work. This area is dominated by steep cliffs composed of lower Paleozoic sedimentary rocks with some significant faults and folds.

Stratigraphy

The Yeso Formation is exposed in valley bottoms and the lower portions of valley side slopes, whereas the overlying San Andres Formation comprises the upper portions of valley slopes and caps the ridges (Figure 3, Plate 1). This pattern extends to a few miles east of longitude 105°30'0" west (a few miles east of Mayhill) where the easterly dip of the sedimentary rock layers causes the Yeso Formation to plunge beneath the ground surface. From this point east, the exposed bedrock is almost entirely the San Andres Formation. Furthermore, in this same vicinity it becomes possible to subdivide the San Andres Formation into the lower Rio Bonito member and the overlying Bonney Canyon member. As noted by Kelley (1971) and Black (1973), this subdivision is generally not possible further west because of tree cover and poor exposures. For example, it is likely that there is additional surface extent of the Bonney Canyon Member in the southwest portion of the study area, in the high elevation areas east of Timberon.

The Yeso Formation is composed of yellow to tan siltstone and fine sandstone, red to pink muddy siltstone and fine sandstone, gray to tan, often silty, carbonate rocks (limestone and dolomite, hereafter referred to generally as "carbonates"), and the evaporite minerals gypsum, anhydrite, and halite (Figure 4). Good, natural exposures of the Yeso Formation are rare, as it is less resistant than the overlying San Andres Formation and is usually covered with colluvium and valley bottom alluvium. A complete section is not exposed in the study area; Pray (1961) and Kelley (1971) measured one complete and two partial sections on the western escarpment, 11 miles north of the present study and at the extreme southwest corner of the present study. They estimated total thickness at 1300 – 1400 feet. The deep water well near Cloudcroft shown in Figure 4 penetrated 1650 feet of the Yeso formation. Anhydrite and/or gypsum is first observed at 930 feet below the top of the Yeso in this well, but at 260 feet depth in the southern surface section of Pray (1961). Anhydrite and minor halite were observed below 940 feet beneath the top of the Yeso in the Southern Production Co. #1 oil test well between Cloudcroft and the Rio Peñasco. No evaporites have been observed in surface exposures in the study area. In the upper portions of the Yeso Formation the evaporites have been dissolved, resulting in chaotic bedding dips. As a result, individual beds are not traceable laterally for more than a few tens of meters. In the area encompassing this study, Kelley (1971) and Pray (1961) noted that the gypsum content of the Yeso Formation increases to the north and the carbonate content increases to the south.

The San Andres Formation is composed of light to dark gray and bluish-gray carbonate rocks. Freshly broken surfaces are darker gray than weathered surfaces and often fetid. Subdivision of the San Andres into the lower dominantly thick-bedded Rio Bonito Member and overlying dominantly medium- to thin-bedded Bonney Canyon member (Kelley, 1971) was based largely on interpretation of aerial photographs. In most areas, the differences in the nature of the bedding are not reliably distinguishable on the ground. Kelley estimated thicknesses for the Rio Bonito Member at 250-350 feet and the Bonney Canyon Member at up to 300 feet. Based on our mapping, cross-sections, and well log interpretations, the thicknesses are ~580 and 400 feet, respectively. These differences are significant, but Kelley mapped at a much smaller scale (1:125,000) using a mix of air photo and topographic bases, and presented no cross-sections or well control to constrain his thickness estimates. Thickness variations on the order of ± 100 feet are likely in both members across the study area.

For the purposes of this study, younger geologic units have been generalized into Quaternary undivided alluvium, Quaternary landslide deposits and colluvium, and Quaternary and Tertiary terraces and gravels. The undivided alluvium includes unconsolidated alluvium in modern drainages, aeolian sand sheets, travertine

