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Background and Considerations for a Statewide Groundwater-Level Monitoring Network in New Mexico

Robert Pine, Stacy Timmons, Sara Chudnoff, Geoffrey C. Rawling, and B. Talon Newton

OPEN-FILE REPORT

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New Mexico Bureau of Geology and Mineral Resources
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New Mexico Bureau of Geology staff measuring depth to water in a dedicated monitoring well in Albuquerque. *Photo by Christi Bode, Moxiecran Media LLC*

CHAPTER I. INTRODUCTION

Robert Pine

Groundwater is one of New Mexico's most precious resources. An estimated 92% of the state's community drinking water systems are entirely or partly dependent on groundwater for their water source (NMED Drinking Water Bureau, n.d.). In addition, there are over 100,000 permitted domestic wells in the state. More than 12,000 irrigation wells are permitted by the New Mexico Office of the State Engineer (OSE), which estimated that 54% of all irrigated acreage in 2015 exclusively utilized groundwater and 15% utilized a combination of groundwater and surface water (Magnuson et al., 2019). Clearly, New Mexico's groundwater is essential to its social and economic wellbeing, and it must therefore be protected and properly managed to ensure that it remains an abundant and safe source of water for future generations.

However, this goal is by no means assured. Some aquifers are under considerable pressure due to the amount of current or proposed groundwater production. The OSE has temporarily or permanently closed several regions to new appropriations due to declining water levels or a deluge of applications for new water rights; however, a closure to new appropriations may not prevent groundwater levels from declining further if there are no changes to groundwater production rates. Climate change is resulting in increasing demand and decreasing aquifer recharge (Dunbar et al., 2022; IPCC, 2022), which adds additional stress on this essential resource and will likely lead to increasing rates of water-level decline. The need to understand and manage New Mexico's groundwater has never been greater, and the most essential tool for this is a properly designed statewide network of groundwater-level monitoring wells.

Wells are our window into the otherwise unseen realm of groundwater. In addition to producing water, the data that can be obtained from water wells can help us track long-term trends in water level and water quality, characterize aquifers, determine the direction of groundwater flow, understand aquifer response to production, understand aquifer recharge, understand groundwater-surface water interaction, build and update groundwater models, and set and track goals for proper water resource management. If we are to manage our groundwater resources in New Mexico to ensure a long-term supply for our community water systems, agriculture, and other essential uses, a properly designed groundwater monitoring network is crucial. Additionally, these data need to be readily accessible for a range of audiences for improved water management and planning.

THE IDEAL MONITORING NETWORK

An ideal groundwater-level monitoring well has the following characteristics:

1. It is located and designed to meet specific monitoring goals. Examples of monitoring goals include monitoring high-use areas where large drawdown and high variability in the water level are expected, monitoring background areas where there is little impact from production and where variability in water level more reflects changes in recharge or natural discharge, monitoring groundwater-surface water interaction, and determining the direction of groundwater flow.
2. It is properly designed and installed to meet state well construction requirements and monitor the target aquifer(s).
3. It is geologically and hydrogeologically characterized by logging during installation by a professional geologist, including data collection such as geophysical logging, water

chemistry sampling, and aquifer testing. It is not often that we have this level of characterization in the vicinity of a monitoring well.

4. It is guaranteed to have long-term access so the well is always available for manual measurements or equipment maintenance and the well will generate long-term time-series data. If the well is privately owned and/or located on private land, the ability to access the well may change over time, and routine and long-term use of the well are thus not guaranteed. According to the U.S. Geological Survey (USGS), "Long-term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time, to develop ground-water models and forecast trends, and to design, implement, and monitor the effectiveness of ground-water management and protection programs" (Taylor and Alley, 2001, p. 1).
5. It is dedicated exclusively to groundwater monitoring. If a production well is used as a monitoring well, the water level may not be static if the well had been in operation shortly before measurement.
6. It is monitored at the desired rate, which may be continuous, seasonal, annual, or some other appropriate frequency. There is often a lot of variability in water levels on a daily or seasonal basis, and this variability goes undetected if the monitoring frequency is insufficient (see discussion below).

An ideal groundwater-level monitoring network of wells monitoring a particular region or aquifer has the following characteristics:

1. It is composed of ideal monitoring wells.
2. It is monitored for the long term, with funding and staff to support operation and maintenance of equipment and data collection.
3. The monitoring data are made rapidly and readily available to the public.

However, despite the large amount of groundwater data that have been produced over the years in New Mexico (and elsewhere), few of the wells or monitoring networks that have produced these data are close to ideal.

GROUNDWATER-LEVEL MONITORING IN NEW MEXICO

Groundwater-level data in New Mexico have been primarily collected by the USGS and the New Mexico Bureau of Geology and Mineral Resources (NMBGMR). Additionally, groundwater data have been collected by OSE, both on a regular and ad hoc basis, and by other various public and private regional entities such as local homeowners' associations, the Pecos Valley Artesian Conservancy District (PVACD), the Elephant Butte Irrigation District, Bernalillo County, and the Estancia Basin Water Planning Committee. The USGS and NMBGMR make their data readily available online, but the data collected by the other various entities can be difficult to obtain and may be stored in a manner that requires consolidation of multiple datasets, reformatting, and/or transformation of data, which can be quite time consuming.

The vast majority of wells that have been used for groundwater monitoring are wells of opportunity, i.e., wells that were installed for production purposes but have been made available for water-level monitoring. These wells can be problematic because they may 1) at times be unavailable or inaccessible; 2) have been producing water just prior to water-level measurement, which may make a static water level unobtainable; 3) be of unknown construction, so it may not be clear which aquifer is being monitored in a multiple-aquifer scenario (approximately 110 of the active annual USGS wells are listed as "depth unknown"); and 4) not be located in optimal locations to meet the monitoring objectives. It should be noted that USGS is planning to start obtaining total depth measurements at all the annual wells in the future at a regular interval (L. Henson, personal communication).

The amount of USGS monitoring has been variable over time but has generally been decreasing. Figure 1-1 shows the number of USGS monitoring wells and measurements from 1950 through 2021. The reasons for the decrease are not completely clear based on conversations with USGS personnel but are likely due to a combination of funding and change in focus. Some of the measurements were collected as part of a 5-year measurement cycle, some of which have been discontinued.

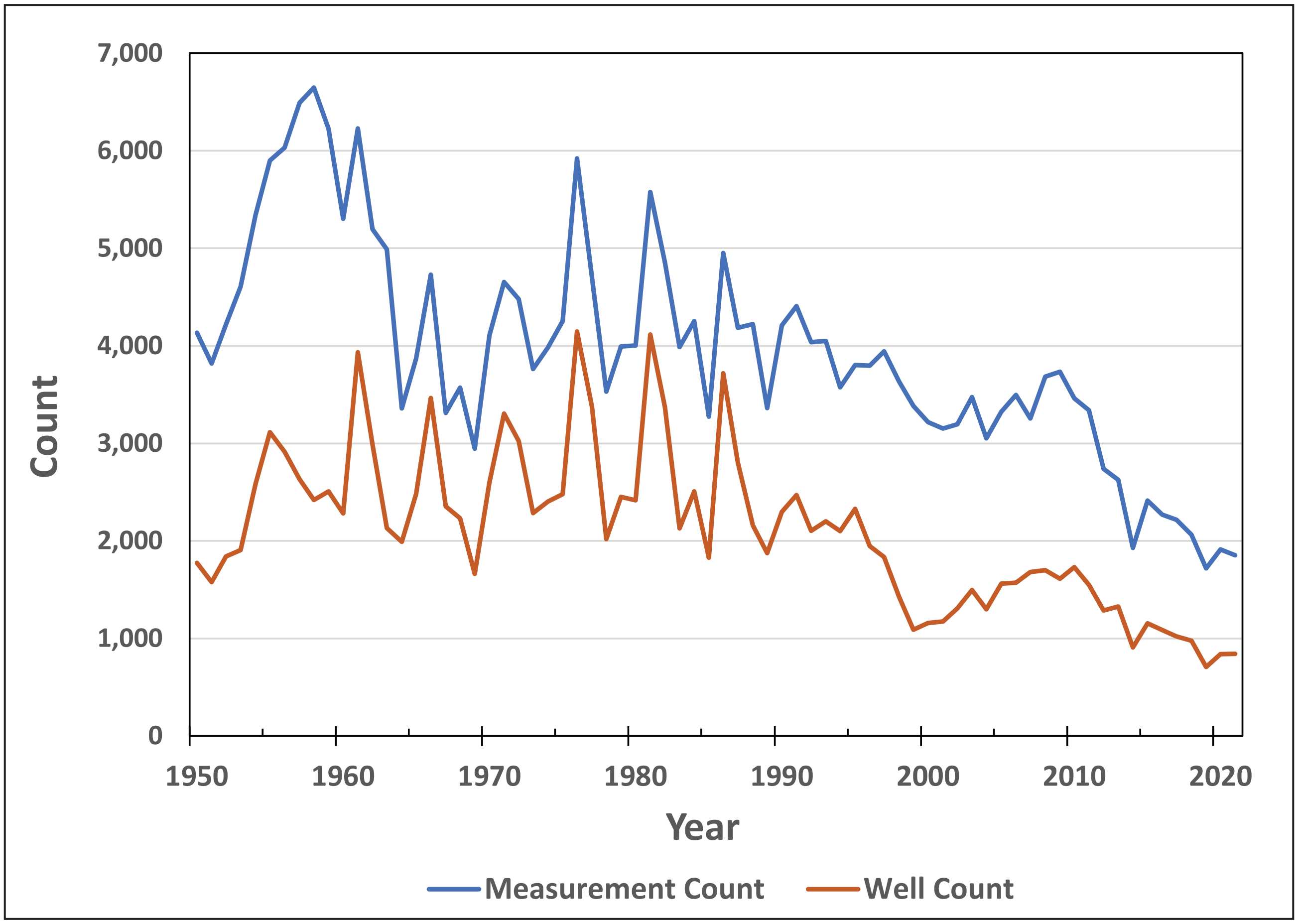

Figure 1-1. Changes in the number of USGS monitoring wells and water-level measurements in New Mexico from 1950–2021. Based on data obtained from USGS from wells not continuously monitored.

Many of the well measurements were one-time measurements that were collected as part of basin-specific studies, which have declined in number in recent years. The USGS annual network is funded in large part by OSE, and attempts are made to measure these wells each year, though issues such as accessibility or obstructions may prevent a measurement from being taken. If a well must be removed from the annual cycle, a replacement well is sought.

The extent of currently active monitoring wells in New Mexico is quite variable depending on location. Figure 1-2 shows the distribution of active USGS and NMBGMR monitoring wells throughout the state. This is also available for interactive viewing online at https://newmexicowaterdata.org/new-mexico-water-data-viz/. Regarding this spatial distribution of wells, the following should be noted:

1. The areas in the state with the highest density of monitoring wells are within the Rio Grande corridor (i.e., within about 4 mi of the river) in the Middle and Lower Rio Grande basins and in various locations within the High Plains aquifer in eastern New Mexico.
2. There are many areas in the state that currently have little or no active groundwater monitoring, including entire declared underground water basins. Some of these regions have a considerable amount of permitted agricultural or commercial groundwater diversion and may have public supply wells and many domestic wells.
3. There are currently 112 USGS continuously monitored wells across the state, approximately 80% of which are within the Rio Grande corridor, leaving relatively few for the rest of the state.

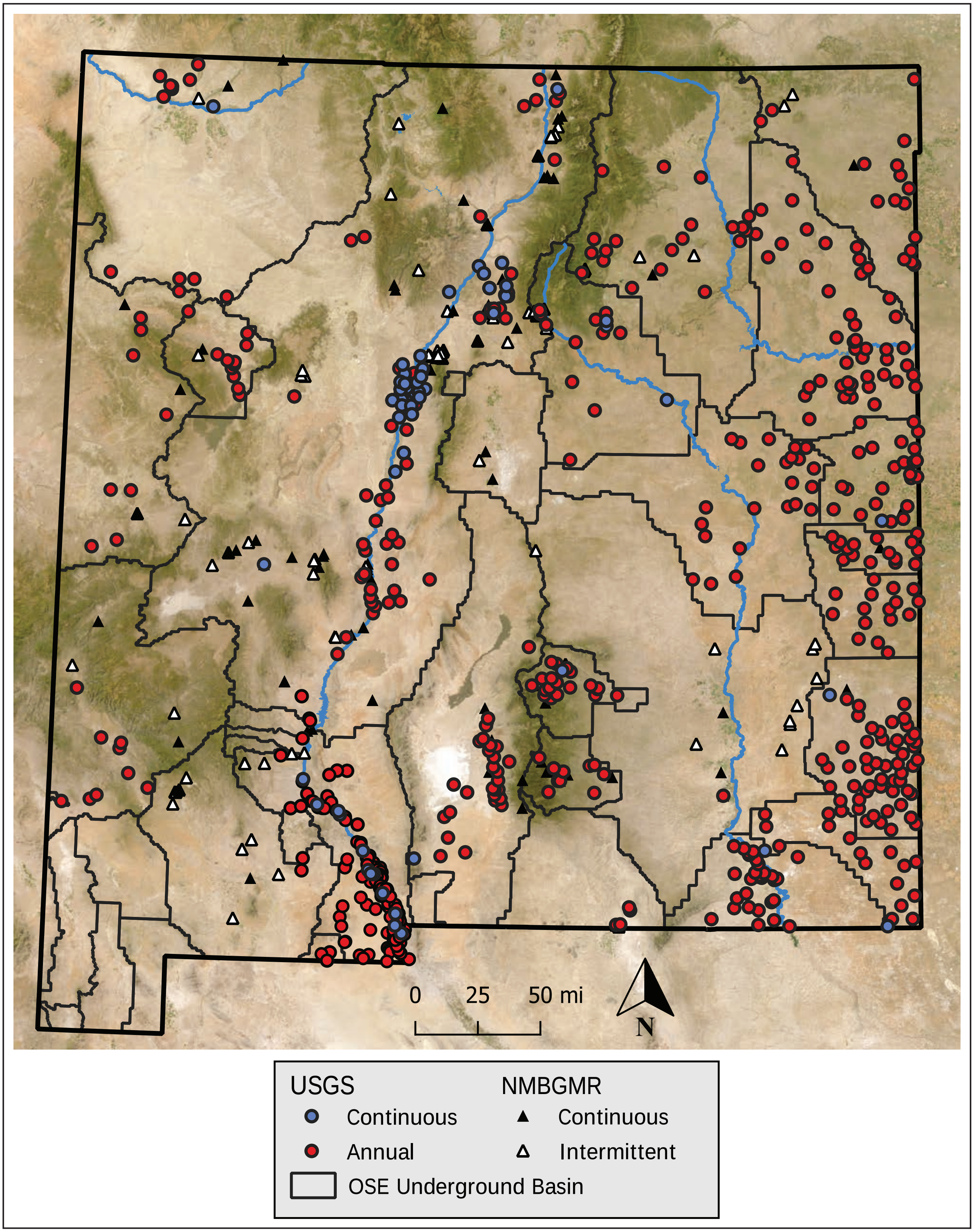

Figure 1-2. Currently active USGS and NMBGMR monitoring wells in New Mexico.

PROJECT OVERVIEW

The goal of this project, supported by the Thornburg Foundation, is to provide background information for New Mexico to guide development of a modern and dedicated statewide groundwater-level monitoring network that can reliably support effective water resource management and planning, i.e., to develop an ideal groundwater monitoring network. It is not intended to replace any monitoring regime that may currently be in place. Instead, it is meant to supplement and enhance it by guaranteeing high-quality, continuous, long-term data in strategic locations.

Methods

The scope of the project, while statewide, was focused on 10 selected priority regions. Various people were interviewed prior to selecting the priority regions, including OSE district managers, OSE Hydrology Bureau staff, and hydrology consultants, to learn their thoughts on groundwater monitoring needs, which helped focus the selection of the 10 regions. Criteria used to select the regions were 1) a lack of sufficient active groundwater monitoring, 2) declining water levels or a recent increase in demand that may result in declining water levels, 3) a lack of reliable or available surface water supply, and 4) significant groundwater demand for drinking water, irrigation, and/or commercial use. The 10 regions selected are shown in Figure 1-3.

For each project region, groundwater use (quantity and geographic distribution), active and historical groundwater monitoring, geology, hydrology, modeling efforts, and land ownership are reviewed. Groundwater models were not used in this analysis to determine proposed well locations; however, before installing a proposed well, consultation with modelers actively involved in the construction, calibration, or updating of a model in a project region of interest is recommended to see if particular well locations would be beneficial for the modeling effort. Land ownership is considered because one of the primary goals of the network is to guarantee long-term access to each well, and that is best accomplished by locating the well on public land. For the 10 regions, differing amounts of federal and state public land can be found. For state land, this generally means land owned and managed by the New Mexico State Land Office. For federal land, it usually means land managed by the Bureau of Land Management (BLM), though in some cases there may be land managed by the U.S. Forest Service. The locations of the proposed wells in the 10 regions are shown in Figure 1-3.

Summary of Results

After reviewing the data for each of the 10 regions, desired locations for the installation of dedicated monitoring wells were selected. Goals for siting monitoring wells were primarily to track long-term trends in areas of high use and to monitor background levels. Background water levels are important to monitor because changes in groundwater level could be caused by both groundwater pumping and changes in recharge. A strategically placed background monitoring well that is minimally impacted by groundwater pumping could help distinguish between the different potential causes of water-level changes. Water quality monitoring was not the focus, though proposed wells certainly could be used to monitor water quality.

In order to ensure proper well construction and advance our geologic and hydrogeologic knowledge of the aquifer, each well installation will include 1) attendance and logging by a professional geologist during installation, 2) geophysical logging to include gamma ray density and electrical resistivity, and 3) aquifer testing (single well or multi-well when feasible), both step drawdown and constant rate. These data, paired with water-level data, would improve the quality of groundwater models that are essential tools for active groundwater management and water rights administration.

We also propose that each of the recommended wells be instrumented with a transducer, logger, and telemetry to enable continuous water-level monitoring and to allow for instantaneous data retrieval. Continuous water-level monitoring of each well is desired in order to understand the aquifer response to daily and seasonal changes in production and recharge. Figure 1-4 is a graph of water-level data for 2021 from NMBGMR well NM-28255, a PVACD dedicated monitoring well located northwest of Hagerman in an area of significant groundwater irrigation. One can readily see that there is a considerable amount of variability in the water level, with a range of over 137 ft. This variability is not just seasonal but varies on a weekly basis.

