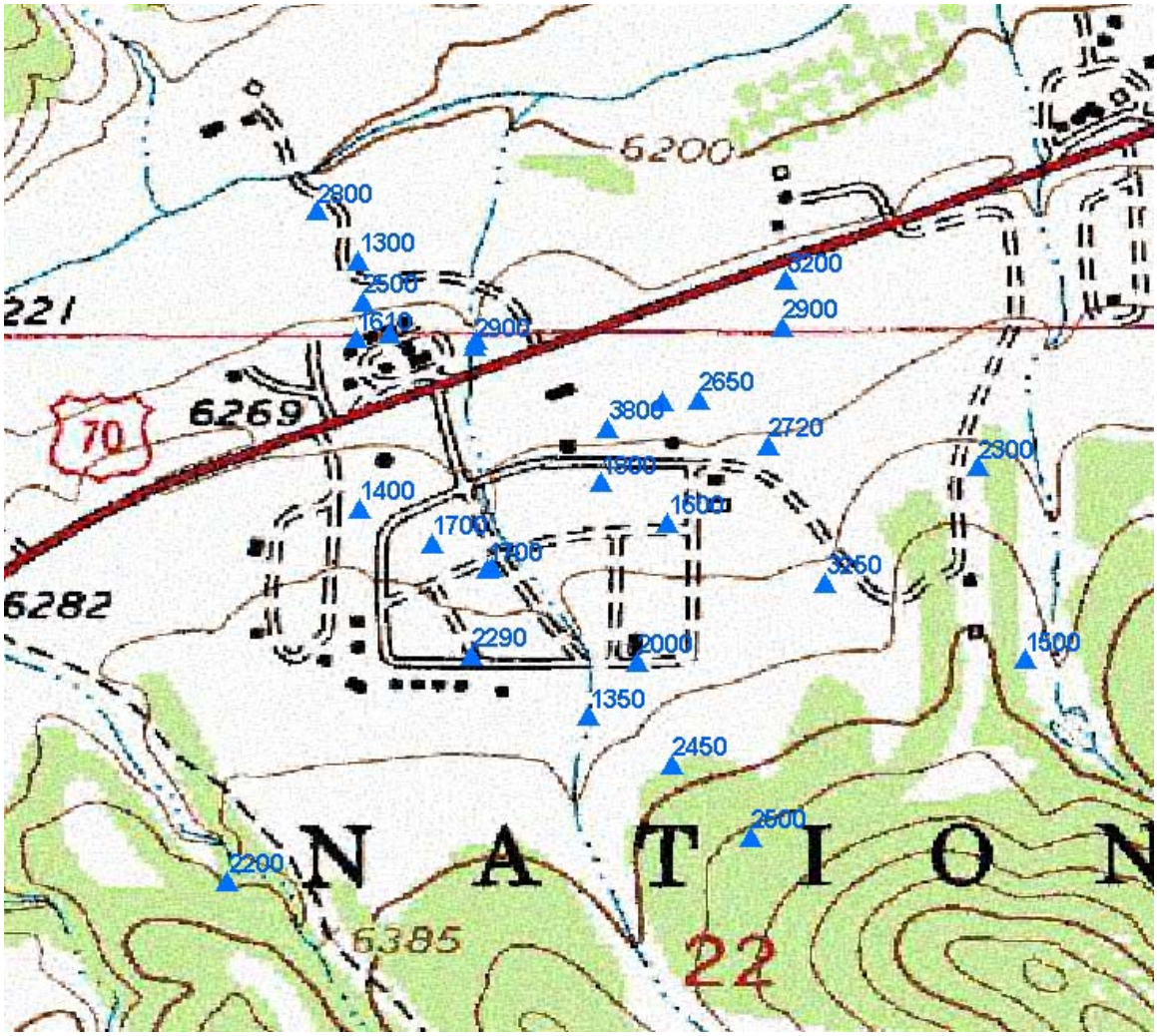


Figure 5. Nitrate plus nitrite (mg/L as N).