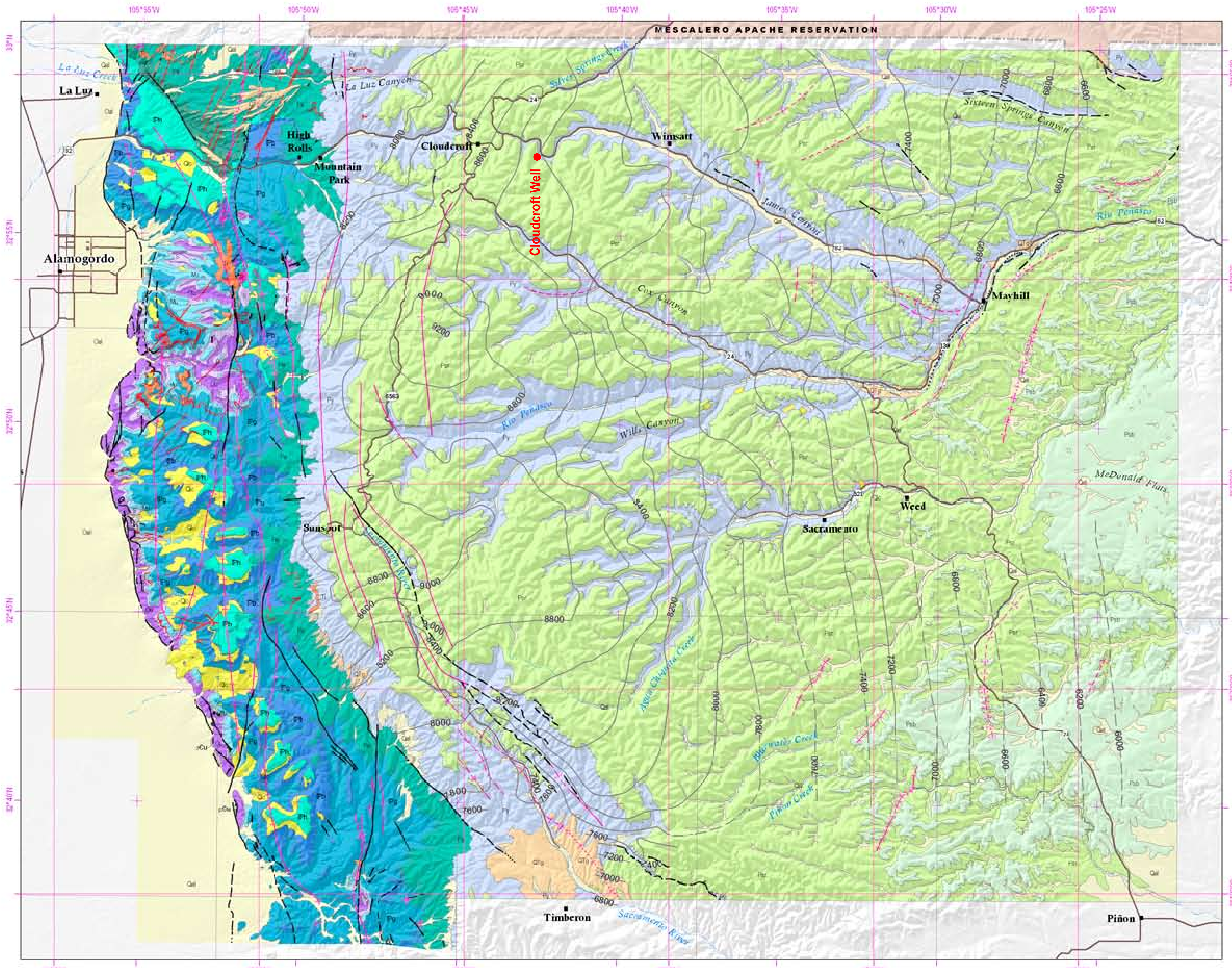

Figure 3–Generalized geologic map showing geologic units, faults and folds, and structural contours of the contact between the San Andres and Yeso Formations.

Explanation of Map Symbols

- Structural contour of the top of the Yeso Formation, dashed where approximately located (ft asl) Contour interval 200 ft
- Stream
- 7.5 min. Quadrangle boundary
- County boundary
- Tribal lands boundary
- Geologic contact

Faults

- Fault, certain, exposed
- Fault, certain, intermittent-obscured
- Fault, certain, concealed
- Fault, probable, intermittent-obscured
- Fault, probable, concealed
- Intrusion

Folds

- Anticline, certain, exposed
- Anticline, certain, intermittent-obscured
- Anticline, certain, concealed
- Syncline, certain, exposed
- Syncline, certain, intermittent-obscured
- Syncline, certain, concealed
- Monocline, certain, intermittent-obscured
- Monocline, probable, intermittent-obscured
- Monocline, probable, concealed