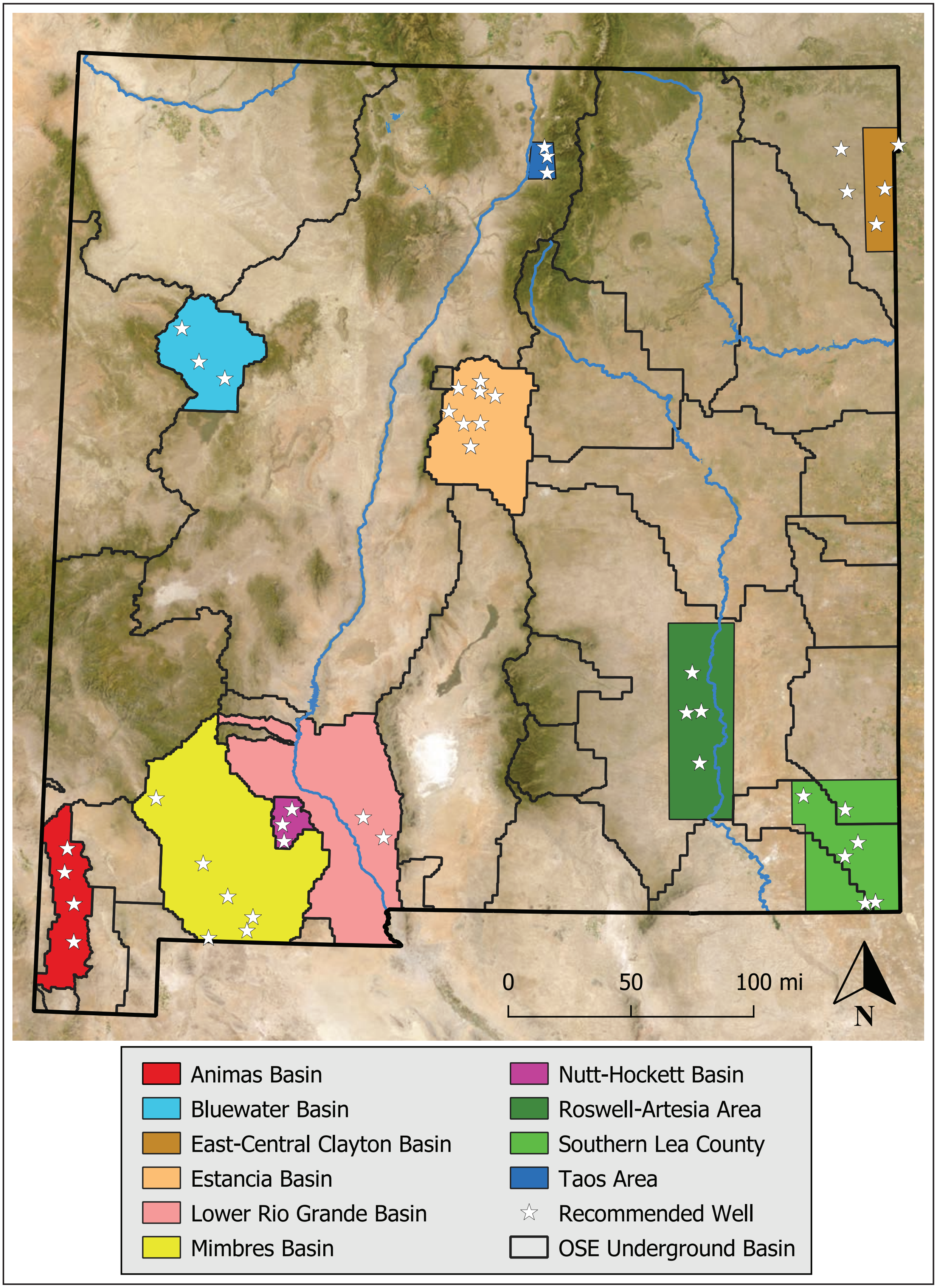

Figure 1-3. Ten selected monitoring well network project regions and locations of proposed wells.

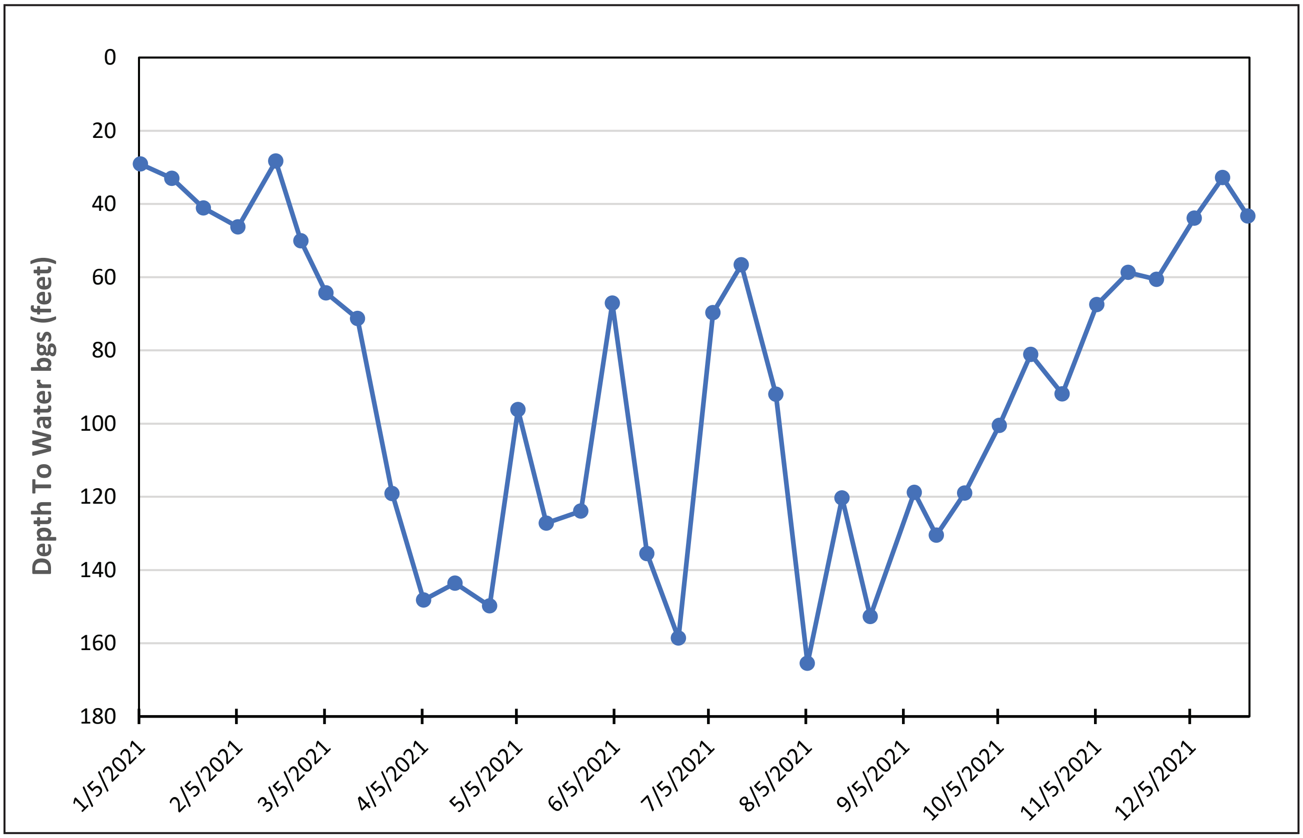

Figure 1-4. Depth to groundwater below ground surface (bgs) from NMBGMR monitoring well NM-28255 for 2021 showing the extent of variability. This well is located northwest of Hagerman in the Roswell Artesian Basin in an area of significant groundwater irrigation.

If one took annual or quarterly measurements from this well, a very skewed picture of water-level changes would be obtained, likely missing the extreme values. Therefore, continuous monitoring is considered essential, at least for the first few years of operation until there is a clear picture of the aquifer response. It may be determined over time that less-frequent measurements would be sufficient.

For each region, the cost for the recommended wells was estimated based on information obtained from various drillers, consultants, geophysical testing companies, and past expenses for instrumenting wells in the NMBGMR network. These costs are tabulated at the end of each region's description. Actual costs may vary depending on local conditions and inflation. An estimate of the potential costs per region can be found in Table 1-1, which lists the regions in ranked priority order (see Chapter 12 for more information on ranking). A review of possible next steps for this work can be found in Chapter 12.

Table 1-1. Estimated costs for proposed wells by region. More detailed descriptions for each region are found at the end of each chapter.

Priority Rank	Region	Number of Wells	Cost Estimate	
			Low	High
1	Estancia Basin	8	$1,178,000	$1,376,000
2	Roswell Area	4	$334,000	$406,000
3	Southern Lea County	6	$779,000	$1,265,000
4	Lower Rio Grande Basin	2	$322,000	$358,000
5	Nutt-Hockett Basin	3	$432,000	$487,000
6	East-Central Clayton Basin	5	$695,000	$785,000
7	Bluewater Basin	3	$545,000	$600,000
8	Mimbres Basin	6	$729,000	$838,000
9	Animas Basin	4	$368,000	$440,000
10	Taos Area	3	$284,000	$338,000
TOTAL			$5,666,000	$6,893,000

TERMINOLOGY

The term "basin" is commonly used in hydrology and geology but has multiple meanings depending on the context. In groundwater hydrology, the term is defined by Fetter (2001) as a "subsurface volume through which groundwater flows toward a specific discharge zone." However, this definition is problematic because a geographic area defined as a basin may have multiple aquifers, each with different boundaries, and any particular aquifer may have multiple discharge zones. The term "basin" is used in this report in two ways:

1. An OSE Declared Groundwater Basin (also referred to by OSE as a Declared Underground Water Basin), defined by OSE as "an area of the state proclaimed by the State Engineer to be underlying by a groundwater source having reasonably ascertainable boundaries" (OSE, n.d.). Once the State Engineer declares a basin, OSE has "jurisdiction over the appropriation and use of groundwater from the source." The entire state has been divided into 39 declared basins. These basins should be thought of as administrative rather than hydrologic because in many cases the boundaries of aquifers contained in the basins do not align with the boundaries of the basin. The 39 declared groundwater basins are shown in Figures 1-2 and 1-3. Some of the 10 project regions are declared groundwater basins, while others are contained within a basin.
2. Structural depressions that have filled with fluvial and eolian deposits that host aquifers are referred to as basins. The Lower Rio Grande Declared Groundwater Basin contains portions of two such basins, known as the Mesilla Basin and Jornada del Muerto Basin.

The OSE's database for tracking water rights is the Water Administration Technical Engineering Resource System (WATERS), which also tracks wells associated with New Mexico's water rights. Some of these wells were entered into the system through the application process for a new, replacement, or supplemental well. For many of these wells with an approved application, OSE never received a well log, and so it is not clear if the wells were ever drilled. Many wells entered into WATERS were submitted to OSE as part of a declaration, meaning the well was drilled and put to beneficial use prior to the basin being declared; such wells rarely have a well log available in WATERS or the OSE files. Regardless of how the well came to be entered into WATERS, such wells are referred to in this report as "OSE wells."

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CHAPTER 2. ANIMAS BASIN

Robert Pine

The Animas Underground Water Basin (referred to here as the Animas Basin or the Basin) is located in the southwestern corner of New Mexico within Hidalgo County. The city of Lordsburg lies just to the east of the northern portion of the Basin. The Basin is approximately 1,073 mi^2. There are no municipalities within the Basin, but the unincorporated communities of Animas and Cotton City, with populations of around 120 and 320, respectively, do lie within the Basin. The New Mexico Office of the State Engineer (OSE) published administrative guidelines for the Basin in 2016, with the central portion of the Basin being designated a Critical Management Area (CMA; Fig. 2-1). Applications for new appropriations are denied inside the CMA but are accepted outside of the CMA.

GEOLOGY AND HYDROLOGY

The Animas Basin is located within the Basin and Range physiographic province. It is bounded on the west by the Guadalupe-Peloncillo range, which rises in places 2,200 ft above the basin floor. The Animas Mountains form the eastern boundary of the southern basin, rising as much as 3,400 ft above the valley floor. The continental divide approximately follows this eastern boundary of the Animas Basin along these mountains. North of the Animas Mountains, the eastern boundary follows the Pyramid Mountains, which rise approximately 1,600 ft from the valley floor. The northern boundary is a hilly region that forms the divide separating the Basin from the Gila River drainage.

The Animas Basin is a hydrologically closed basin with respect to surface water, i.e., surface water does not flow out of the Basin. It is divided into the upper (southern) and lower (northern) basin, with the dividing line located approximately 4 mi south of the community of Animas (see Fig. 2-1). This division was recognized as early as 1918 (Schwennesen), but the dividing line is not clearly defined. The distinction between the upper and lower basin is based on multiple factors.

1. Topography: The grade of the valley floor of the upper basin is steeper than the lower basin, and the mountains on either side of the lower basin have considerably more relief, forming a narrower valley than in the lower basin.
2. Surface water: Most of the surface water in the Animas Basin is ephemeral, though there are a few short semi-perennial stretches of Animas Creek, the primary stream in the Basin, and other ephemeral streams such as Clanton Draw in the lower basin. When Animas Creek does flow, water tends to fully infiltrate by the time it reaches north of the community of Animas. Approximately 30 mi north of the community of Animas are playa lake beds—remnants of a late Pleistocene lake—that occasionally fill with surface water, although this drainage is primarily from the Lordsburg Basin (Hawley et al., 2000). There is a peak-flow stream gage (USGS 09438200) located on Animas Creek approximately 6.8 mi north of the Basin's southern boundary. Over its period of record from 1959–2020, the average annual peak flow was 1,686 cubic feet per second (cfs), with a couple of years of no flow and an extreme event in July of 2020 of 6,040 cfs.
3. Aquifer thickness: The primary aquifer in the Animas Basin is in the Gila Group that fills the valley. It is significantly thicker in the lower basin.

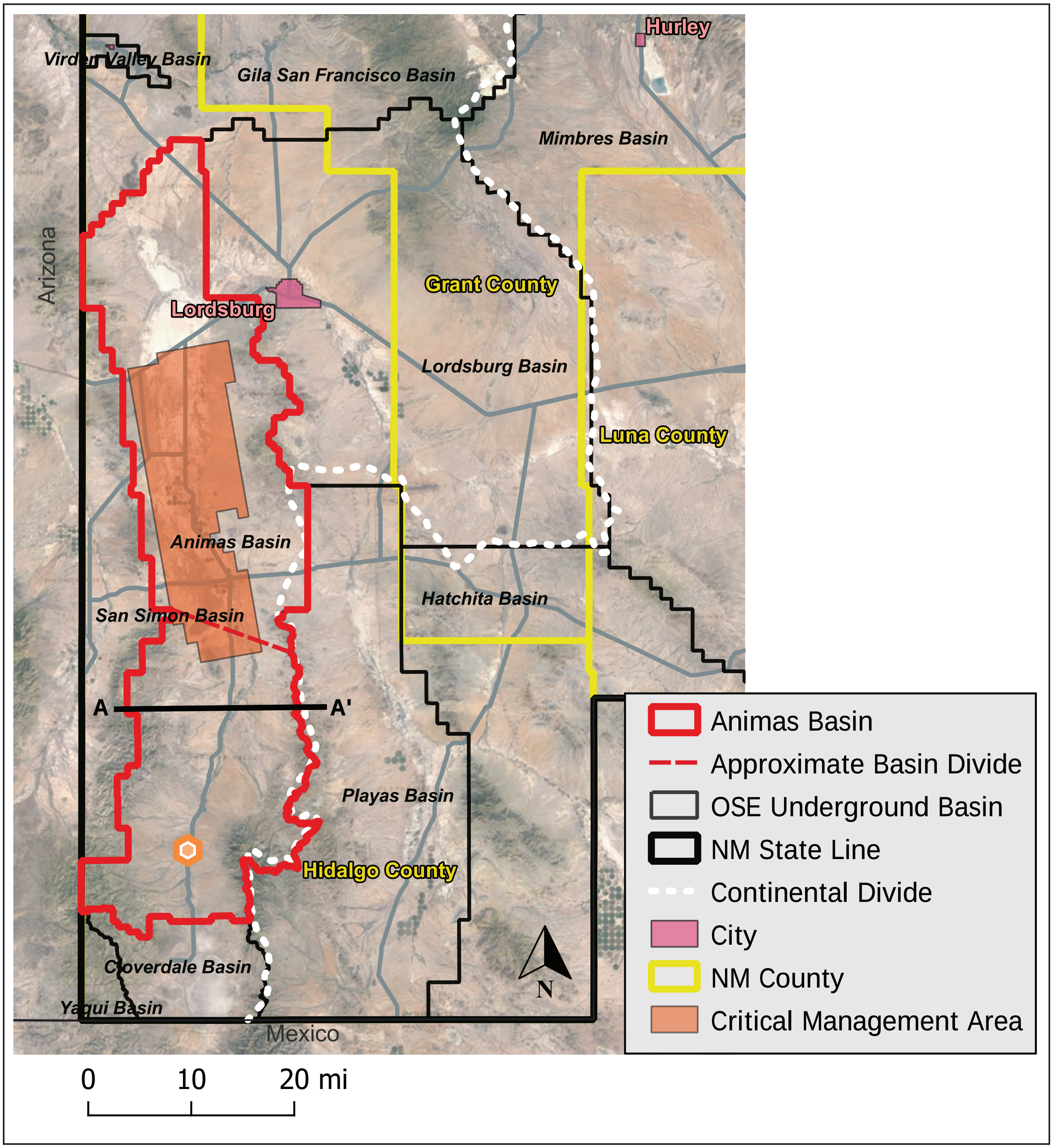
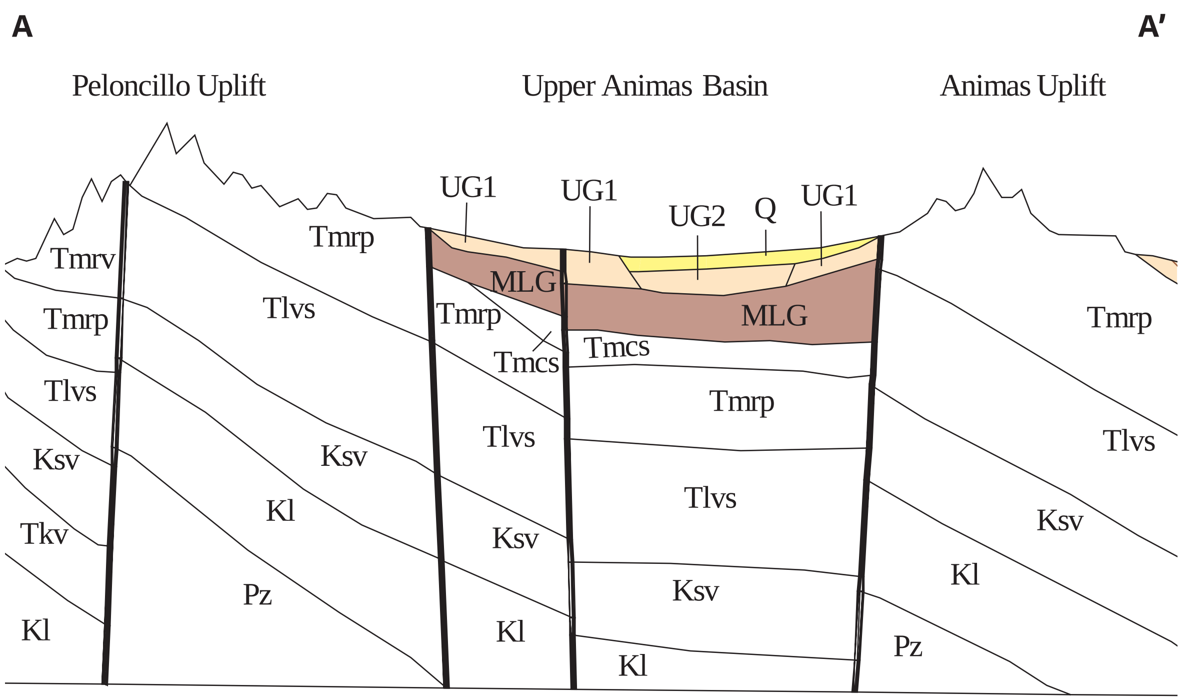


Figure 2-1. Overview of the Animas Basin showing OSE administrative areas, continental divide, and neighboring declared underground water basins. Line A–A' indicates cross section shown in Figure 2-2.

The Neogene and Quaternary Animas Basin fill, classified as Gila Group, is typical of the Basin and Range Province, having a characteristic hydrostratigraphic profile with a coarser texture near the mountain block and increasingly finer texture as one moves down to the basin floor (Hawley et al., 2000). However, vertical stratification occurs with layers of clay interbedded with coarser layers of sand and gravel (O'Brien and Stone, 1982). The basin fill is reported to reach a thickness of over 2,000 ft on the west side of the lower basin southwest of Lordsburg based on seismic studies (Klein, 1995). Despite this thickness, the majority of wells completed in the basin fill are less than 500 ft deep and mostly do not reach bedrock (based on review of many driller's logs). The Gila Group deposits underlie Quaternary alluvial, floodplain, and lacustrine deposits that generally are not saturated.

Bedrock below the basin fill is generally Tertiary volcanics with occasional interbedded sedimentary rock. Underlying the volcanics are Paleozoic and Mesozoic sedimentary formations. Volcanic and sedimentary rock thickness, based on seismic and drillhole data, is on the order of 3,200 ft (Klein, 1995). A drillhole located in the northern portion of the Basin approximately 12 mi southwest of Lordsburg had approximately 1,500 ft of volcanics underlying the Gila Group (Thompson, 1981). Figure 2-2 is a generalized geologic cross section from the upper Animas Basin.