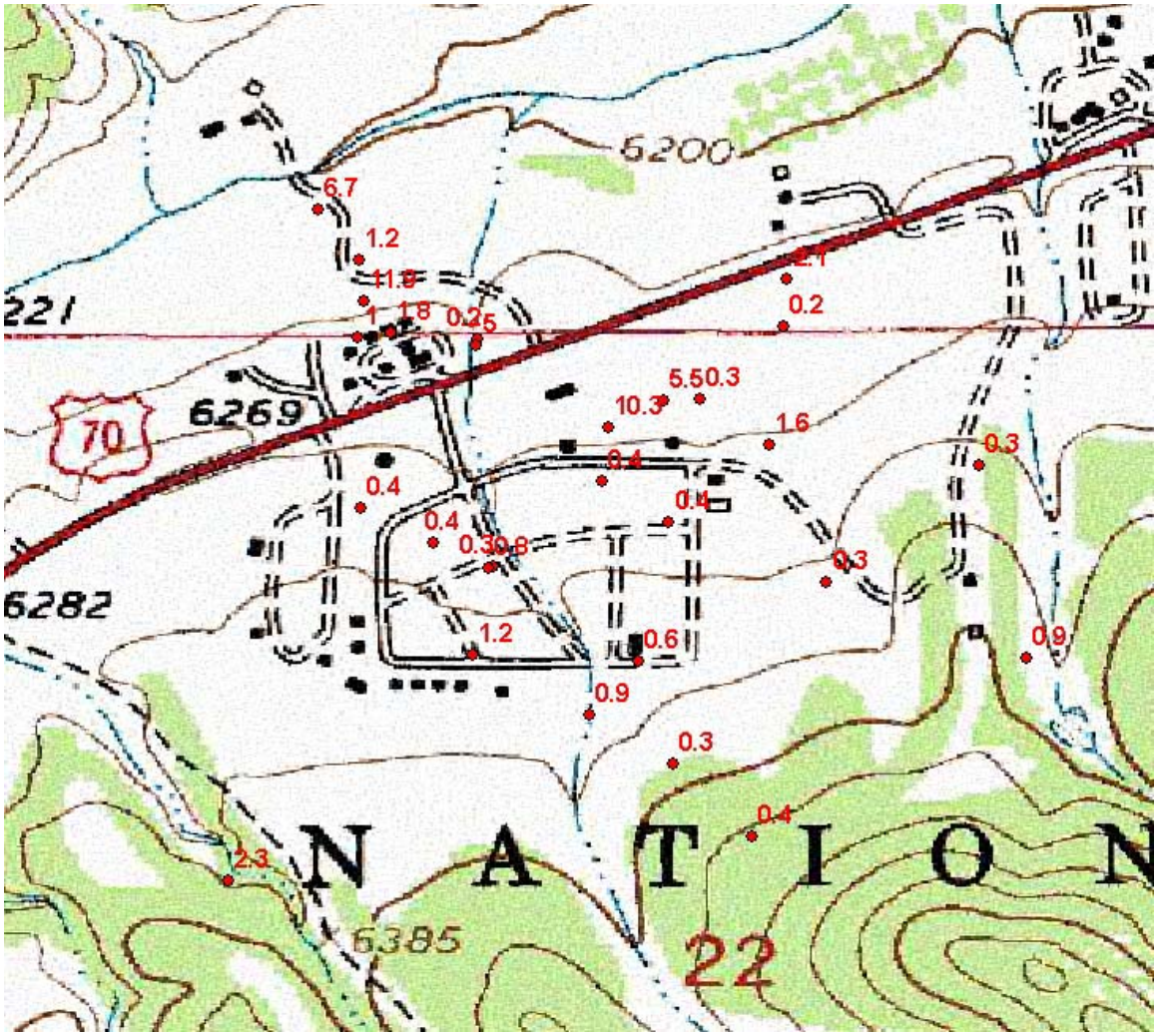


Figure 6. Iron (mg/L).