Geologic Units

Qal	*Quaternary alluvium in channels and valley bottoms, alluvial fan deposits, and spring deposits, undivided*
Qlc	*Quaternary and Tertiary (?) landslide deposits and colluvium, undivided*
QTg	*Quaternary and Tertiary terrace gravels*
Ti	*Tertiary intrusive igneous rocks, undivided*
Psb	*Bonney Canyon Member of the San Andres Formation*
Psr	*Rio Bonito Member of the San Andres Formation*
Py	*Yeso Formation*
Pa	*Abo Formations, undivided*
Pb	*Bursum Formations*
IPh	*Holder Formation*
IPb	*Beeman Formation*
IPg	*Gobbler Formation*
Mu	*Mississippian, undivided*
S	*Silurian, undivided*
Ou	*Ordovician, undivided*
p€u	*Precambrian, undivided*
daf	*Disturbed land/artificial fill*

N W E S

1:200,000

Miles 0 1 2 3 4 5

0 1 2 3 4 5 Kilometers

Base from U.S.Geological Survey 7.5-minute topographic maps 1927 North American datum, Universal Transverse Mercator Projection 10,000-meter UTM grid tics, zone 13, shown in pink

III. HYDROGEOLOGY

Introduction

As shown in Figure 7, Plate 2, the study area has been divided into four regional aquifers. The boundaries are largely based on topography (surface water drainage basins) and the water table map that represents the average surface of the water table on a regional scale. The boundary between the high mountain aquifer system and the Pecos Slope aquifer is based on water chemistry and flow characteristics and is approximately where the Yeso Formation dips below the ground surface. In this section, we will discuss the different types of data for the various physical components of the hydrologic system, which include precipitation, perennial streams, springs, and the deeper ground water system that is accessed by wells. We will discuss how these data vary on a regional scale and within the different aquifers.

Precipitation

Regional Weather Patterns

Precipitation is the primary source of all ground water recharge in the study area. To accurately estimate this input, it is necessary to understand how precipitation in the area varies both

Hydrogeology Background

The ease with which water can move through a rock is a reflection of the rock's permeability. This in turn is controlled by the rock's porosity, or percentage of internal void space, and the degree of interconnectivity of the pores. Related to permeability is transmissivity, which incorporates the thickness of the water-bearing unit; this term is often used when neither the permeability nor thickness is known exactly.

Aquifers are bodies of rock that are permeable enough to conduct ground water and that yield economically significant quantities of said water to springs and wells. The distinction between confined and unconfined aquifers needs to be understood to interpret the water level data we have collected. Confined aquifers are those in which there is an impermeable or relatively low-permeability layer between the aquifer and the ground surface that prohibits or inhibits the upward movement of water. Often water within confined aquifers is at pressures greater than atmospheric. This pressure causes water levels in wells penetrating confined aquifers to rise above the top of the aquifer, and can result in naturally flowing (artesian) wells where the water reaches the land surface. Unconfined aquifers are those in which there is no low-permeability layer preventing easy movement of water between the aquifer and the ground surface. The water level in a well that penetrates an unconfined aquifer will coincide with the top of the aquifer or the water table. In reality aquifers can exhibit behavior between these two extreme types. If a zone of low permeability material overlies or is within higher permeability materials, for example a clay or shale bed surrounded by sandstone, a perched aquifer can develop.

An example relevant to the present study is valley alluvium of mixed clay and sand on top of limestone bedrock. Perched aquifers are almost always unconfined, and result from ground water moving downward and collecting on top of the low permeability layer. Few geologic materials are totally impermeable, and thus there is usually slow downward leakage through the low permeability layer, resulting in some hydrologic connection with the underlying, more widespread, regional aquifer. This leakage may become more abundant during especially wet periods. Because of the likelihood of this leakage, in this report we refer to leaky aquifers which overlie the regional aquifer.