Q	Generalized late Quaternary deposits, including fluvial, terrace, and piedmont deposits	**Tmrp**	Middle Tertiary ash-flow tuffs
UG1	Upper Gila Group piedmont slope facies	**Tlvs**	Lower Tertiary volcaniclastic sedimentary rocks and some andesite flows
UG2	Upper Gila Group basin floor deposits	**Ksv**	Upper Cretaceous undivided sedimentary and volcanic rocks
MLG	Middle and lower Gila Group	**Tkv**	Lower Tertiary and Upper Cretaceous andesite flows and breccias
Tmcs	Middle Tertiary sedimentary rocks, mainly volcaniclastic conglomerate and sandstone	**Kl**	Lower Cretaceous undivided sedimentary rocks
Tmrv	Middle Tertiary lavas, with some dacite breccias, silicic ash-flow tuffs, and andesite flows	**Pz**	Paleozoic undivided sedimentary rocks

Figure 2-2. Generalized geologic cross section of the upper Animas Basin (modified from Hawley et al. [2000]). See Figure 2-1 for location of cross section.

Groundwater in the lower basin occurs in the Gila Group and in both the Gila Group and more recent deposits in the upper basin. It is possible that groundwater occurs in the underlying volcanics, but this has not been studied. Saturated thickness throughout the Basin has not been mapped, but deeper Gila Group deposits tend to be very fine grained (Hawley et al., 2000) and so may not produce sufficient quantities of water to function as an aquifer. The general groundwater flow direction in the Basin is to the north. Though the Basin is closed with respect to surface water, groundwater mapping implies that groundwater exits the Basin toward the Gila River in the northern portion of the Basin (O'Brien and Stone, 1981). In addition, mapping shows that groundwater flows into the Animas Basin from the Lordsburg Basin. Hawley et al. (2000) consider the Lordsburg Basin to be part of the Animas Basin, and so like many other OSE declared underground water basins, the Animas Basin is more an administrative basin than a hydrologic basin.

In the vicinity of Cotton City is a geothermal hot spot, discovered in the 1950s, known as the Lightning Dock Known Geothermal Resource Area. Cyrq Energy is currently generating power from geothermal waters that it pumps to the surface from two wells and reinjects to similar depths in seven injection wells in a process that is ostensibly non-consumptive. Oversight of the production and injection wells is by the Energy Conservation and Management Division of the New Mexico Energy, Minerals and Natural Resources Department rather than by OSE.

Several estimates of groundwater recharge in the region have been made (Reeder, 1957; Trauger, 1972; O'Brien and Stone, 1983; Hawley et al., 2000), all being fairly crude estimates. This is an area in need of more rigorous study.

WATER RIGHTS AND WATER USE

The primary consumptive use of groundwater in the Animas Basin is agricultural. The Basin has 35,558 acre-feet per year (acre-ft/yr) of irrigation water rights, of which 3,840 are surface diversions. Crops grown include cotton, alfalfa, chile, and pecans. Irrigation began in the valley in the early 1900s, but the late 1940s and 1950s saw a significant increase in irrigated acreage and well installation. The Basin is also home to AmeriCulture, a tilapia fish farm with 1,775.52 acre-ft/yr of water rights, though this water use is claimed to be non-consumptive through reinjection. Most of the agricultural diversions are found in the lower basin and within the CMA. There are no municipal supply wells in the Basin; however, there are 299 permitted domestic wells, of which 265 have submitted well records. There are 247 permitted livestock wells in the Basin (51 of these are permitted for both domestic and livestock use). Figure 2-3 shows the distribution of production wells in the Basin.

GROUNDWATER MONITORING

Currently, neither the U.S. Geological Survey (USGS) nor the New Mexico Bureau of Geology and Mineral Resources has any active monitoring wells in the Basin. There are several wells in the Basin that were previously monitored by OSE (with data provided to USGS for inclusion in the National Water Information System), with time-series data available. Many of these wells have shown a steady decline. Table 2-1 lists some of these wells and their average rate of decline (see Fig. 2-3 for locations). These wells are located in the lower basin where most of the agricultural activity takes place. Wells in the upper basin and the northern portion of the lower basin do not show much or any decline.

Table 2-1. Average rates of decline for select wells in the Animas Basin.

USGS Well Number	Well Depth (ft)	Period of Measurement	Average Rate of Decline (ft/yr)
321002108523701	100	1951–2008	0.64
320528108523701	205	1948–2008	1.1
315949108495001	200	1948–2008	1.1
315616108491601	300	1948–1975	1.7

GROUNDWATER MODELS

The OSE utilizes a calibrated groundwater model it created in 2002 called the Animas-Lordsburg Model to administer water rights within the lower Animas Basin and the Lordsburg Basin (Johnson and Rappuhn, 2002). The model has one layer simulating the upper Gila Group with no-flow boundaries representing the Peloncillo Mountains and Pyramid Mountains.

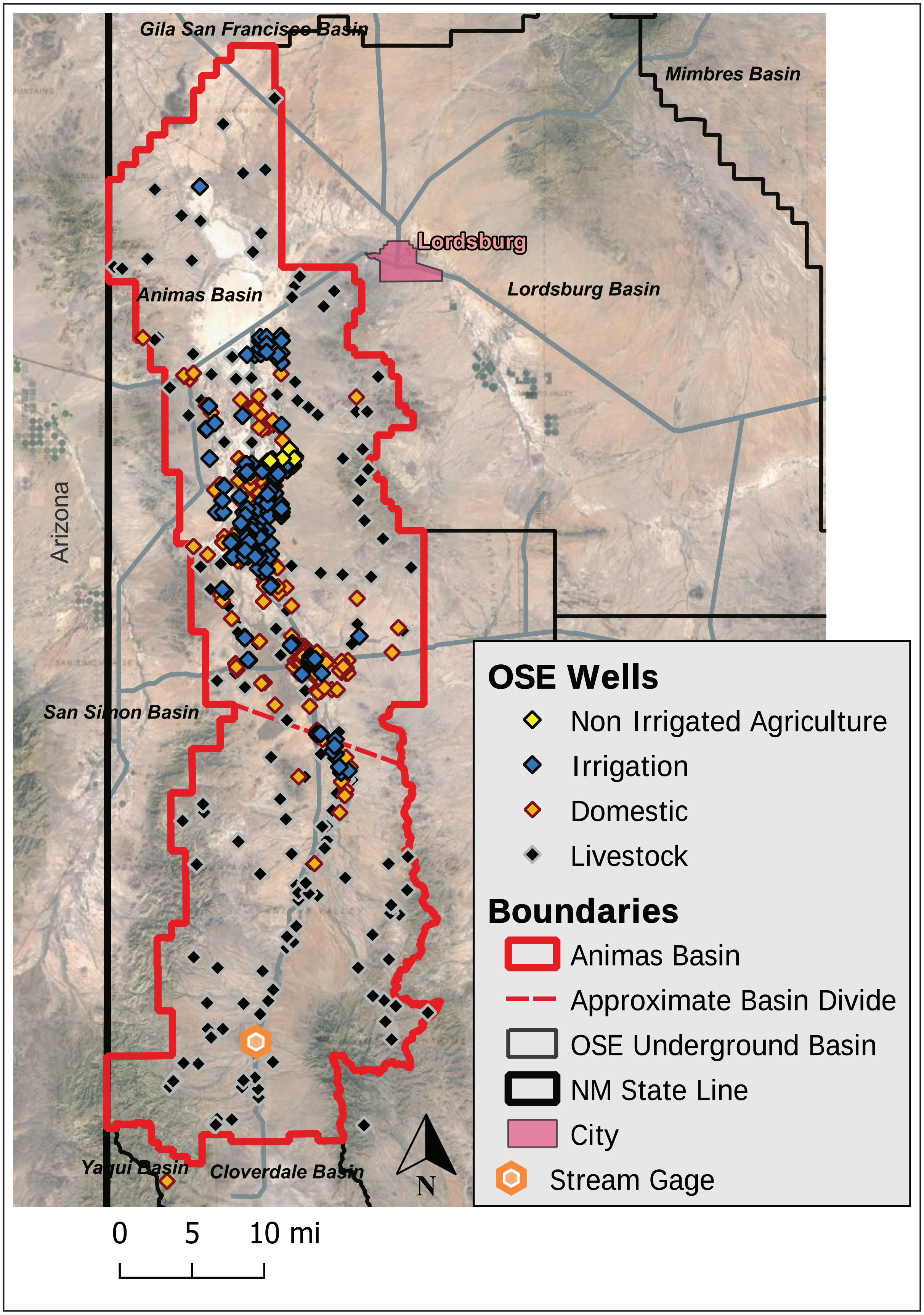


Figure 2-3. OSE wells in the Animas Basin by use. Declining groundwater-level monitoring wells shown are described in Table 2-1.

LAND SURFACE OWNERSHIP

Within the Animas Basin there is a mix of state, federal (Bureau of Land Management [BLM]), and private land as shown on Figure 2-4. Abundant public land is found in the portions of the Basin with the most agricultural production. However, a significant portion of this land is in roadless areas.

MONITORING RECOMMENDATIONS

Figure 2-4 shows recommended locations for groundwater monitoring. Estimated costs to install these wells can be found in Table 2-2.

Table 2-2. Cost estimates for recommended monitoring wells in the Animas Basin.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
				Low	High
1	300	100	No	$100,000	$118,000
2	400	100	No	$119,000	$137,000
3	150	50	No	$70,000	$88,000
4	200	50	No	$79,000	$97,000
TOTAL				$368,000	$440,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. High-use area just downgradient from the largest cluster of irrigation wells in the vicinity of Cotton City and near the AmeriCulture and Cyrq Energy geothermal wells. This site contains several sections of state land that can be accessed by road. There are well logs in the area with conflicting geologic information, some saying basin fill material down to 300 ft and others below 500 ft. Depth to water in the area is approximately 120 ft, so this monitoring well should be drilled to a depth of at least 300 ft.

Location 2. High-use area just downgradient from the cluster of irrigation wells near the community of Animas. There are several sections of state land with road access in this area. Depth to water in this area is approximately 170 ft, but the hydrograph for USGS 315802108500001 suggests that the water table can drop 100 ft during irrigation season, so the recommended monitoring well depth should be at least 400 ft.

Location 3. Background well in the upper Animas Basin located near Animas Creek approximately 12 mi downstream of the USGS annual peak-flow gage. There are several options within 2.5 mi of the creek on state or BLM land with road access. Depth to water for the shallow aquifer is approximately 60 ft; the bottom depth is not known, but for estimation purposes will be assumed to be 150 ft. Depth to water for the deeper aquifer is greater than 160 ft. This well should be drilled to the bottom of the shallow aquifer, which enables a look at aquifer response to ephemeral flow in the creek.

Location 4. Background well within the lower basin near the intersection of Interstate 10 and Highway 338. It is primarily BLM land with some state and private land. Locations farther north would have been preferred for a background well, but road access to the north of this area is quite limited. There are no historical monitoring wells in this area, but USGS well 321515108464501, located approximately 4 mi to the southwest, has shown a steady rate of decline of only 0.17 ft/yr. Depths to groundwater and to the bottom of the bolson deposits are unknown, so it is difficult to estimate the cost of this well, but a depth of 200 ft will be assumed for estimation purposes.

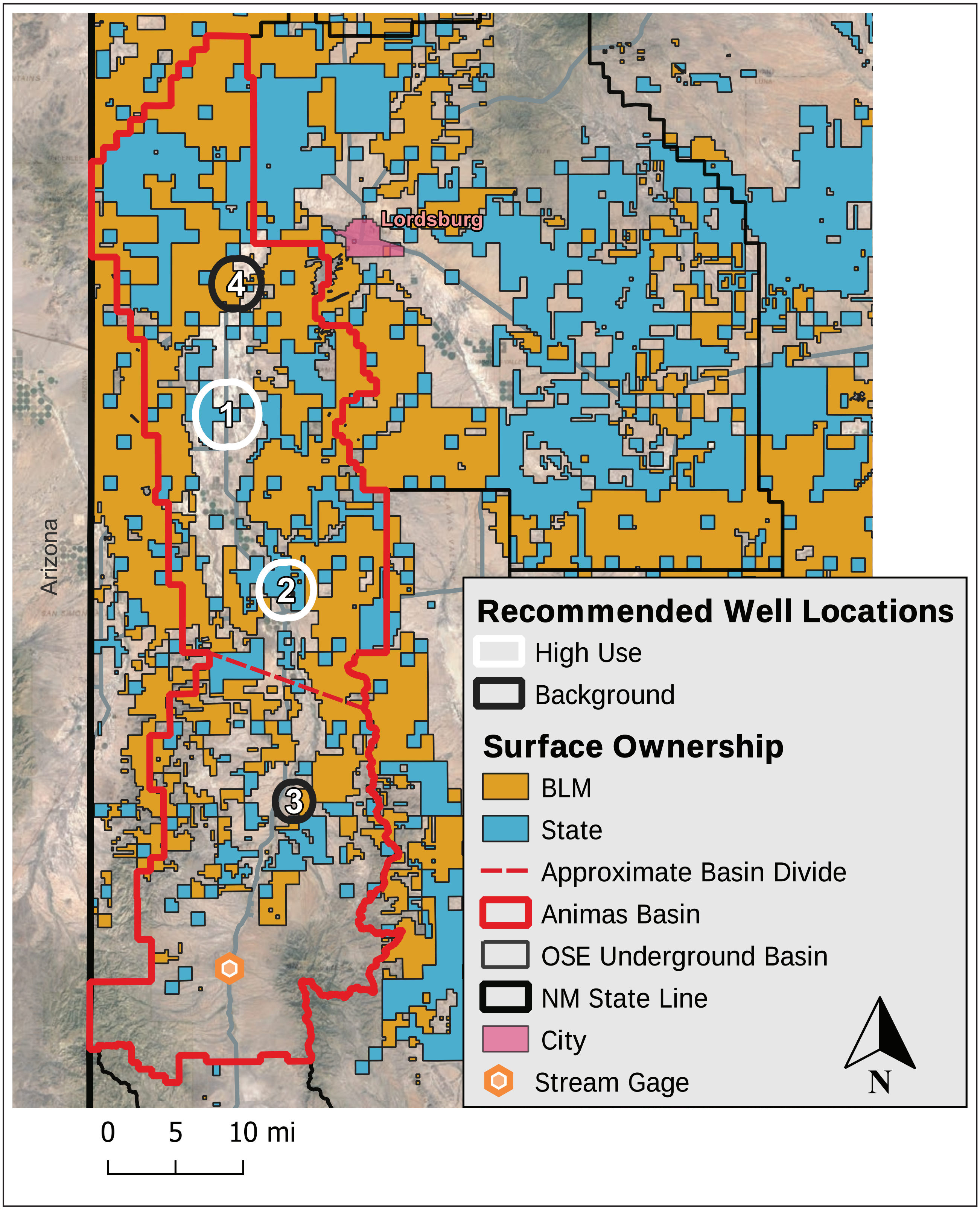


Figure 2-4. Animas Basin recommended well locations and land surface ownership. No color indicates private land.

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CHAPTER 3. BLUEWATER BASIN

B. Talon Newton

The Bluewater Underground Water Basin (referred to here as the Bluewater Basin), as declared by the New Mexico Office of the State Engineer (OSE) in 1956, is located in western New Mexico in northern Cibola County and south-central McKinley County (Fig. 3-1). The Bluewater Basin is a broad valley with adjacent highlands on the flanks of the Zuni Mountains and the volcanic area surrounding Mount Taylor. Most residents in the Bluewater Basin live in Grants, Milan, Thoreau, and San Rafael. Grants is the largest city in the Bluewater Basin, with a population of 9,163 according to the 2020 census. Milan and Thoreau have much smaller populations of between 2,000 and 3,000 residents. All other cities or villages have fewer than 1,000 residents.

The population of Grants (and this area in general) increased from 2,251 in 1950 to 10,226 in 1960 due to the development of extensive uranium deposits in the area, which lasted through the early 1980s. Between 1951 and 1980, the Grants mineral belt (also known as the Grants uranium district; Fig. 3-1) produced more uranium than any other district in the United States (McLemore, 2010). There are two subdistricts of the Grants mineral belt within the Bluewater Basin: the Smith Lake district, located on the northwestern edge of the Basin, and the Ambrosia Lake district, located along the eastern edge of the Basin (Fig. 3-1). The Ambrosia Lake district is one of the largest subdistricts in the Grants mineral belt, with over 30 uranium mines in operation at different times between 1950 and 2002 (McLemore, 2010). Most uranium in the Grants mineral belt is extracted from the Westwater Canyon Member of the Morrison Formation, which is a regional artesian aquifer in the Ambrosia Lake area. Therefore, mining the uranium required extensive dewatering, which resulted in a significant decline in the potentiometric surface. Brod and Stone (1981) determined that over a 30-year period, the potentiometric surface near Ambrosia Lake had declined approximately 400 to 500 ft. While there is currently no active uranium mining in the area, there is the possibility of mining projects in the future. For example, a feasibility study for the Crownpoint and Hosta Butte Uranium Project, located just outside of the Bluewater Basin, is being conducted (Beahm et al., 2022).

Groundwater contamination related to uranium mining and the milling process in the Ambrosia Lake area is an ongoing issue. The Homestake uranium mill Superfund site, located north of Milan (Fig. 3-2), has documented water quality impacts on groundwater in the alluvial and Chinle aquifers and is on the National Priorities List (NM Interstate Stream Commission, 2017). Contaminants include uranium, selenium, radium isotopes, and other metals associated with uranium milling. Domestic wells near the site have been shut down, and water from the Milan community system is being provided to residents. In addition to water quality impacts related to uranium mining, groundwater in the area of Grants and Milan has been impacted by organic chemicals derived from solvents and gasoline (NM Interstate Stream Commission, 2017).

GEOLOGY AND HYDROLOGY

Structural features in western New Mexico include the Zuni uplift, Gallup embayment, Acoma embayment, Lucero uplift, Rio Puerco fault zone, and Nacimiento uplift (Fig. 3-3). The Bluewater Basin is located within the Zuni uplift, which is an elongate dome about 75 mi long and 40 mi wide that formed during Laramide compressional deformation about 75 to 50 million years ago. The western boundary of the Bluewater Basin coincides with the continental divide, and the northeastern boundary is roughly defined by the northern boundary of the Zuni uplift. Mount Taylor is located at the far eastern boundary of the Bluewater Basin. Strata in the Zuni Mountains were uplifted vertically several thousand feet.