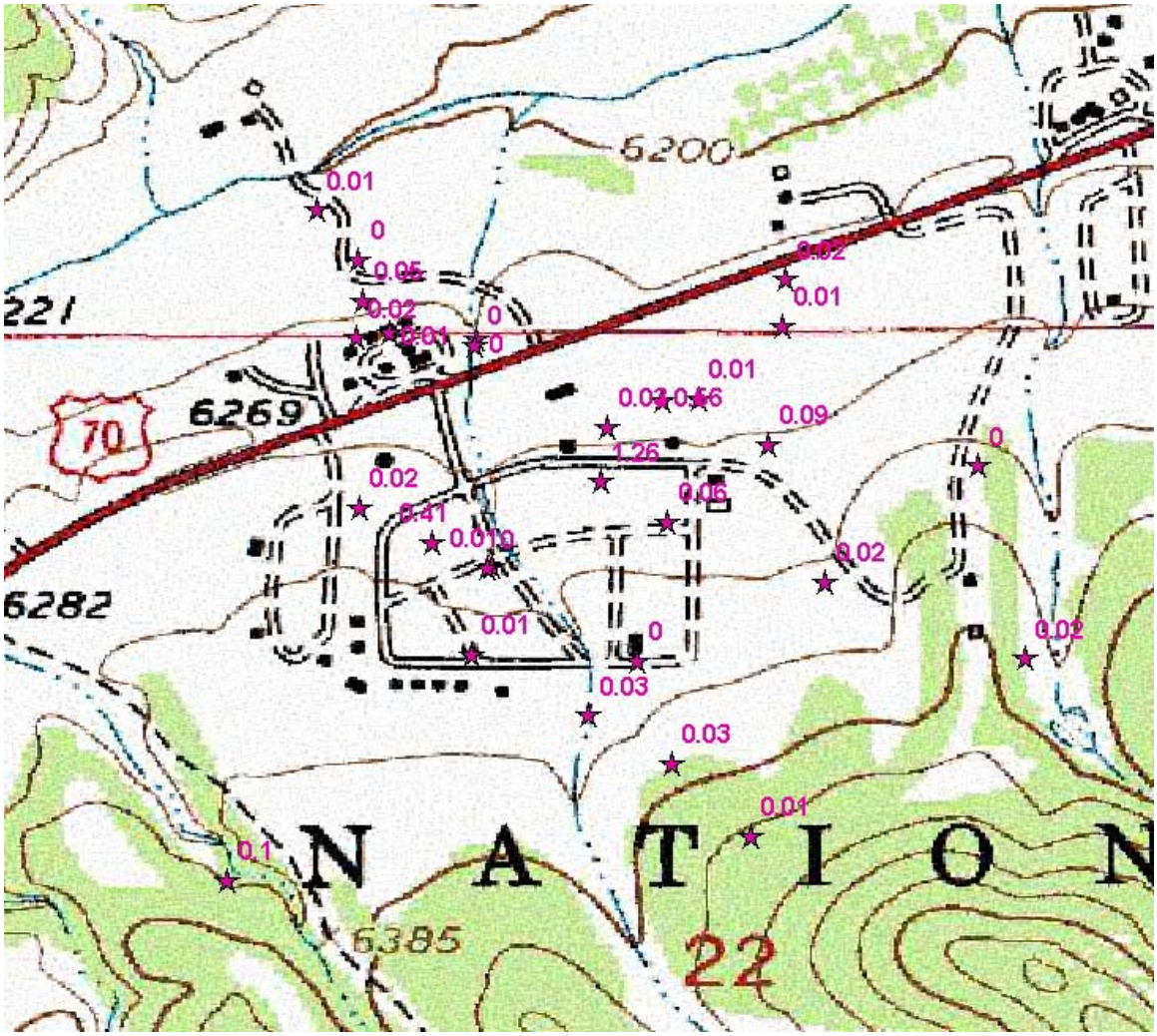


Figure 7. Fluoride (mg/L).