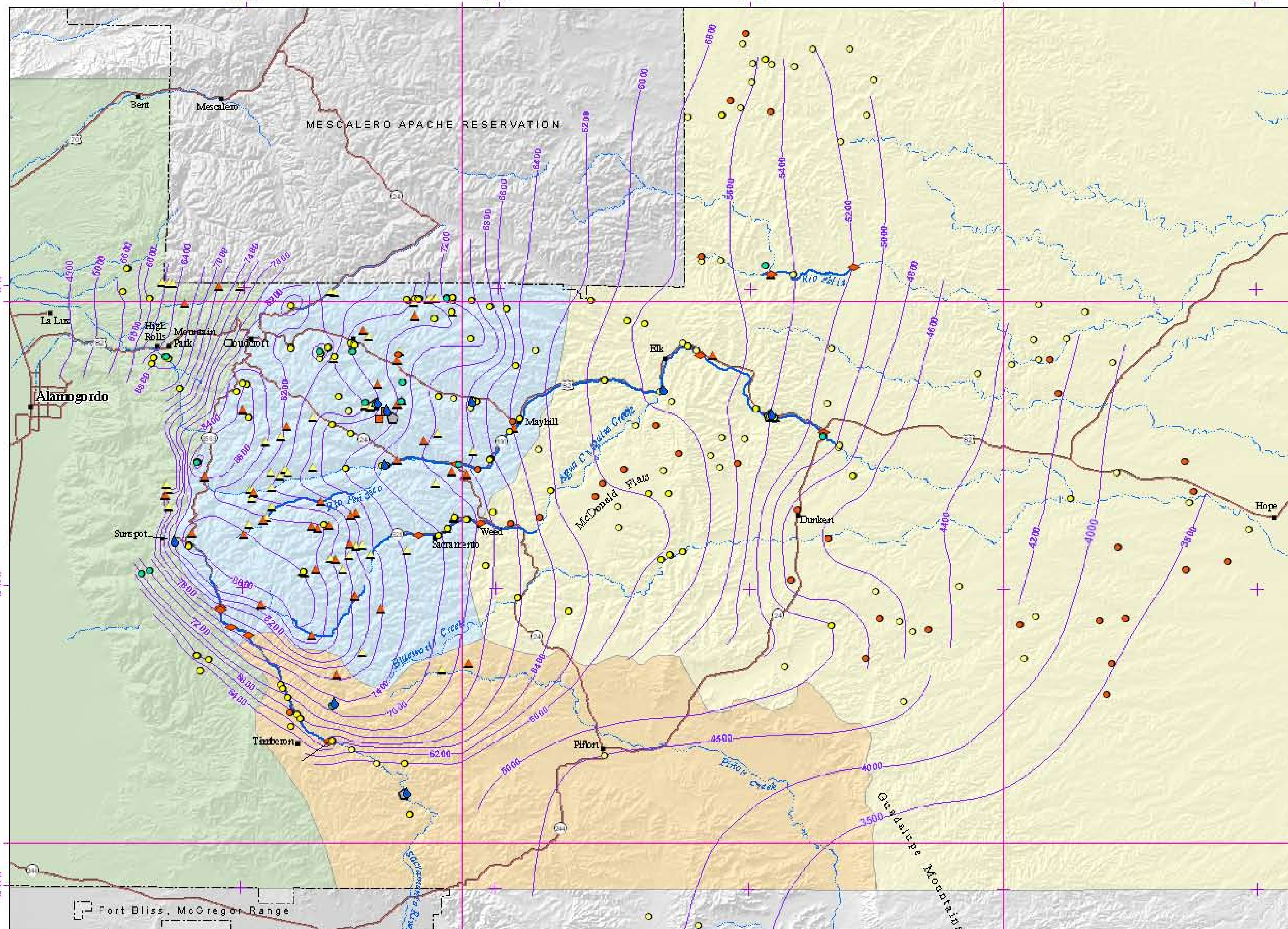

Figure 7–Map showing the regional aquifers and average water level elevation contours (in feet). Regional aquifer boundaries were delineated primarily based on surface water and ground water divides. The boundary between the high mountain aquifer system and the Pecos Slope aquifer is based on geology and water chemistry data. Ground water flow direction from the mountain crest toward Hope is generally west to east.

Hydrology

- Approximate ground water elevation in regional aquifer, March 2008 (ft asl) Contour interval 200 ft or 500 ft
- Ephemeral stream
- Perennial streams as of April 2008

Regional Aquifers

- Tularosa Basin mountain front aquifer
- High mountain aquifer system
- Pecos slope aquifer
- Salt Basin aquifer

Data Inventory

- Well inventoried &/or monitored
- Well sampled
- Well monitored with continuous data logger
- Spring inventoried
- Spring sampled
- Stream sampled
- Pond sampled
- Precipitation collection station
- Weather station

N W E S

1:375,000

Miles 0 2 4 6 8 10

0 2 4 6 8 10 Kilometers