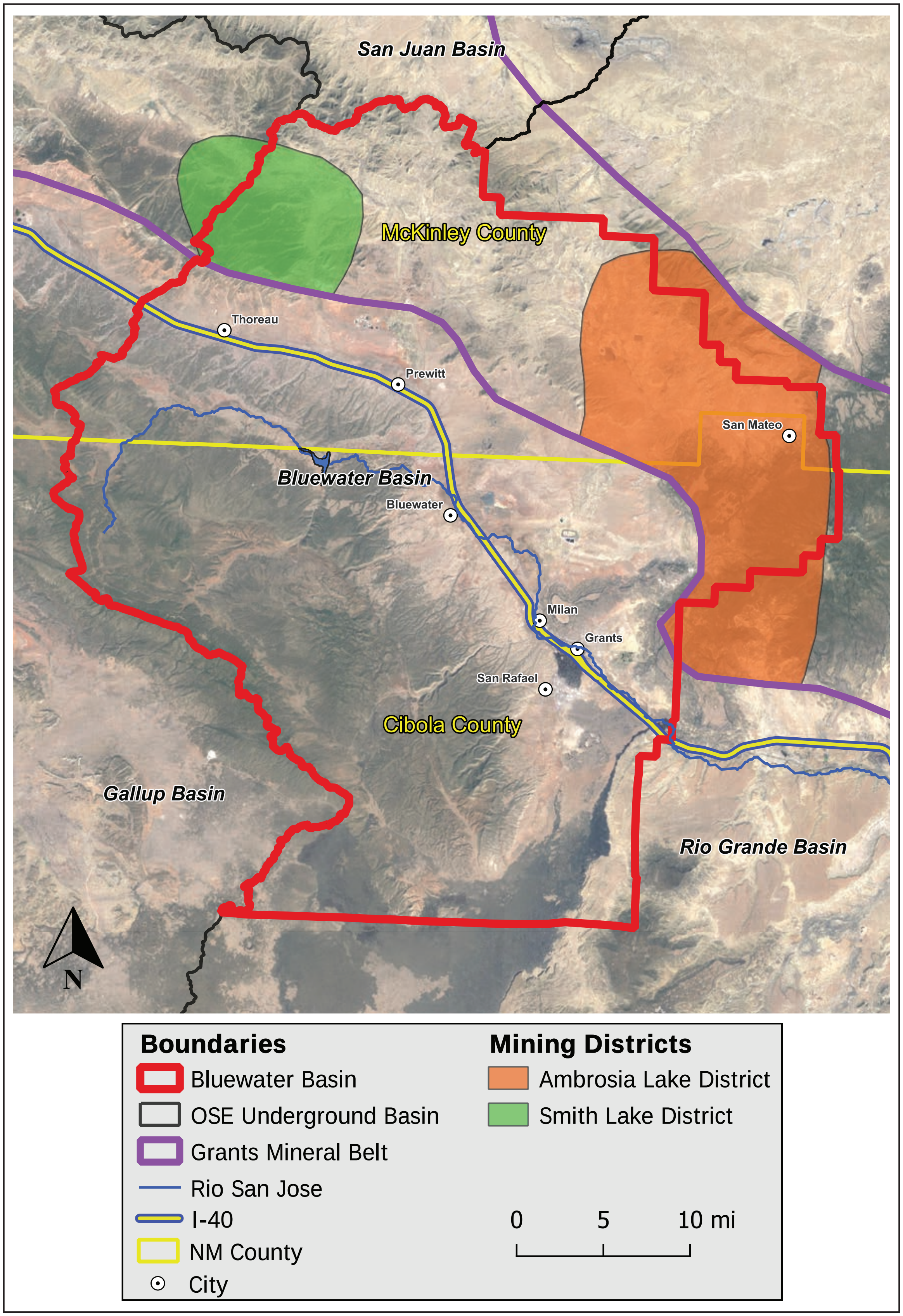

Figure 3-1. Overview of the Bluewater Underground Water Basin, the approximate boundary of the Grants mineral belt, and the different mining districts.

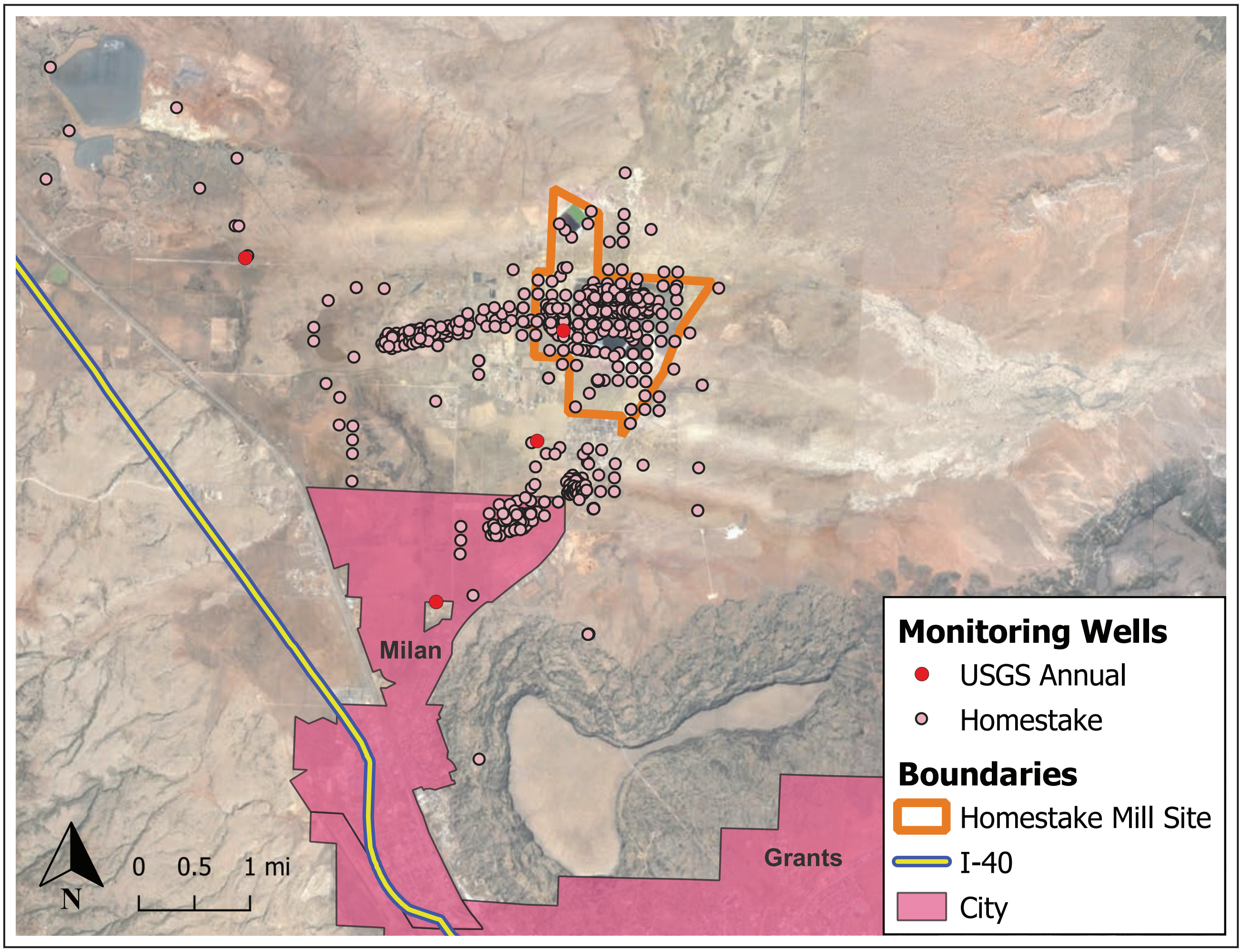

Figure 3-2. Location of the Homestake mining site, which consists of the former uranium mill site and two tailings disposal sites, and Homestake monitoring wells.

Erosion of the Zuni uplift has exposed crystalline rocks of Precambrian age and sedimentary strata of Pennsylvanian, Permian, Triassic, Jurassic, and Cretaceous ages (Baldwin and Rankin, 1995).

Figure 3-4 shows the surface geology within the Bluewater Basin according to the New Mexico state geologic map (Scholle, 2003). Precambrian rocks, which include igneous and metamorphic rocks (Xg, Xvf, and Xpc on geologic map), are exposed in the central core of the Zuni Mountains but are overlain by as much as 6,000 ft of younger rocks as one moves away from the Zuni Mountains. Pennsylvanian rocks, which do not crop out in within the Bluewater Basin, include conglomerate, shale, and limestone.

Permian rocks, including the Abo and Yeso Formations, the Glorieta Sandstone, and the San Andres Limestone, overlie Pennsylvanian strata. The Abo (Pa) and Yeso (Py) Formations are exposed in the Zuni Mountains around the margins of the Precambrian rocks and along the southwestern boundary of the Bluewater Basin. The Glorieta Sandstone (Pg) and the San Andres Limestone (Psa) are exposed along the northeastern flank of the Zuni Mountains. The San Andres Limestone in this area (80–150 ft thick) consists of a lower massive limestone, a middle medium-grained sandstone, and an upper fossiliferous limestone. The San Andres Limestone is characterized by karst features, such as caverns, sink holes, and solution channels.

Triassic rocks in the Bluewater Basin are primarily made up of the Chinle Formation (ŦRc), which is exposed along the northeastern flank of the Zuni Mountains and south of Interstate 40. The Chinle Formation is 1,400 to 1,600 ft thick and consists of varicolored clay and siltstone, interbedded silty sandstone, and some coarse-grained to conglomeritic sandstone.

Overlying the Chinle Formation are sedimentary strata of middle to late Jurassic age. Jurassic rocks (Jsr = San Raphael Group, Jm = Morrison Formation, and J = Upper and Middle Jurassic rocks). The San Rafael Group (Jsr) includes the Entrada Sandstone, Todilto Limestone, Summerville Formation, and Bluff Sandstone. The Morrison Formation is composed mostly of claystone, siltstone, and sandstone. Within the Bluewater Basin, these rocks are exposed in the western portion and north of Interstate 40. It is the Westwater Canyon Member of the Morrison Formation that produces most of the uranium in the Bluewater Basin.

Cretaceous rocks (Kmd = Mancos Shale and Dakota Sandstone, Kml = Mancos Shale, Kg = Gallup Sandstone, Kcc = Crevasse Canyon Formation, Kmm = Mulatto Tongue of Mancos Shale, and Kpl = Point Lookout Sandstone) are exposed in the northern portion of the Bluewater Basin. These strata, which unconformably overlie Jurassic rocks, consist of thick sequences of shale and sandstone and contain some coal seams that are of economic value (Gordon et al., 1961).

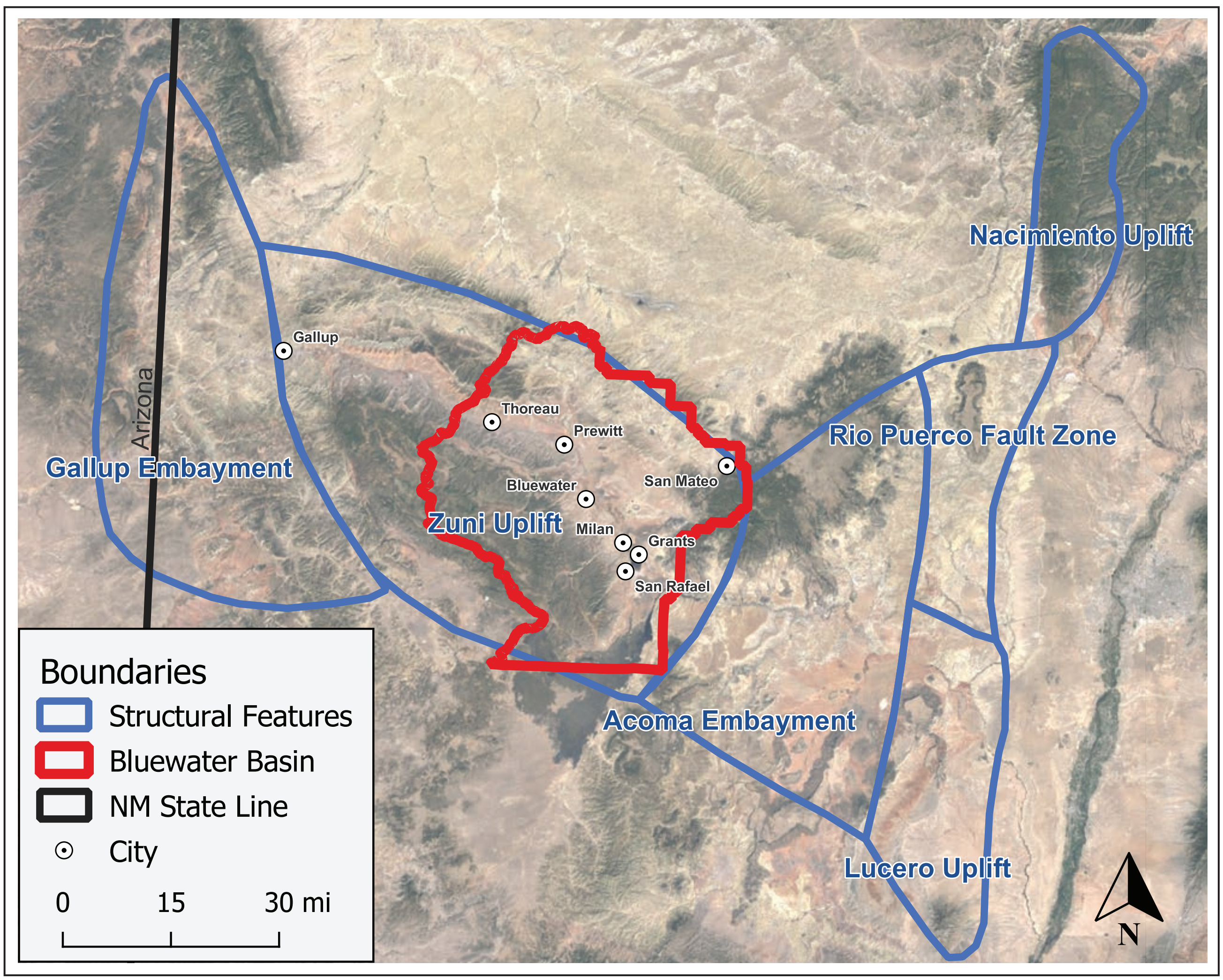

Figure 3-3. Location of the Bluewater Basin with respect to important structural geologic features.

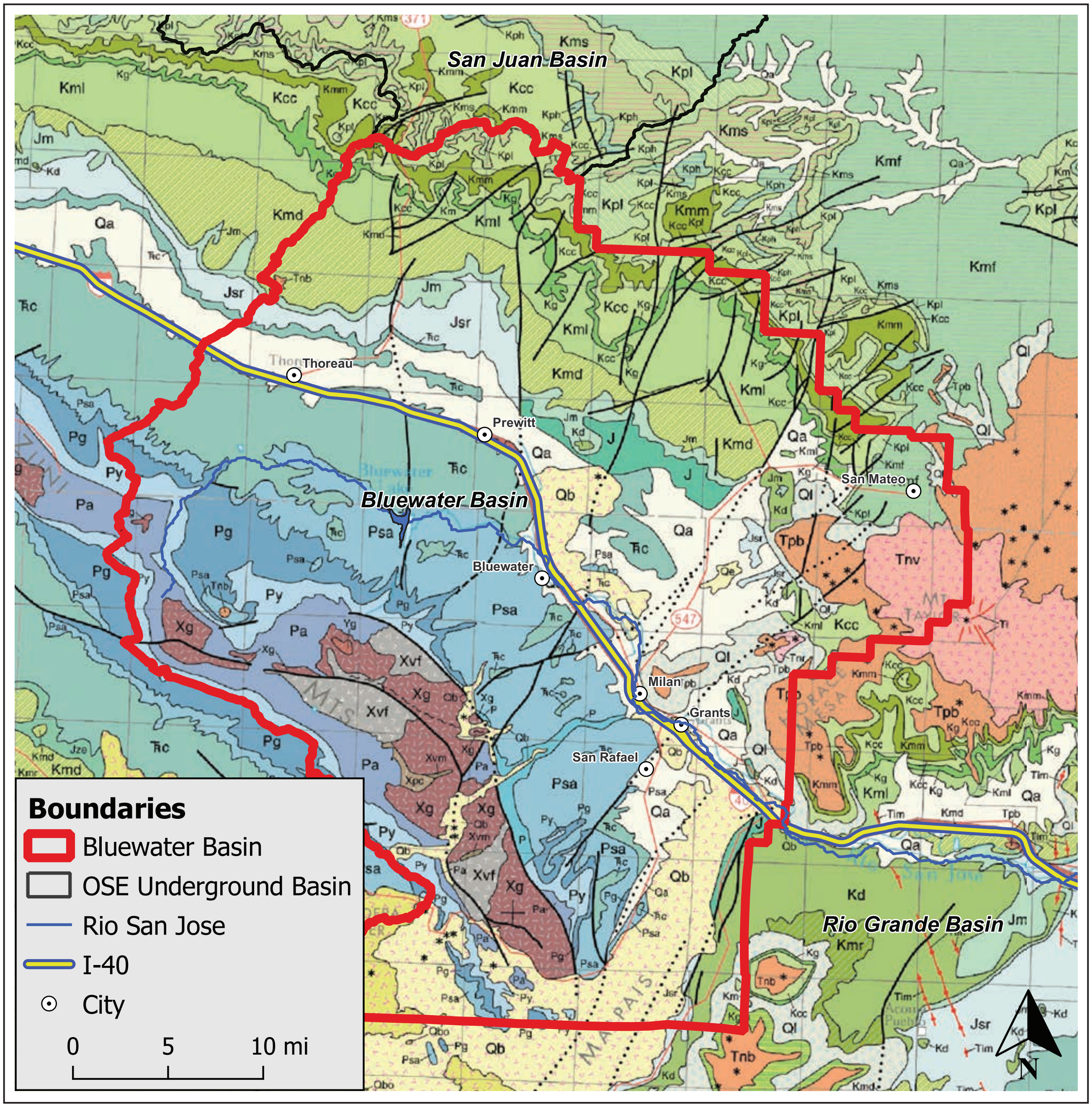

Figure 3-4. Geologic map of the Bluewater Basin (modified from Scholle [2003]).
Qa = Quaternary alluvium, Qb = Quaternary basaltic lava flows, Qe = Quaternary eolian deposits, Ql = Quaternary landslide deposits, Tnv = Tertiary silicic to intermediate volcanic rocks, Tpb = Tertiary basaltic lava flows, Kcc = Cretaceous Crevasse Canyon Formation, Kd = Cretaceous Dakota Sandstone, Kmf = Cretaceous Menefee Formation, Kml = Cretaceous Mancos Shale (lower), Kmm = Cretaceous Mulatto Tongue of Mancos Shale, Jsr = Jurassic San Rafael Group, ₮c = Triassic Chinle Group, Psa = Paleozoic San Andres Formation, Pg = Paleozoic Glorieta Sandstone.

Extrusive Neogene rocks (Tnv = mostly andesitic volcanic rocks, Tnr = rhyolite and dacite lava flows with minor tuffs, and Tpb = basaltic andesitic lava flows) associated with local lava flows overlie strata of Triassic, Jurassic, and Cretaceous rocks and are observed in the far eastern portion of the Bluewater Basin.

Quaternary volcanic deposits (Qbo = middle to lower Pleistocene basaltic and andesitic lava flows, Qb = Holocene to middle Pleistocene basaltic and andesitic lava flows, and Qa = Holocene alluvium) mostly make up the Malpais lava flows at the far southern boundary of the Bluewater Basin. Modern alluvium covers the surface mostly to the north and east of Interstate 40.

Climate conditions in the Bluewater Basin vary spatially, mostly related to elevation and topography. The average temperature range for Grants is 88°F (31°C) in July to 17°F (-8°C) in January. Average annual precipitation ranges from less than 10 in. (25 cm) to more than 30 in. (76 cm) at higher elevations.

Most of the Bluewater Basin is within the Rio San Jose watershed (Fig. 3-5). Surface water is limited because most streams in the area are ephemeral. The primary surface water drainage in the Bluewater Basin is the Rio San Jose, which discharges into the Rio Puerco. Bluewater Lake, located on the northern flank of the Zuni Mountains (Fig. 3-5), is a reservoir constructed in 1927 (NM Interstate Stream Commission, 2017) and has a storage capacity of 44,150 acre-feet. Currently, Bluewater Lake provides water for irrigation.

The San Andres-Glorieta aquifer is the principal aquifer in the Bluewater Basin that provides water for municipal, industrial, and irrigation supplies. Wells completed in this aquifer yield 10 gallons per minute (gal/min) to several thousand gal/min. While alluvial aquifers are limited in depth and extent, some wells are completed in the alluvial aquifers, which along with fractured Quaternary basalt provides water supplies for domestic, livestock, and irrigation use. Well yields are generally several hundreds of gal/min. Wells and springs from the Gallup Sandstone (Kg in Fig. 3-4), located along the northern boundary of the Bluewater Basin, produce some water for domestic use, livestock, and coal operations. Well yields range from a few to several hundred gal/min. Within the Jurassic and Triassic rocks, which crop out just south of Interstate 40 on the northern flank of the Zuni Mountains, water from the Morrison Formation (where water quality is suitable) is used for domestic, industrial, and livestock supplies, with yields ranging from a few to several hundred gal/min. Aquifers in the Jurassic Entrada Sandstone and Triassic Chinle Formation provide small amounts of water for domestic and livestock uses. These aquifers in the Bluewater Basin are mainly recharged from precipitation and runoff on outcrops of the San Andres Limestone and Glorieta Sandstone on the northeastern flank of the Zuni Mountains, precipitation on the alluvium and the basaltic lava flows, and seepage of water from Bluewater Lake, Bluewater Creek, and the irrigation canal system. Recharge also occurs to the east near Mount Taylor.