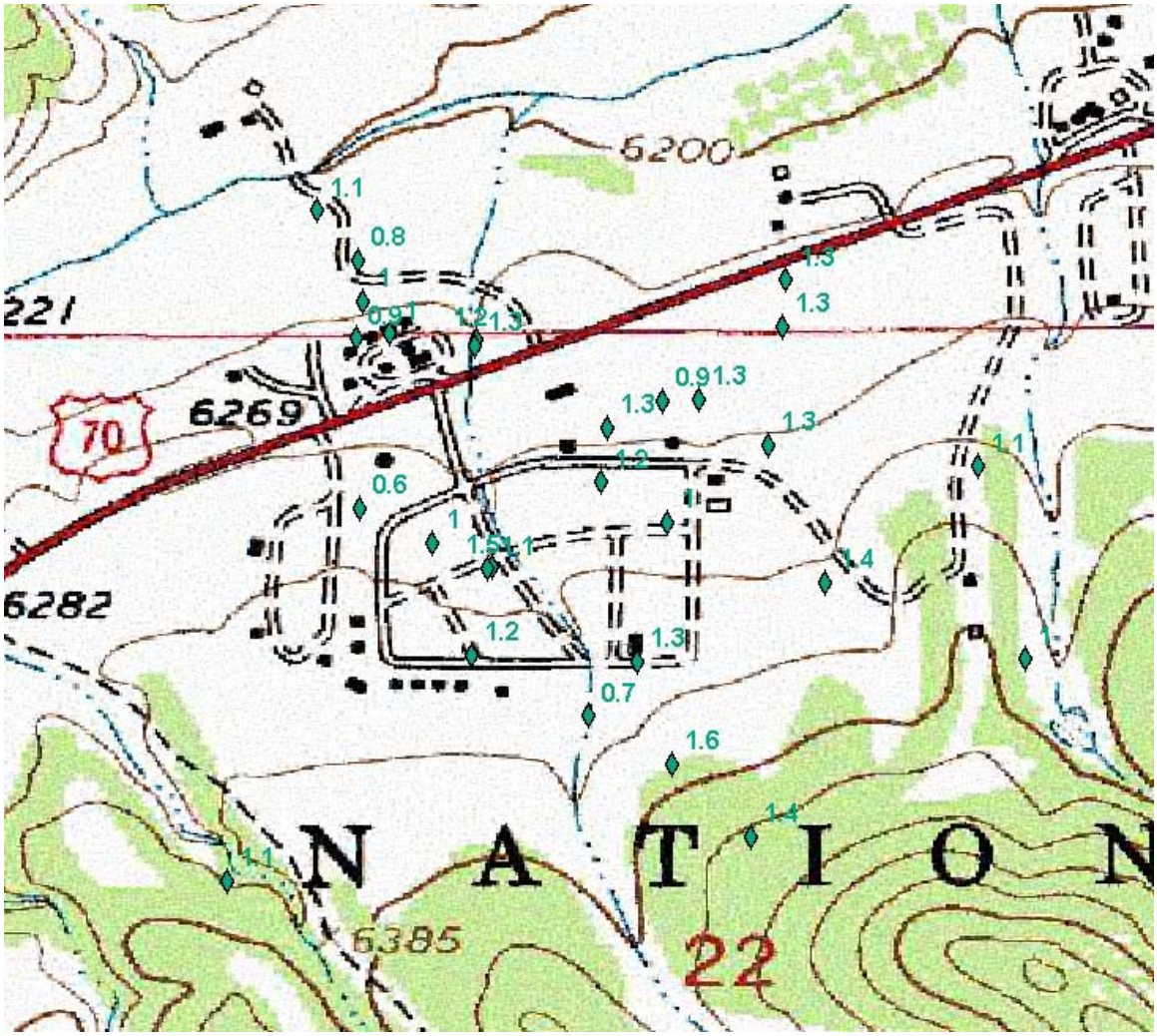
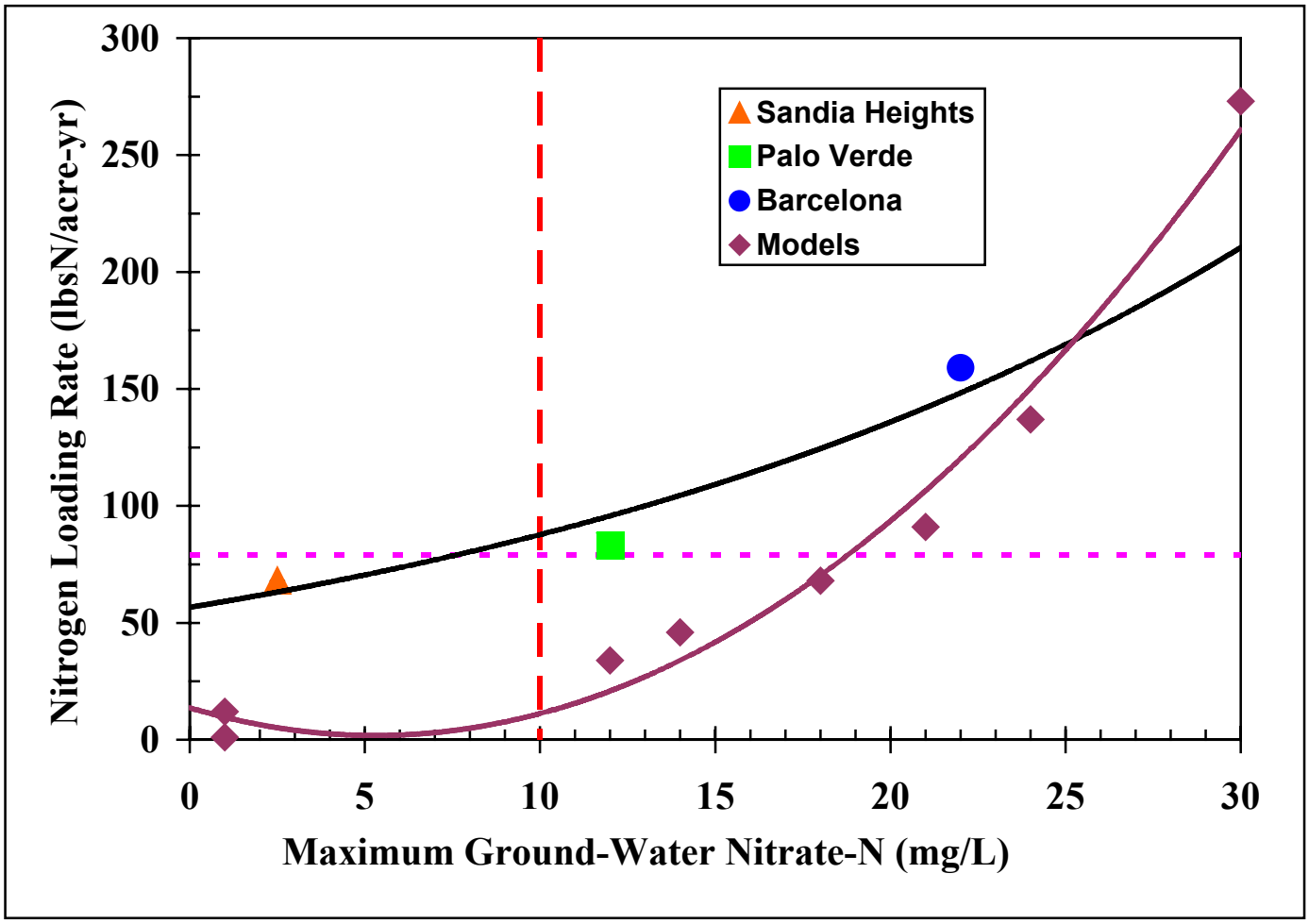


Figure 8. Nitrogen Loading Rates and Maximum Ground Water Nitrate Contamination from On-Site Septic Systems.

Data for three field sites in New Mexico (Sandia Heights, Palo Verde and Barcelona) are compared with modeling simulations for sites in New Mexico and Utah.

The health standard for nitrate in ground water and drinking water is 10 mg/L as N (vertical red dashed line). The allowable NLR in N.M. is 79 lbsN/acre-year (horizontal purple dashed line). The trendline for Sandia Heights, Palo Verde and Barcelona field study sites is shown in black. Modeling simulations are shown in plum with a plum trendline.