While there has been very little research on the hydrogeology of most of the Bluewater Basin, Brod and Stone (1981) assessed water levels in the different aquifers in the Ambrosia Lake area and determined local and regional groundwater flow directions. Groundwater in shallow alluvial aquifers mostly tends to flow in the general direction of the local drainage that it occupies. However, aquifers in consolidated formations, such as the San Andres Limestone-Glorieta Sandstone, the Westwater Canyon Member of the Morrison Formation, and the Chinle Formation, are part of a larger regional confined flow system, with groundwater flowing along the regional dip to the northeast. It is possible that these observed groundwater flow directions in the Ambrosia Lake area are largely representative of the larger aquifer system within the Bluewater Basin.

WATER RIGHTS AND WATER USE

Figure 3-6 shows the location of all active OSE wells, indicated by use. Domestic wells account for the majority of existing wells. The majority of wells (high-use area) are located along Interstate 40 between Grants and Prewitt and along NM State Road 53 from south of San Rafael to Grants. The apparent depth to water (determined from well logs) for domestic wells in this area is mostly less than 200 ft below the ground surface (Fig. 3-7). These wells are completed mostly in the San Andres Limestone-Glorieta Sandstone, the Chinle Formation, or a local alluvial aquifer.

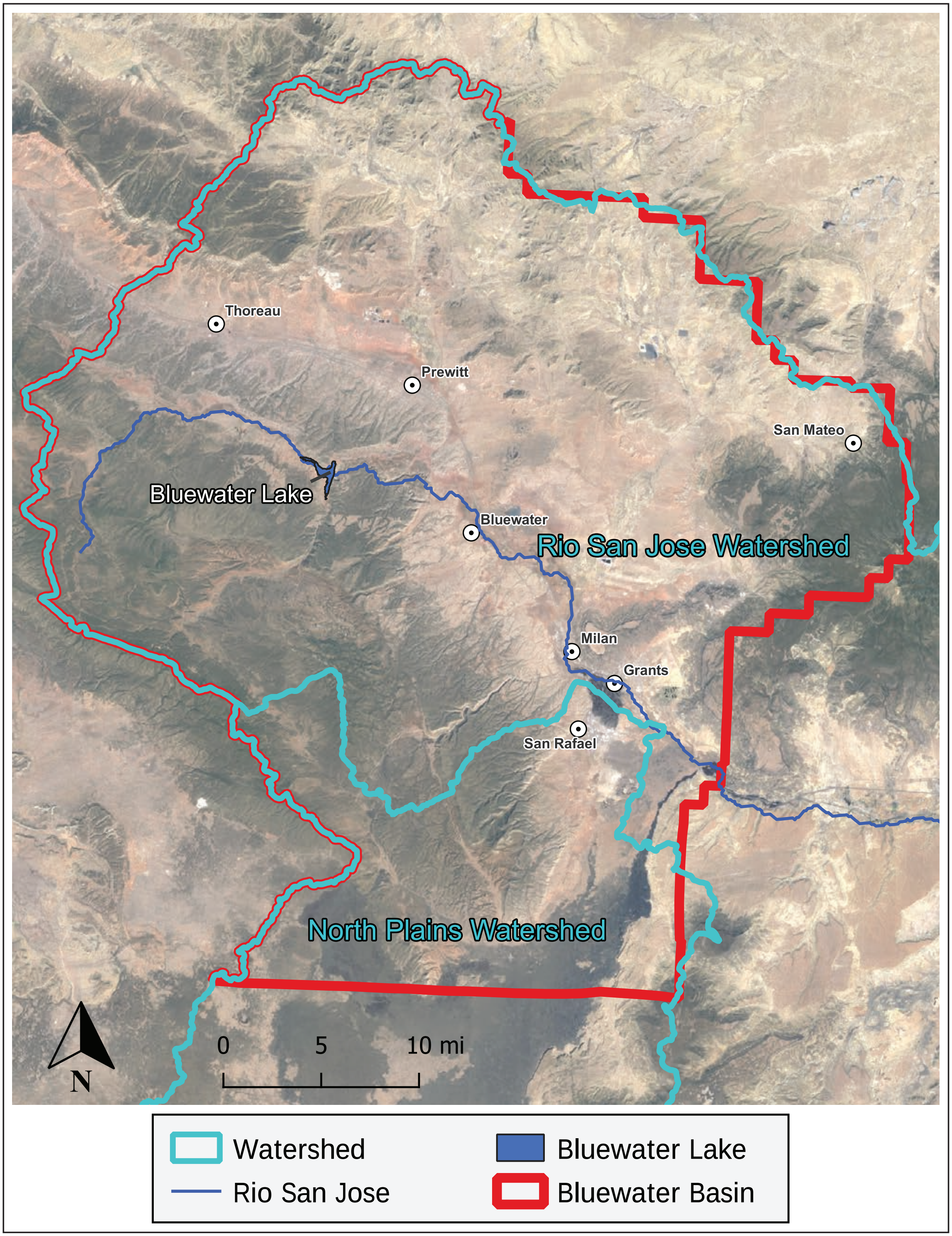

Figure 3-5. Location of surface watershed boundaries and ephemeral and perennial streams.

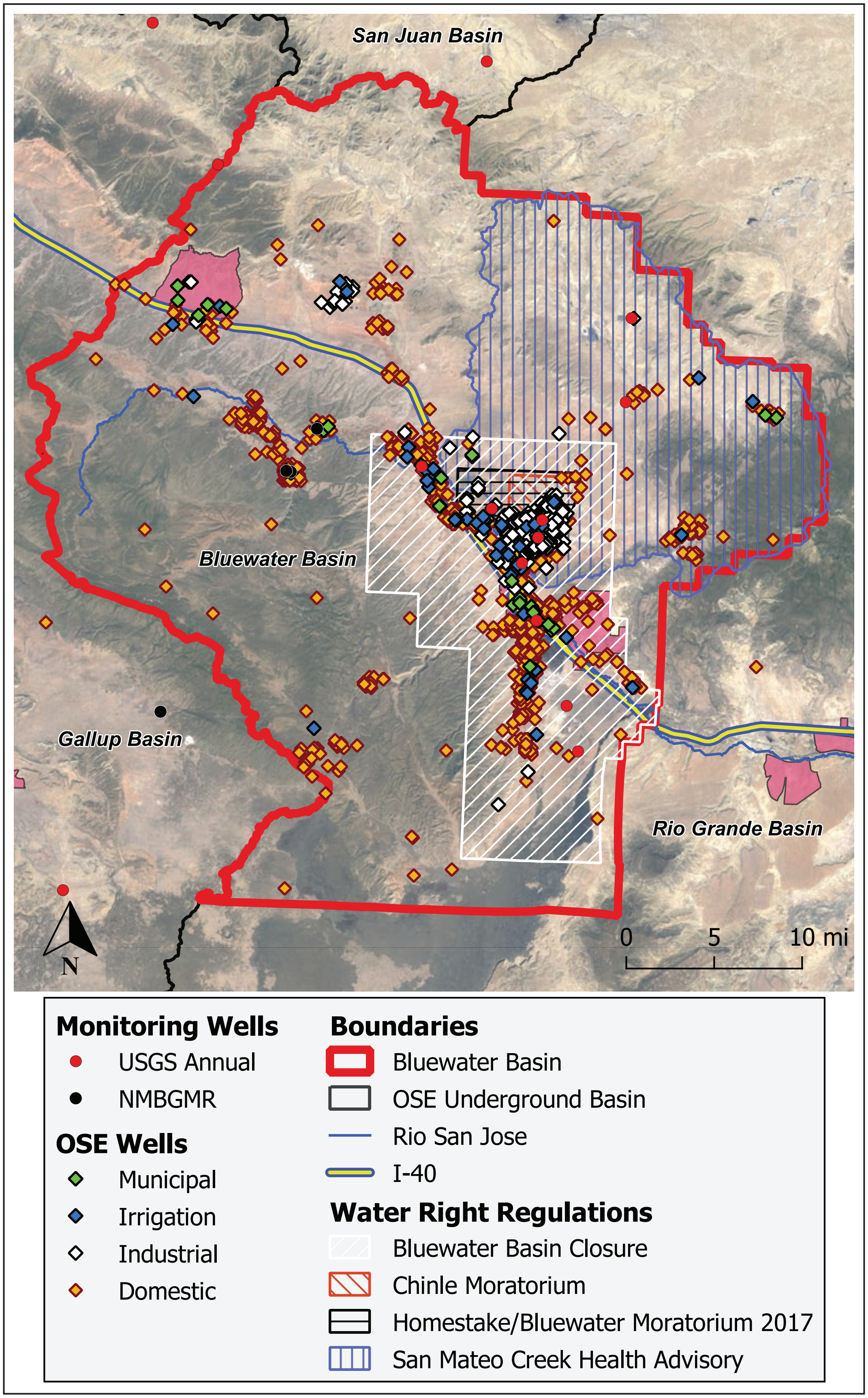

Figure 3-6. OSE wells, active monitoring wells, and water right restricted areas.

The Bluewater Basin was declared in 1956. Included with the declaration was a closure of new appropriations for irrigation, industrial, and municipal purposes in an area around Gants and Milan and extending south of San Rafael due to concerns of over-appropriation of water resources (see Fig. 3-6). As stated above, the Bluewater Basin has many issues with groundwater and surface water contamination (both natural and anthropogenic), mostly associated with uranium mining and the milling process. Due to concerns about health issues related to potentially contaminated groundwater, a large portion of the Bluewater Basin has been closed to new water rights (Fig. 3-6). The numerous wells monitoring the Homestake mill contamination site, which are located in the Grants and Milan area along NM State Road 65 going toward Ambrosia Lake and San Mateo, are shown in Figure 3-2. These wells are located within the Homestake/Bluewater Moratorium area where there is a prohibition against drilling new, replacement, or supplemental wells due to excessive groundwater contamination.

Groundwater accounts for 100% of water use for public, domestic, commercial, industrial, and mining water supplies (Magnuson et al., 2019). While agriculture is limited to the area near Bluewater, and some surface water is used for irrigation, groundwater supplies the majority of irrigated agriculture.

GROUNDWATER MONITORING

Likely due to concerns about potential contamination in the area, a number of wells annually monitored by the U.S. Geological Survey (USGS) are located in the eastern portion of the Bluewater Basin (Fig. 3-8). They are completed at different depths in different aquifers, provide records of changes in depth to water (Figs. 3-9a through 3-9e), and are located in the high-use area. All five hydrographs show a net decline in the water levels over the last 40 to 50 years. A well completed in the Westwater Canyon Member of the Morrison Formation (Fig. 3-9a) shows a steady water-level decline of about 70 ft since the late 1970s. Figure 3-9b shows a hydrograph for the USGS monitoring well near Interstate 40 north of Bluewater. This well, which is 500 ft deep and was completed in the Yeso Formation, shows an overall rise in water level between the mid-1950s and the early 1980s, but then water levels show an overall decline over 30 years. Figures 3-9c and 3-9d show hydrographs for USGS monitoring wells located south of San Rafael in the alluvial and San Andres-Glorieta aquifers, respectively. The alluvial well is only 70 ft deep, and since the late 1950s, the water level has dropped about 20 ft, leaving only about a 10 ft water column. Figure 3-9e is a hydrograph for USGS well 351211107532901 in the Milan area just west of Grants completed in the San Andres-Glorieta Formation to a depth of 480 ft. Though this well has had periods of rising and steady water levels, water levels have been in decline since 1990.

GROUNDWATER MODELS

In 1992, USGS published a groundwater flow model (Frenzel, 1992) covering the Acoma embayment and the eastern Zuni uplift (see Fig. 3-3), an area that includes the majority of the Bluewater Basin. It is a two-layer MODFLOW model that simulates groundwater flow in the San Andes-Glorieta aquifer as well as the valley-fill aquifer. This model was never used by OSE for administrative purposes.

In 2020, USGS published a 3D geologic model (i.e., a 3D geospatial database) of the Rio San Jose groundwater basin (Sweetkind et al., 2020), an area that includes the Bluewater Basin. This geologic model, which includes 18 stratigraphic units, was intended "to be used as digital geologic input data for numerical simulation of the hydrologic system of the Rio San Jose watershed." Such a model has been constructed by USGS, but at the time this paper was published, the model had not yet been released and no documentation was available.

LAND SURFACE OWNERSHIP

McKinley County (northern Bluewater Basin) and Cibola County (southern Bluewater Basin) have a significant Native American population, with tribal land accounting for about 60% and 24% of total land in the counties, respectively. Figure 3-10 shows land surface ownership in the Bluewater Basin and surrounding area. The far northern portion of the Bluewater Basin is mostly tribal land associated with the Navajo Nation. The U.S. Forest Service owns most of the land in the Zuni Mountains to the southwest and in the far eastern portion of the Bluewater Basin. The rest of the Bluewater Basin is a checkerboard of private, tribal, Bureau of Land Management, and state land.

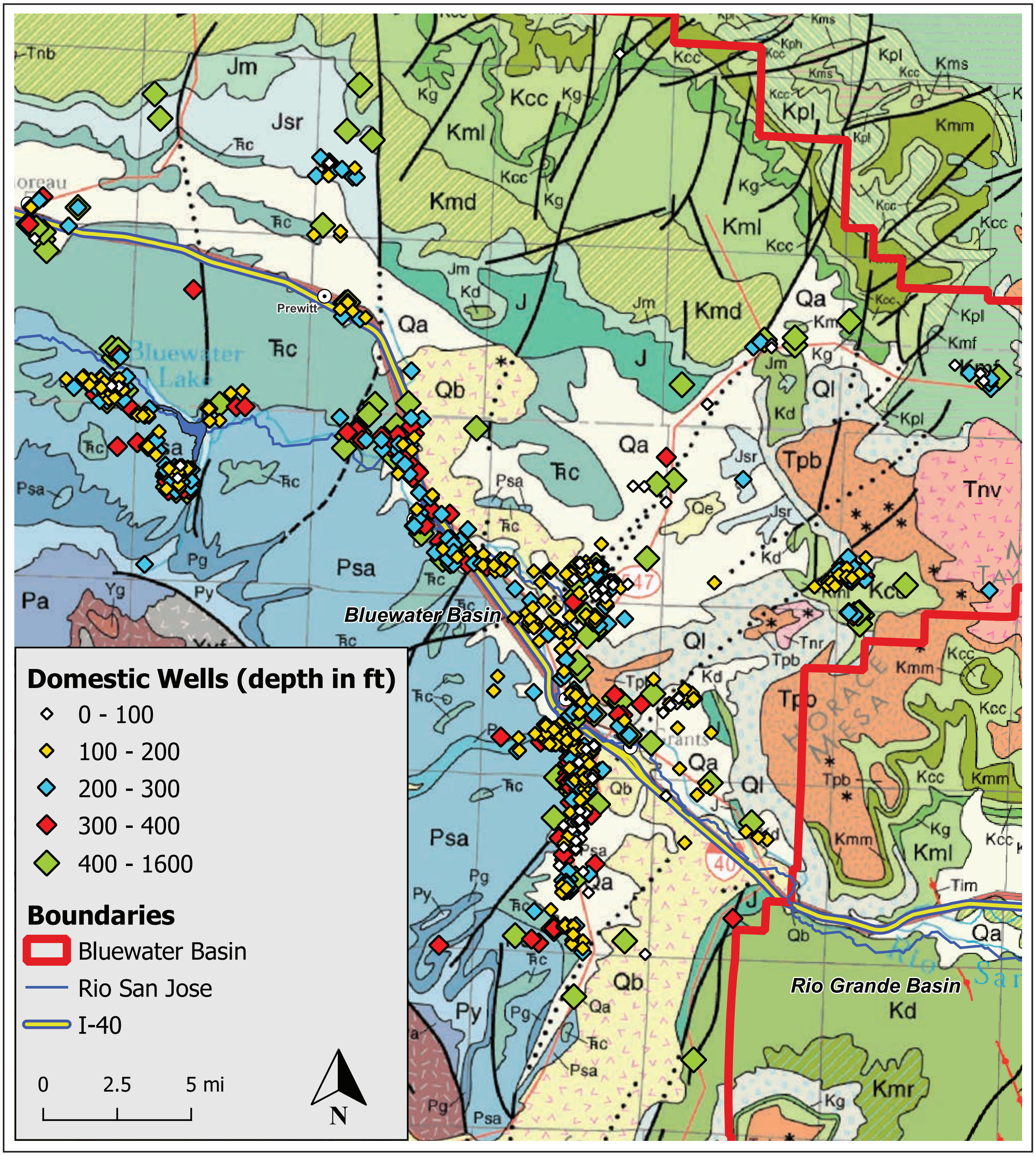

Figure 3-7. Domestic wells in the Grants/Bluewater area. Point size is proportional to the depth of water below the land surface. Local geology is also shown.

Qa = Quaternary alluvium, Qb = Quaternary basaltic lava flows, Qe = Quaternary eolian deposits, Ql = Quaternary landslide deposits, Tpb = Tertiary basaltic lava flows, Kcc = Cretaceous Crevasse Canyon Formation, Kd = Cretaceous Dakota Sandstone, Kml = Cretaceous Mancos Shale (lower), Kmm = Cretaceous Mulatto Tongue of Mancos Shale, Jsr = Jurassic San Rafael Group, ₮c = Triassic Chinle Group, Psa = Paleozoic San Andres Formation, Pg = Paleozoic Glorieta Sandstone.

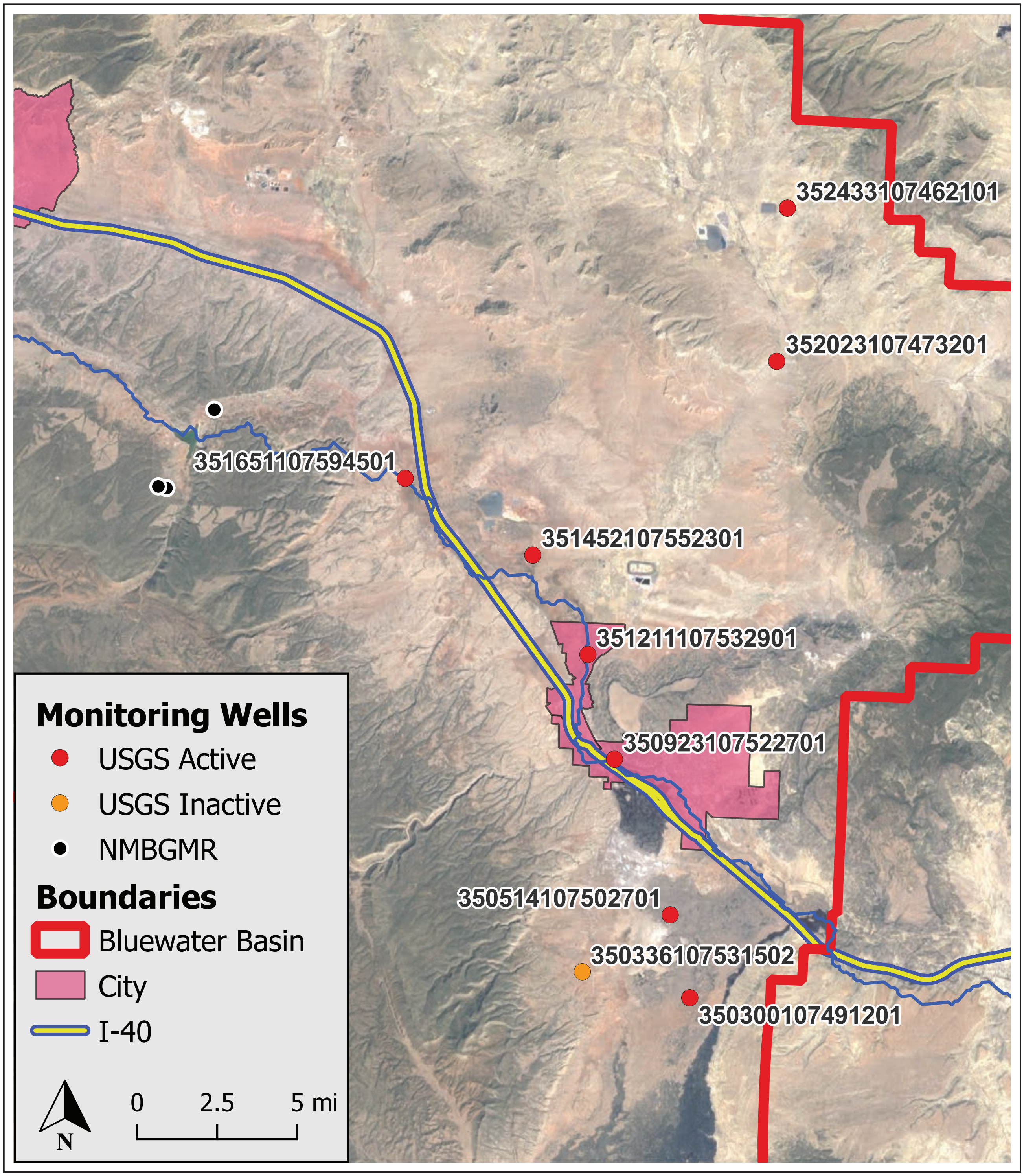

Figure 3-8. USGS active annual monitoring wells in the Bluewater Basin and inactive USGS well 350336107531502. Hydrographs for five of these wells are shown in Figures 3-9a through 3-9e.

A

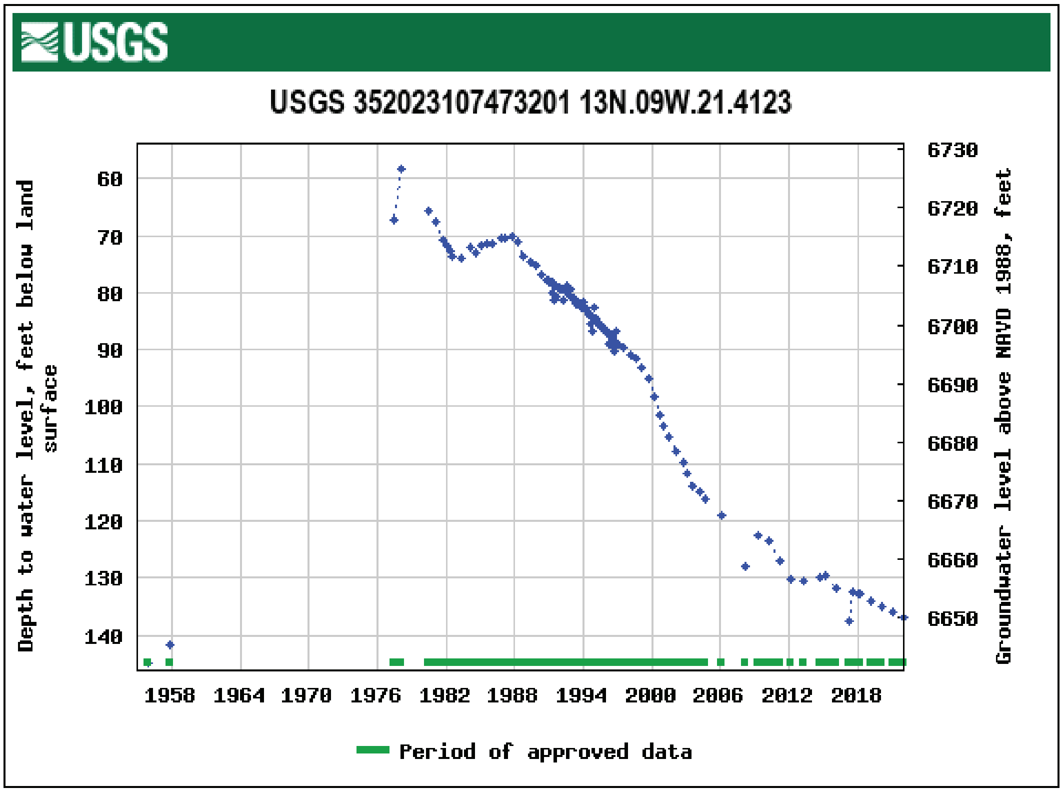

Figure 3-9a. Active USGS monitoring well northwest of Grants on NM State Road 605, depth 155 ft, completed in the Westwater Canyon Member of the Morrison Formation (see Fig. 3-8 for location).

B

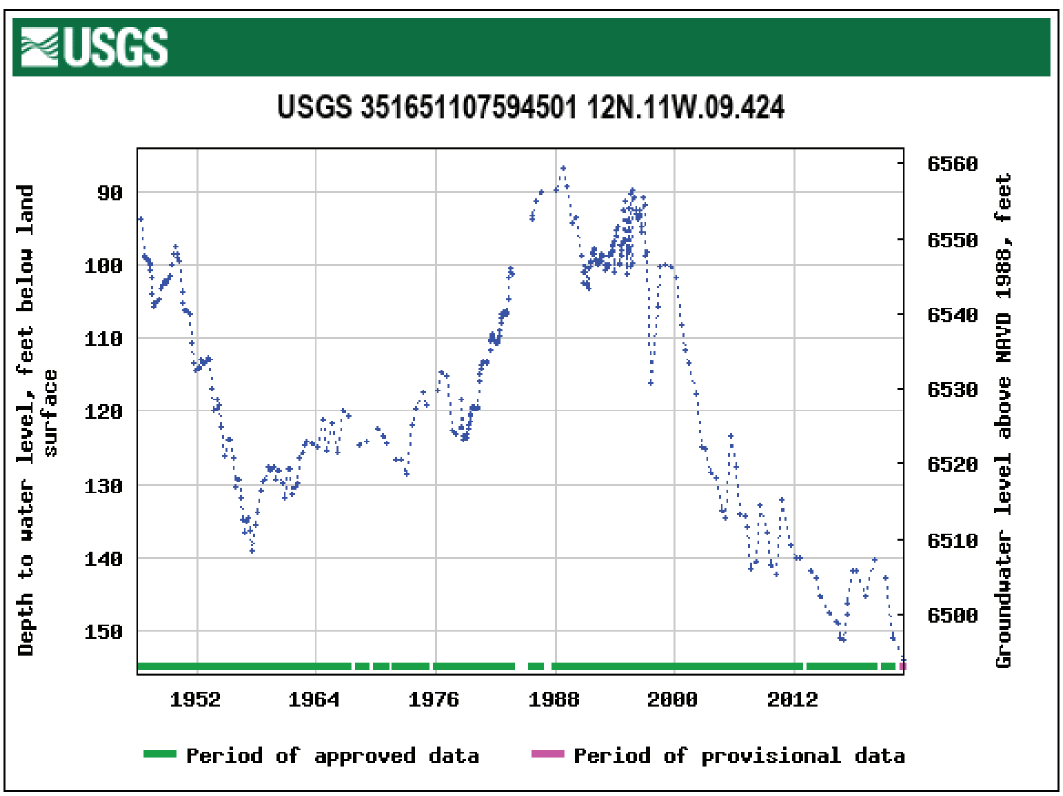

Figure 3-9b. Active USGS monitoring well located near Interstate 40 just north of Bluewater, depth 500 ft, completed in the Yeso Formation (see Fig. 3-8 for location).

C

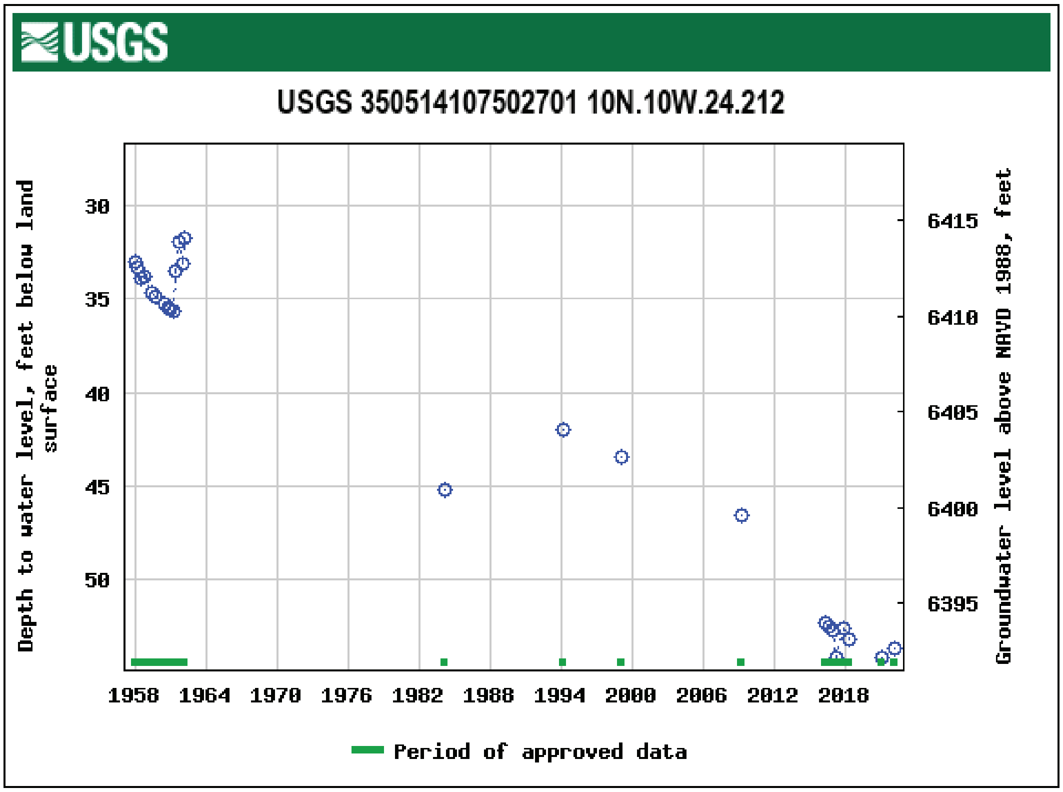

Figure 3-9c. Active USGS monitoring well located southeast of San Rafael, depth 70 ft, completed in the alluvium (see Fig. 3-8 for location).

D

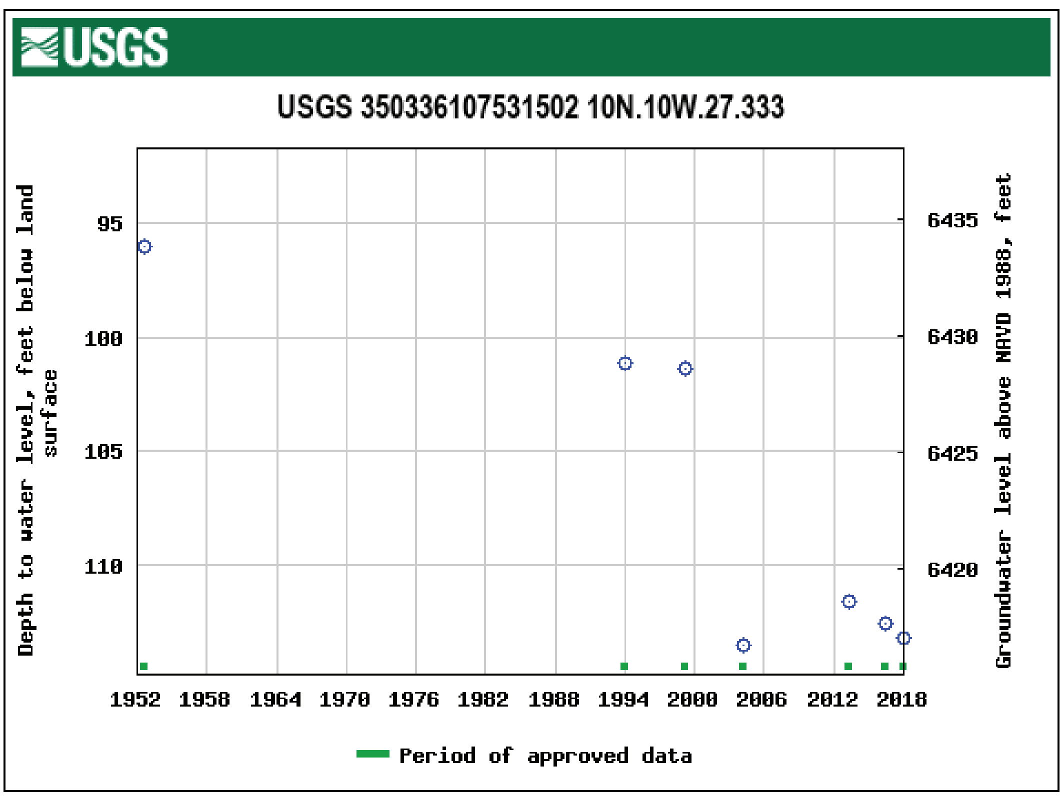

Figure 3-9d. Inactive USGS monitoring well located just south of San Rafael, depth 150 ft, completed in the San Andres-Glorieta Formation (see Fig. 3-8 for location).

E

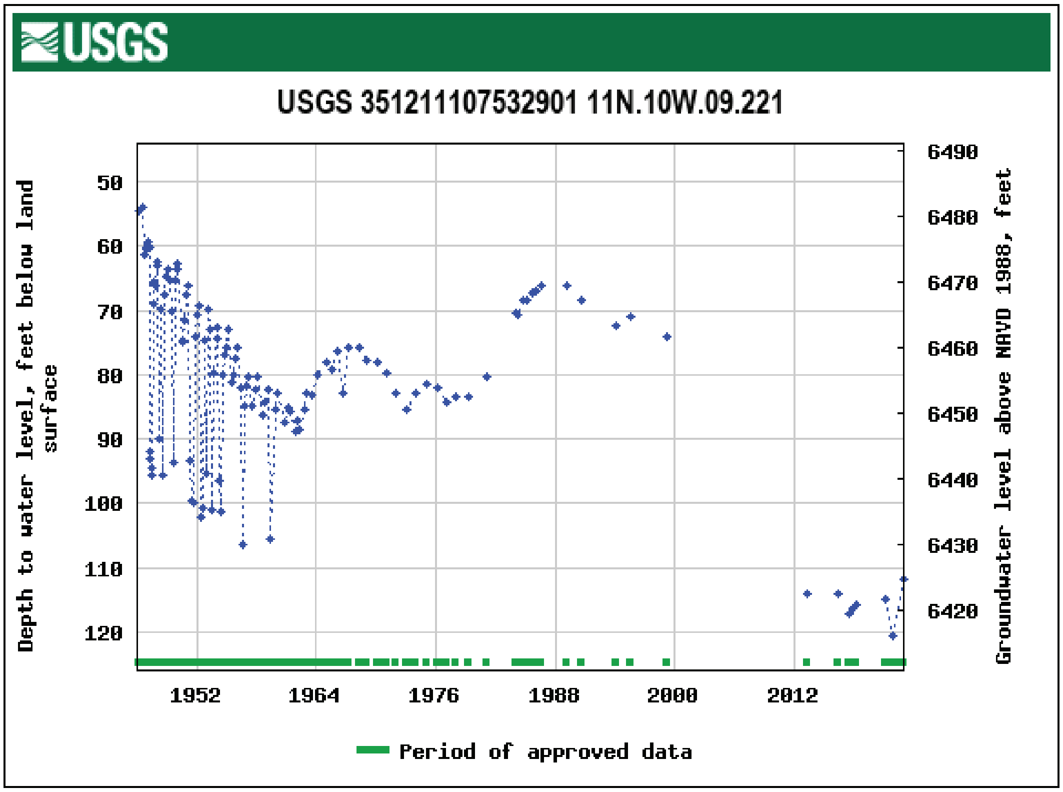

Figure 3-9e. Active USGS monitoring well located in Milan just west of Grants, depth 480 ft, completed in the San Andres-Glorieta Formation (see Fig. 3-8 for location).

MONITORING RECOMMENDATIONS

The observed downward trend in groundwater levels makes clear the need for long-term water-level monitoring in the Bluewater Basin. The goals for this basin are to monitor relatively high-use areas utilizing the San Andres-Glorieta aquifer that are under-monitored, as well as to monitor background levels in that aquifer. Figure 3-10 shows recommended locations for groundwater monitoring. Estimated costs to install these wells are found in Table 3-1.

Table 3-1. Cost estimates for recommended monitoring wells in the Bluewater Basin.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
				Low	High
1	220	50	Yes	$85,000	$103,000
2	1,200	150	Yes	$300,000	$319,000
3	550	150	Yes	$160,000	$178,000
TOTAL				$545,000	$600,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. High-use area near San Rafael completed in the San Andres-Glorieta aquifer. It appears that in this area there is approximately 80 ft of alluvium with a declining water table (see Fig. 3-9c), and a deeper aquifer in the San Andres-Glorieta Formation in which water levels are also declining. It is likely, though not certain, that these aquifers are connected. The water supply well for San Rafael is completed in the San Andres-Glorieta Formation. The proposed well would be completed at an approximate depth of 220 ft and may require an artesian completion.

Location 2. High-use area along Interstate 40 near Thoreau within the San Andres-Glorieta aquifer. There are no available time-series data or any current monitoring in this area. While this area is not one of very high use, Thoreau has four water supply wells in this area completed in the San Andres-Glorieta Formation. A monitoring well in this area will help close the data gap between existing USGS wells along Interstate 40. Approximate well depth is 1,200 ft.

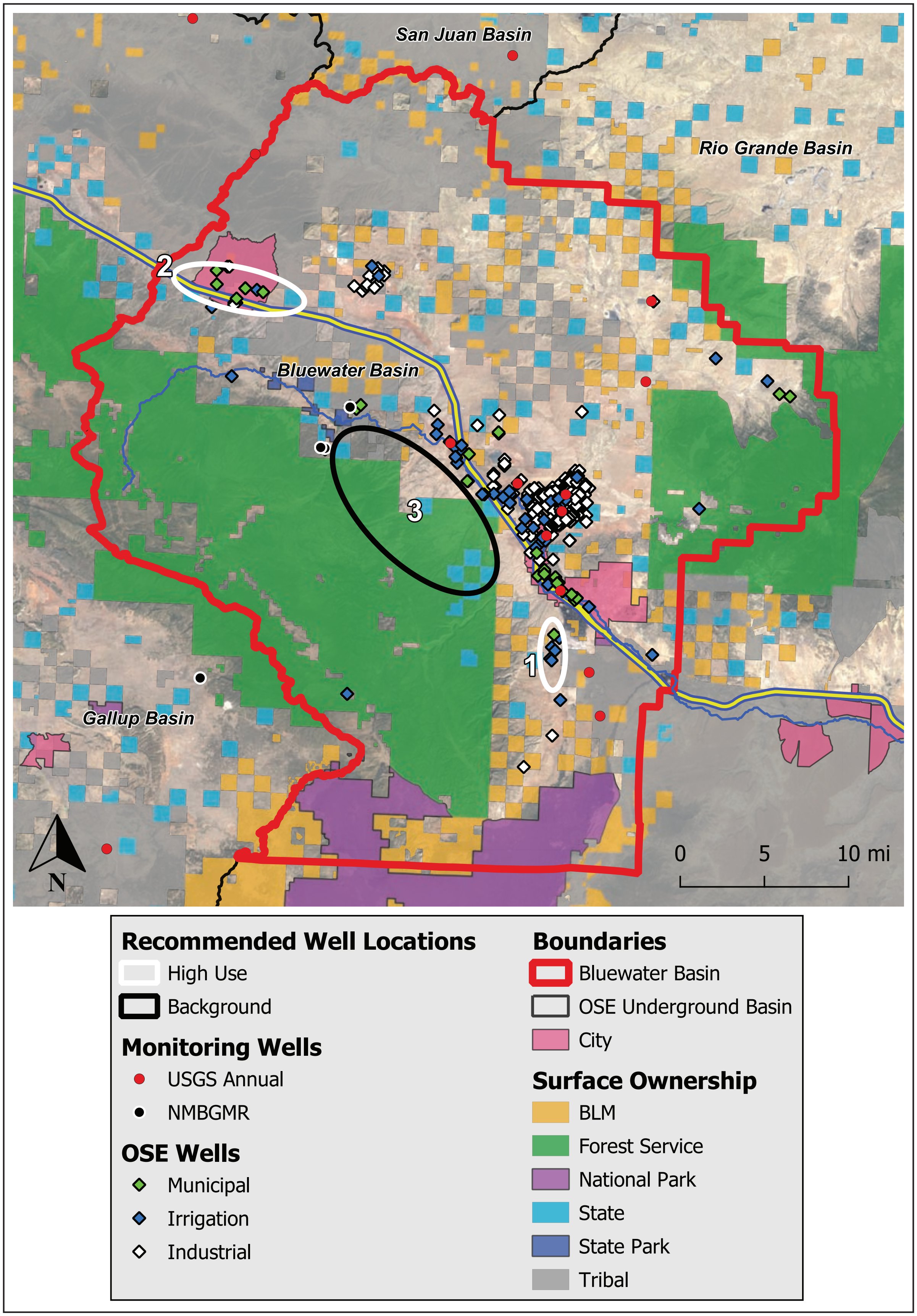

Figure 3-10. Recommended monitoring well locations and land surface ownership in the Bluewater Basin.

Location 3. Background well completed in the San Andres-Glorieta aquifer recharge zone in the Zuni Mountains. There is currently no water-level monitoring in the recharge area. Monitoring water levels in this area will help to estimate future groundwater supplies in the Bluewater Basin that vary based on short-term and long-term precipitation trends. There is a considerable amount of public land in this area, but most of it does not have road access. Approximate well depth is 550 ft.

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CHAPTER 4. EAST-CENTRAL CLAYTON BASIN

Robert Pine

The Clayton Underground Water Basin (referred to here as the Clayton Basin) occupies the northeastern corner of New Mexico, primarily within Union County but also within small portions of Colfax, Harding, and Quay Counties. The east-central portion of the Clayton Basin, as shown in Figure 4-1, has an area of approximately 641 mi^2. This region contains the town of Clayton, with a population of approximately 3,000, and the unincorporated community of Sedan, with a population of approximately 100. The New Mexico Office of the State Engineer (OSE) published administrative guidelines in January of 2019 for the eastern portion of the Clayton Basin, and within that it defined a Critical Management Area (CMA). Those regions are shown in Figure 4-1.

GEOLOGY AND HYDROLOGY

Eastern Union County contains the western edge of the High Plains aquifer, which underlies portions of eight different states and is one of the largest aquifers in the U.S. This aquifer is found within the Tertiary Ogallala Formation, which in Union County consists of tan sandy clay, silt, sand, and gravel (Baldwin and Muehlberger, 1959). Where the High Plains aquifer is absent or of insufficient thickness in eastern Union County, the dominant aquifer is in the Cretaceous Dakota Formation, 150 to 250 ft of massive sandstone, shaly sandstone, and light- to dark-gray mudstone. The municipal supply wells for the town of Clayton and all more recent irrigation wells are completed in the Dakota Formation. Rawling (2013) indicates that there are multiple water-bearing zones within the Dakota Formation, but this is difficult to discern from driller's logs. There are some wells that may be completed into formations below the Dakota Formation, but this is not clear from the limited number of driller's logs. The Dakota Formation crops out extensively in western Union County, and this is likely a recharge zone for this aquifer.

Between the Ogallala Formation and the Dakota Formation is a formation known as the Graneros Shale that may function as an aquitard. Baldwin and Muehlberger (1959), Zeigler (2012), and Rawling (2013) suggest that the Graneros Shale is absent over much of eastern Union County. The true extent of the Graneros Shale is unclear at this time because their analyses depend on the interpretation of driller's logs (which are usually of questionable utility) or review of cuttings stored in the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) cuttings repository from a limited set of data points. Thus, the extent to which the Graneros Shale may act as an aquitard between the High Plains aquifer and the Dakota Formation is unclear. In Baca County, Colorado, just north of Union County, groundwater in the Dakota Formation is generally confined (McLaughlin, 1954). In his report on Colfax County, Griggs (1948) indicates that the Dakota Formation aquifer is generally confined "over most of the extent of the aquifer in Colfax County." Water levels in shallow and Dakota Formation wells suggest that the High Plains aquifer and the Dakota Formation aquifer form one unconfined aquifer in the east-central Clayton Basin. However, so many wells have been drilled through the High Plains aquifer into the Dakota Formation without an artesian completion that it is now hard to say whether the Dakota Formation aquifer was at one time confined in parts of this region. Figure 4-2 is a geologic stratigraphic column for the east-central Clayton Basin.

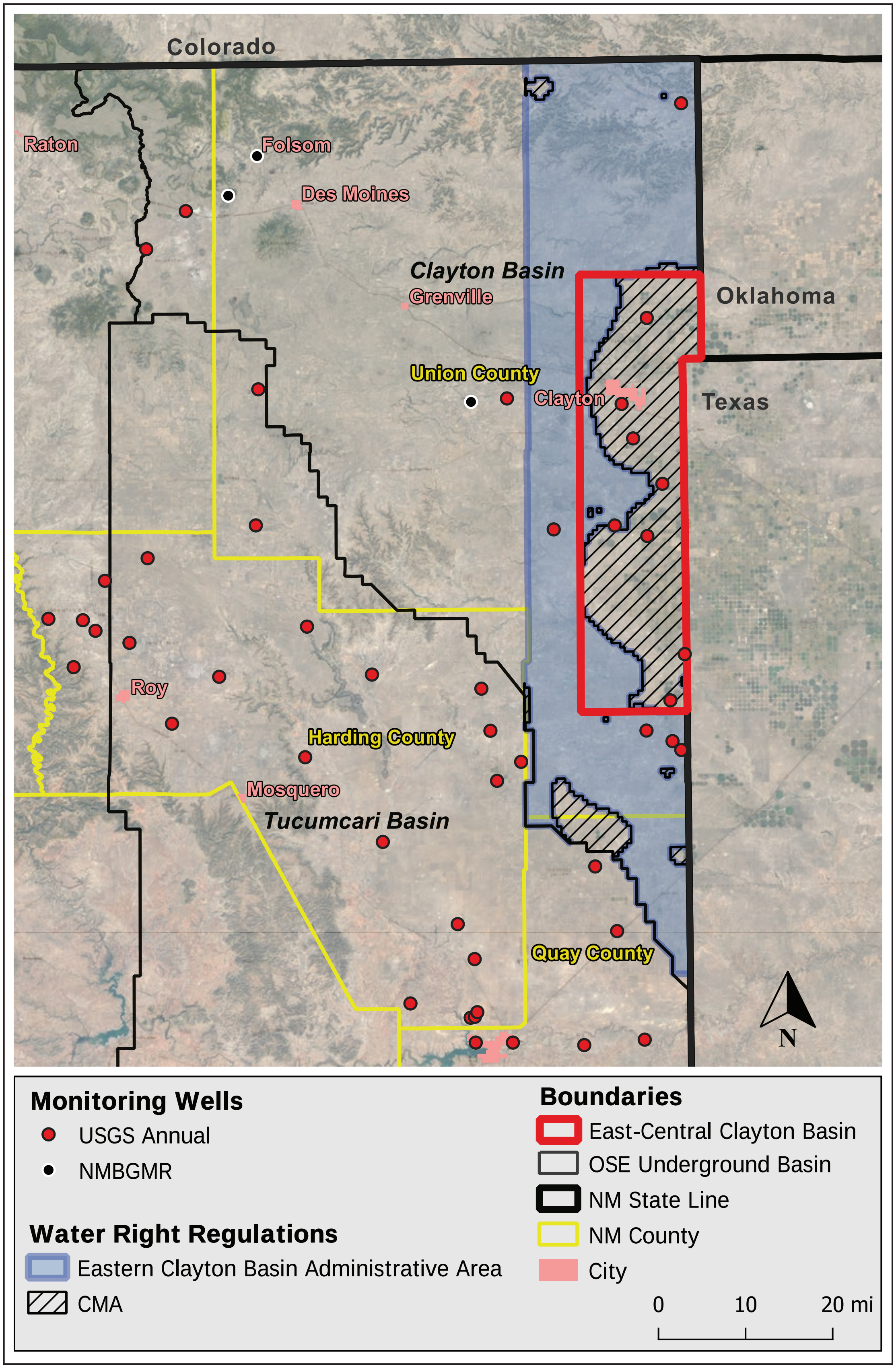
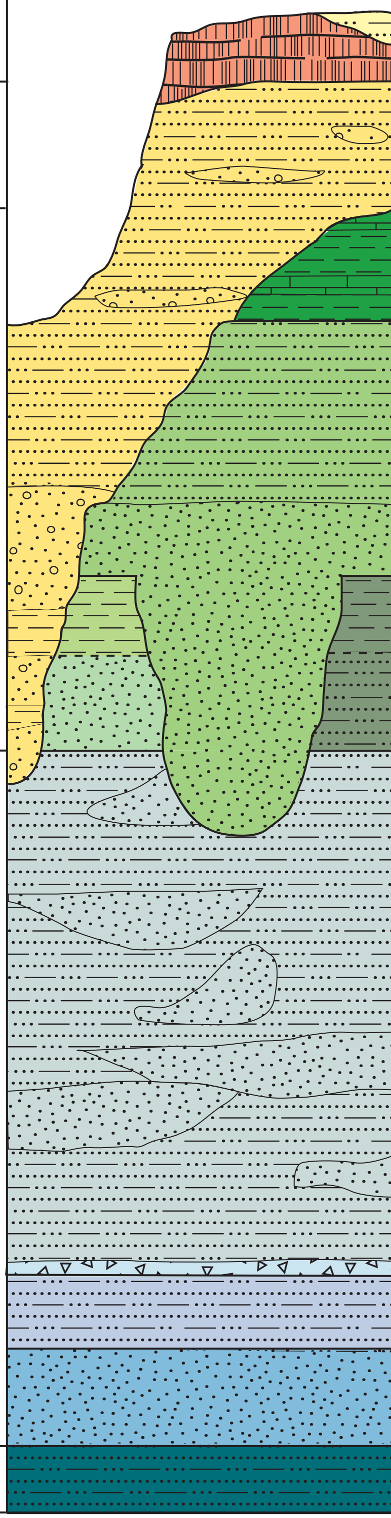


Figure 4-1. Overview of the east-central Clayton Basin showing OSE administrative area, active monitoring wells, and neighboring declared underground water basins.



AGE	GEOLOGIC FORMATION			THICKNESS (feet)	AQUIFER QUALITY
Pleistocene-Recent	Alluvium, valley fill, eolian deposits Qal			0-30 ft	Very good in sand and gravel in paleovalleys, but largely dewatered
	Clayton basalt QTb			20-40 ft	
Miocene-Pliocene	Ogallala Formation To			0-400 ft	
Late Cretaceous	Graneros Shale Kg			0-300 ft	Poor
	Dakota Group	Dakota Formation Kd			Very good in sand-stone beds, much dewatering in shallow levels of formation. Becomes confined at depth.
		Glencairn Formation	Purgatoire Formation Kp	0-120 ft	Probably good in sandstone beds
		Lytle sandstone			
Middle to Late Jurassic	Morrison Formation Jm			170-495 ft	Good in sandstone beds, but probably low connectivity amongst beds; mostly confined except in SW portion of study area
	Bell Ranch Formation			20-95 ft	
	Entrada sandstone			0-50 ft	Very good, but requires deep wells. Confined.
Late Triassic	Triassic undivided			500+ ft	

Figure 4-2. Generalized geologic stratigraphic column of the east-central Clayton Basin (from Rawling [2013]).

WATER RIGHTS AND WATER USE

The town of Clayton is the east-central Clayton Basin's sole municipal water system. According to the OSE Water Administration Technical Engineering Resource System (WATERS) database, the system has 26 production wells, each with its own water rights, with total water rights for the water system of 15,970 acre-feet per year (acre-ft/yr). However, according to the New Mexico Environment Department Drinking Water Bureau's Drinking Water Watch, the system has 12 wells, of which only four are active.

The majority of groundwater irrigation in the Clayton Basin takes place in the east-central portion (there is also a moderate amount of groundwater irrigation along the Dry Cimarron River in northern Union County). There are 131,780.64 acre-ft/yr of irrigation water rights permitted in the region from 290 wells. The wells range in depth from 160 to 777 ft, with an average depth of 412 ft. Also impactful on groundwater levels in the High Plains aquifer in east-central Union County is the considerable amount of irrigation taking place across the state line in Cimarron County in Oklahoma and Dallam County in Texas, although one study (Chudnoff and Logan, 1995) suggests that, farther south in the Southern High Plains aquifer, most of the aquifer declines in New Mexico are a result of pumping in New Mexico. There are also approximately 1,373 OSE wells with 21,400 acre-ft/yr of non-irrigation agricultural water rights in the region, primarily related to livestock (many of these are declarations). Figure 4-3 shows the distribution of municipal, irrigation, and non-irrigation agricultural wells in the region.

GROUNDWATER MONITORING

Within the project region, the U.S. Geological Survey (USGS) currently has no continuously monitored wells, but has eight annual monitoring wells and four within adjoining townships. There have been dozens of wells in the project region that were monitored by USGS in the past that are no longer being monitored. All these wells are completed in the High Plains aquifer or in the Dakota Formation aquifer. Most wells for which there are time-series data show declining water levels. For example, Figure 4-4a shows measurements of USGS well 361741103051001, located approximately 10 mi south-southeast of Clayton (indicated as depth unknown but completed in the High Plains aquifer). It has been showing a steady rate of decline of 2 ft/yr. Figure 4-4b shows measured water levels from USGS well 362206103083801, located approximately 3 mi south of Clayton, that is completed in the Dakota Formation aquifer (depth 411 ft). It shows an average rate of decline of 1.3 ft/yr. It should be noted that there is no well log for USGS well 362206103083801, so it is not known whether this well was screened across the both the High Plains and Dakota Formation aquifers; in all likelihood it was not completed as an artesian well, as is the case with most (or all) deeper wells in this region.

The Northeastern Soil and Water Conservation District has contracted with Zeigler Geologic Consulting LLC since 2007 to take annual water-level measurements in approximately 50 wells currently in Union County, 16 of which lie within this project's defined boundaries. Not all have been monitored since the beginning of the program. Of these wells, eight have shown water-level declines, two have shown a rising trend, and six have shown neither a rising nor a declining trend (Zeigler, 2019).

GROUNDWATER MODELS

In 2014, Balleau Groundwater Inc. created a groundwater model for the Eastern Clayton Basin Administrative Area (shown in Fig. 4-1) under contract with OSE. This model was slightly modified in 2016 by the OSE Hydrology Bureau so that there are two versions of the model. The model (either version) is used for water rights application analysis as required by and described in the administrative guidelines. The model has five layers as shown in Figure 4-5.

LAND SURFACE OWNERSHIP

Within the east-central Clayton Basin, there is a mix of state, federal, and private land as shown in Figure 4-6. The federal land is part of the Kiowa National Grassland that is administered by the U.S. Forest Service. There is no irrigation taking place on the federal land, but there are several private stock wells, suggesting a high likelihood that a monitoring well could be sited on this land.

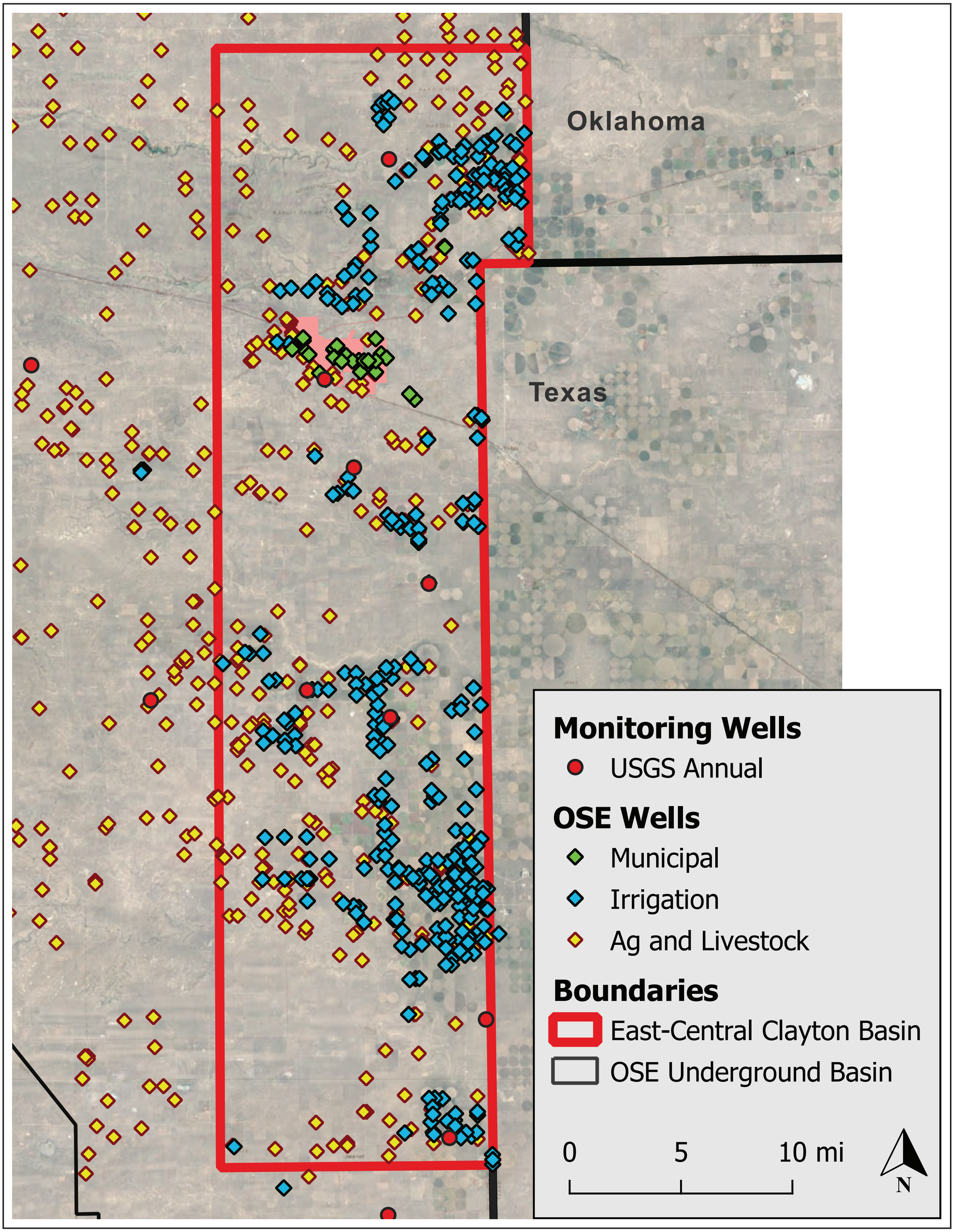
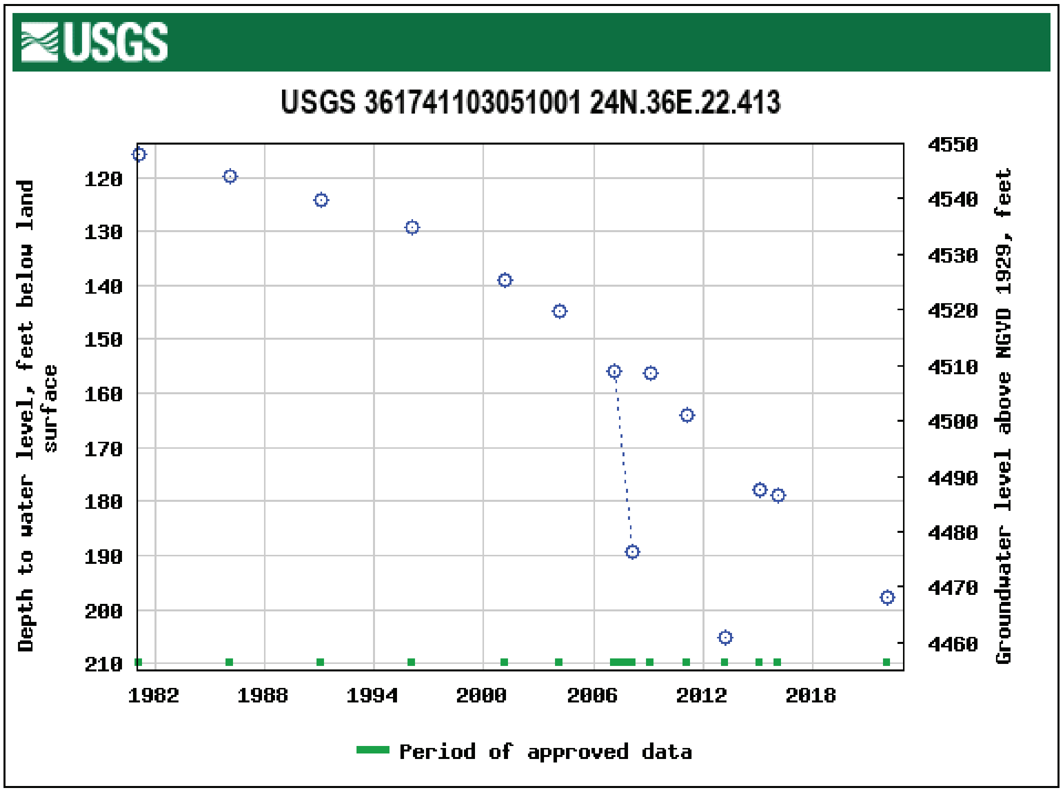


Figure 4-3. OSE production wells within the east-central Clayton Basin. Agricultural and livestock wells are primarily stock wells but may also be used for domestic purposes. Municipal wells are supply wells for the town of Clayton.

A



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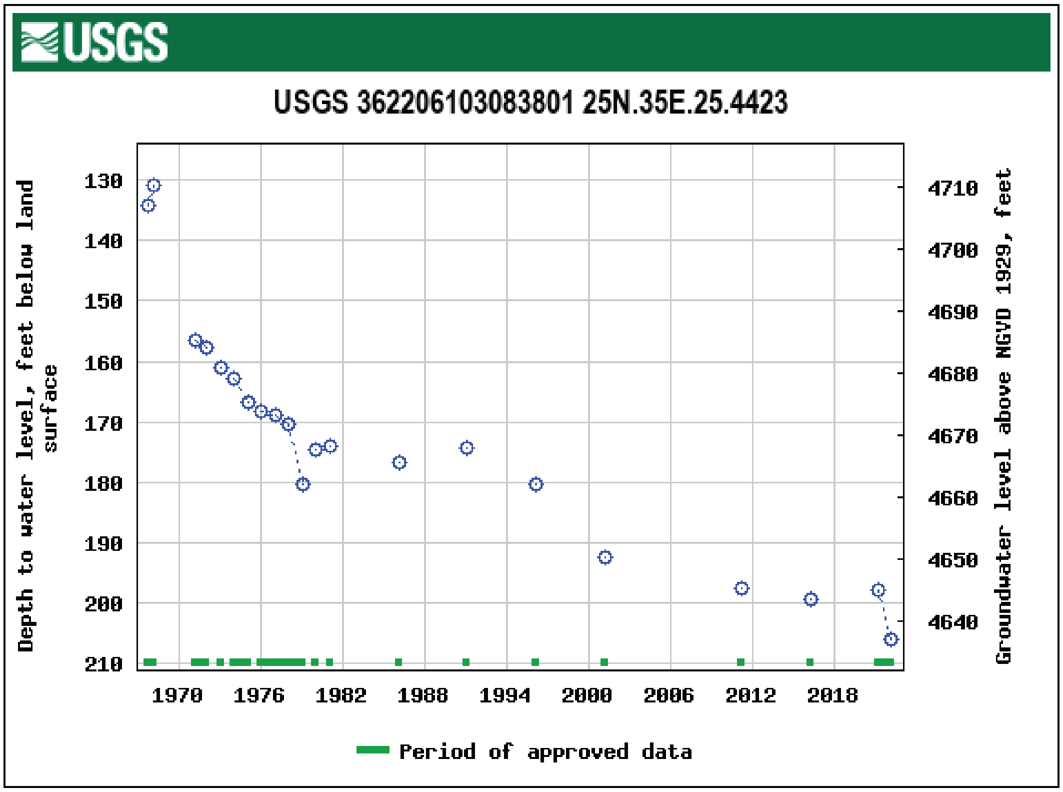

Figures 4-4a and 4-4b. Select wells showing rate of decline. (a) Field measurements of USGS well 361741103051001 completed in the High Plains aquifer and (b) field measurements of USGS well 362206103083801 completed in the Dakota Formation aquifer.

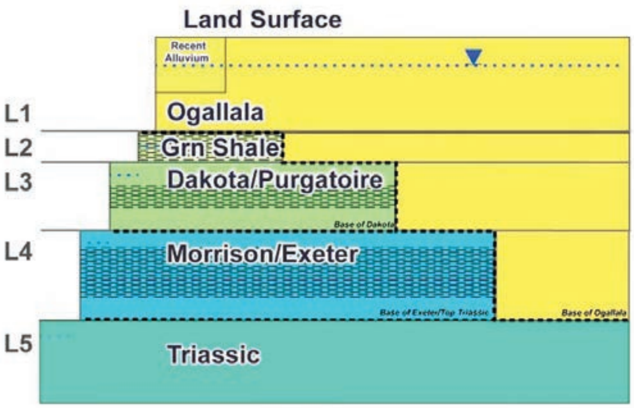

Figure 4-5. Eastern Clayton Basin administrative model layer descriptions (from Balleau Groundwater Inc., unpublished).

MONITORING RECOMMENDATIONS

The target aquifers for monitoring in the east-central Clayton Basin are the High Plains and Dakota Formation aquifers, in both high-use areas and for background levels, because these are the primary aquifers being utilized. Finding areas for monitoring background levels, particularly in the High Plains aquifer, is challenging due to the abundance of active irrigation wells, but extending the possible monitoring area outside of the defined region of interest gives greater flexibility. Recommended well locations and functions are shown in Figure 4-6. Estimated costs to install the recommended wells can be found in Table 4-1.

Table 4-1. Cost estimates for recommended monitoring wells in the east-central Clayton Basin.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
				Low	High
1	450	100	No	$129,000	$147,000
2	400	50	No	$116,000	$134,000
3	400	50	Yes	$127,000	$145,000
4	700	60	Yes	$193,000	$211,000
5	400	100	Yes	$130,000	$148,000
TOTAL				$695,000	$785,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. This high-use area, located northeast of Clayton, contains a section of state land as well as a portion of the Kiowa National Grassland near the Texas state line. The USGS well 362940103025701, located just south of the area and completed in the High Plains aquifer, has shown a steady decline between 1971 and 2006 (the last year of measurement). The Rawling report (2013) indicates that the Dakota Formation is absent in this area, but this seems unclear based on a review of recent well logs in the vicinity. There may be water in the High Plains aquifer in this area, but this too is unclear. Most wells in the area are between 300 and 450 ft, so suggested depth is 450 ft.

Location 2. This high-use area, located south of Sedan, contains state land and is in an area identified by Rawling (2013) as having a significant thickness of the Ogallala Formation. There are many irrigation wells to the northwest, northeast, and southeast of this location. Though most of these wells do not have well logs available because they were drilled prior to the basin being declared, review of many of the water right declarations indicates that some of the wells are likely completed in the Ogallala Formation, while the majority are deeper and likely completed in the Dakota Formation. There are no active monitoring wells near Location 2; however, USGS well 360837103090701, located approximately 2.8 mi north-northeast of Location 2, is ostensibly completed in the Dakota Formation at a depth of 390 ft. This well has shown a steady rate of decline of approximately 1.5 ft/yr measured from 1972 until 2015. Final depth to water was 235 ft. Therefore, the expected current depth to water is 247 ft. Recommended well depth is 400 ft.

Location 3. This high-use area is located within the Kiowa National Grassland in between two areas of irrigation. The USGS well 361741103051001 is located just to the northeast of the area and has shown a steadily declining water level since 1982, with an average rate of decline of 2 ft/yr (the measurement frequency of this well has been irregular) and a most-recent depth to water of 197 ft. The depth of this well is unknown, but USGS indicates that it is in the Ogallala Formation.

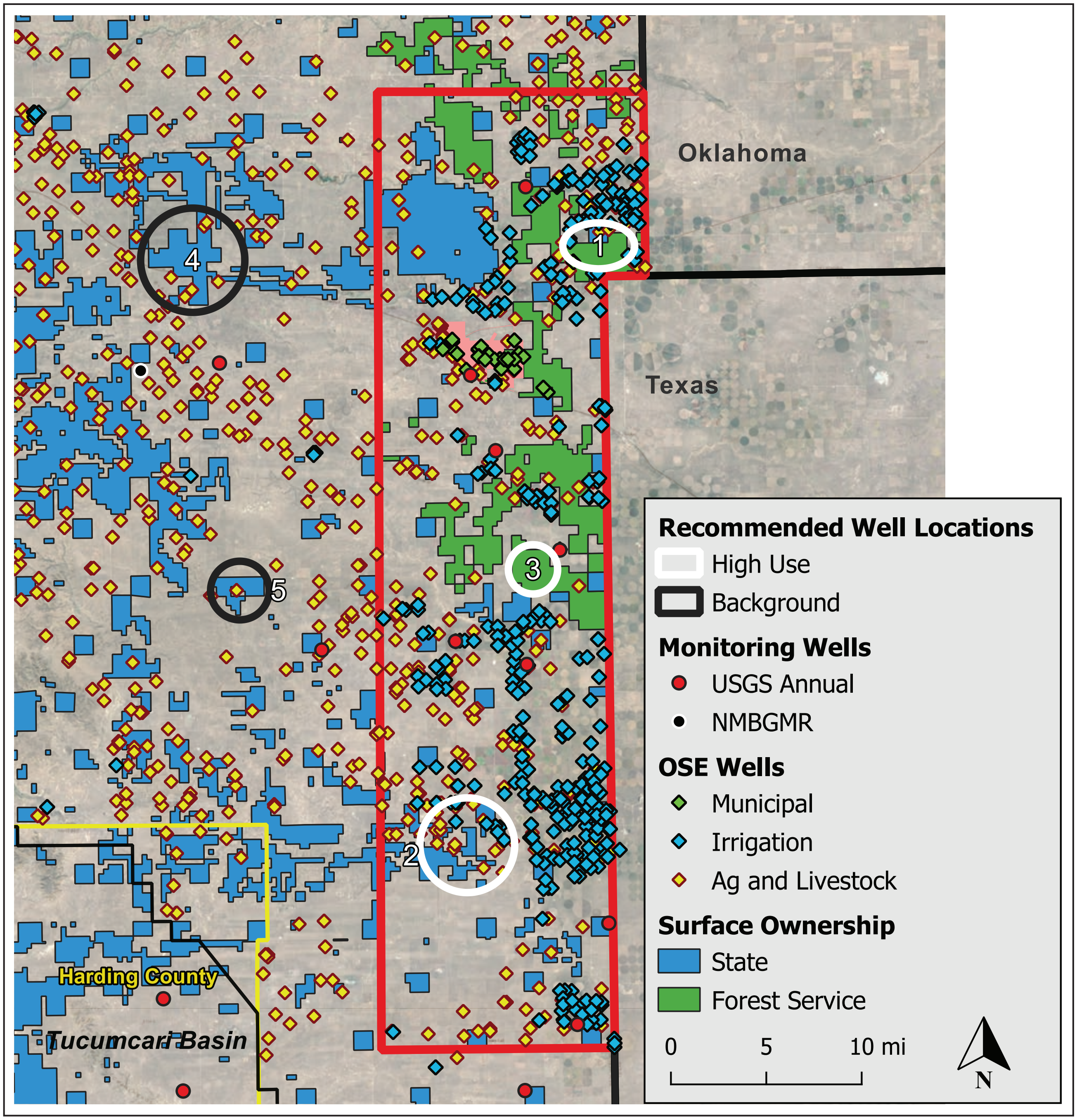

Figure 4-6. East-central Clayton Basin land surface ownership and recommended monitoring well locations.

This likely is correct since well CT-1555, which is very close by, has a declaration indicating a depth of 385 ft, which probably puts the bottom of the well in the Dakota Formation, and a depth to water in 1967 of 188 ft. The proposed well will be completed in the Dakota Formation aquifer with an artesian completion. Recommended well depth is 400 ft.

Location 4. Finding background well locations within the project region is not feasible. This suggested background well location is approximately 7 mi west of the western boundary of our area of interest on state land. There are not many wells in the area with time-series data, but those with data and that appear to be in the Dakota Formation show no appreciable water-level decline. The Healy Collaborative Groundwater Monitoring Network well WL-0115 (OSE well CT-1370), located approximately 5 mi south-southwest of Location 5, which has been continuously monitored since August 2019, has shown no apparent decline over this period. This well, ostensibly completed in the Dakota Formation at a depth of 205 ft, functions as a background well but is also a private production well with no well log. Stock well CT-1275, located within Location 4, was drilled in 2009 to a depth of 705 ft. The primary water-bearing zone was from 640 to 705 ft with artesian pressure; the formation is unclear. There is also an annual USGS monitoring well (362616103241401) located southeast of Location 4, but it is only 76 ft deep and almost certainly not completed in the Dakota Formation. Recommended well depth is 700 ft.

Location 5. This suggested background well, located on state land, is approximately 7 mi west of the western boundary of the project area. There is an annual USGS well (361314103183301) completed to a depth of 207 ft located approximately 5 mi southeast of Location 5, but it appears to be responding to groundwater production to the east. Depth of the Dakota Formation is unknown. Maximum depth would be 600 ft. It is unclear if the well would be artesian in this location but will be assumed as such for cost estimation purposes.

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Depth to water measured in real time using a pressure transducer with telemetry.

CHAPTER 5. ESTANCIA BASIN

Robert Pine

The Estancia Underground Water Basin (referred to here as the Estancia Basin or the Basin) is a hydrologically closed basin with multiple aquifers that covers approximately 1,993 mi^2 within four counties: Bernalillo, San Miguel, Santa Fe, and, primarily, Torrance. It extends from the crest of the Manzano Mountains on the west side to approximately the drainage divide in the east (the Pedernal uplift), and from the edge of the Galisteo Basin escarpment in the north to the Mesa de Jumanos to the south (see Fig. 5-1). Exact population figures for the Estancia Basin are not available, but it is estimated to be approximately 31,000 based on the 2020 census for Torrance County and estimates in the Estancia Basin Water Plan (NM Interstate Stream Commission, 2016).

GEOLOGY AND HYDROLOGY

The Estancia Basin was formed by the Cenozoic uplift of the Manzano Mountains as a result of the Rio Grande rift, which caused a down-warping to the east (Newton et al., 2020). The upper layer of the central portion of the Basin, trending north-south, is primarily Quaternary basin fill consisting of clay, silt, sand, and gravel. In the center of the Basin is a layer of Pleistocene lake deposits. The basin fill contains the primary aquifer in the Basin from which the majority of irrigation wells produce water. These alluvial wells are generally no more than 400 ft deep and have been good producers. This aquifer is recharged from infiltration from surface runoff from snowmelt and rainfall events. The quality of the groundwater in the basin-fill aquifer is increasingly brackish as it moves toward the southern Estancia Basin, exceeding 3,000 parts per million total dissolved solids (TDS). To the east of Estancia and Willard are playa lake beds that are known to be areas of aquifer discharge through evaporation.

Underlying the alluvial deposits is a series of formations of Triassic, Permian, and Pennsylvanian age overlying Precambrian rocks, as seen in the geologic cross sections in Figures 5-2a and 5-2b. Many of these formations are exposed at the surface at various locations within the Basin, most significantly being the Pennsylvanian Madera Group, which is at the surface throughout the majority of the Manzano Mountains and serves as the sole aquifer in this region. The Madera Group consists primarily of limestone with interbedded shale and sandstone, and is recharged from snowmelt and rainfall in the Manzano Mountains. The hydrologic interaction, if any, between the Madera aquifer and the basin-fill aquifer is unknown; many have speculated that the deeper aquifers discharge at the playa lakes, but evidence for this is scant.

Some Permian and Triassic formations above the Madera Group contain aquifers that serve as a source of water in certain areas. These formations are generally not as productive as the basin-fill aquifer but do supply water for irrigation in a relatively small number of wells. Smith (1957) notes a well producing 3,000 gallons per minute from the Glorieta Sandstone, indicating that some areas where bedrock is highly fractured can be very productive. It is often not clear from well logs which formation a well is producing from due to the poor quality of the log and/or because the well appears to have been drilled and completed through multiple formations. The Permian Glorieta Sandstone is a principal aquifer in the northeastern portion of the Basin, and the Yeso Formation is the source of groundwater production in the southwestern portion and portions of the eastern Basin (Smith, 1957). Triassic formations provide groundwater in the northern portion of the Basin.

Based on the presence or absence of certain formations, the Estancia Basin presents a patchwork of different combinations of aquifer availability.

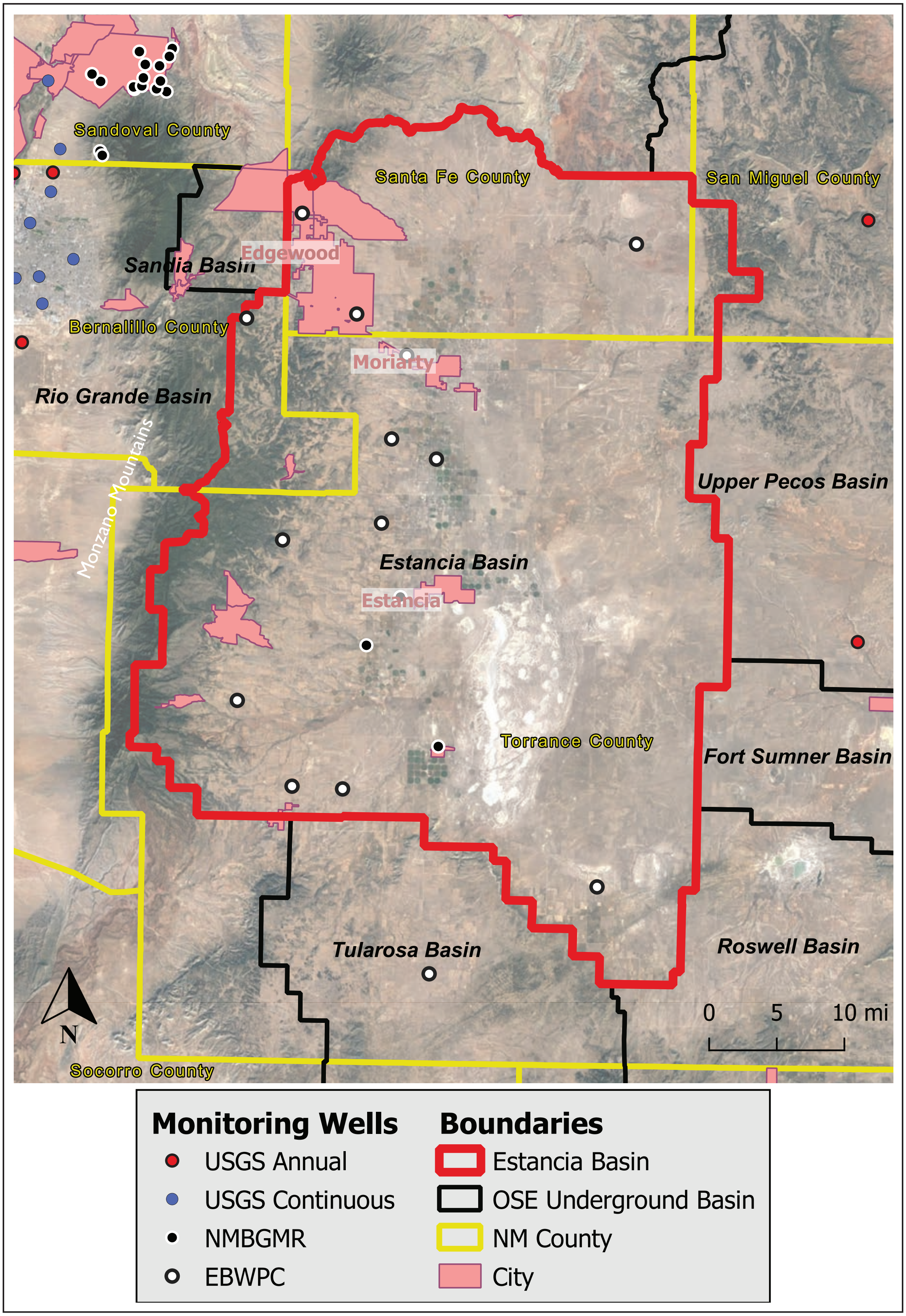
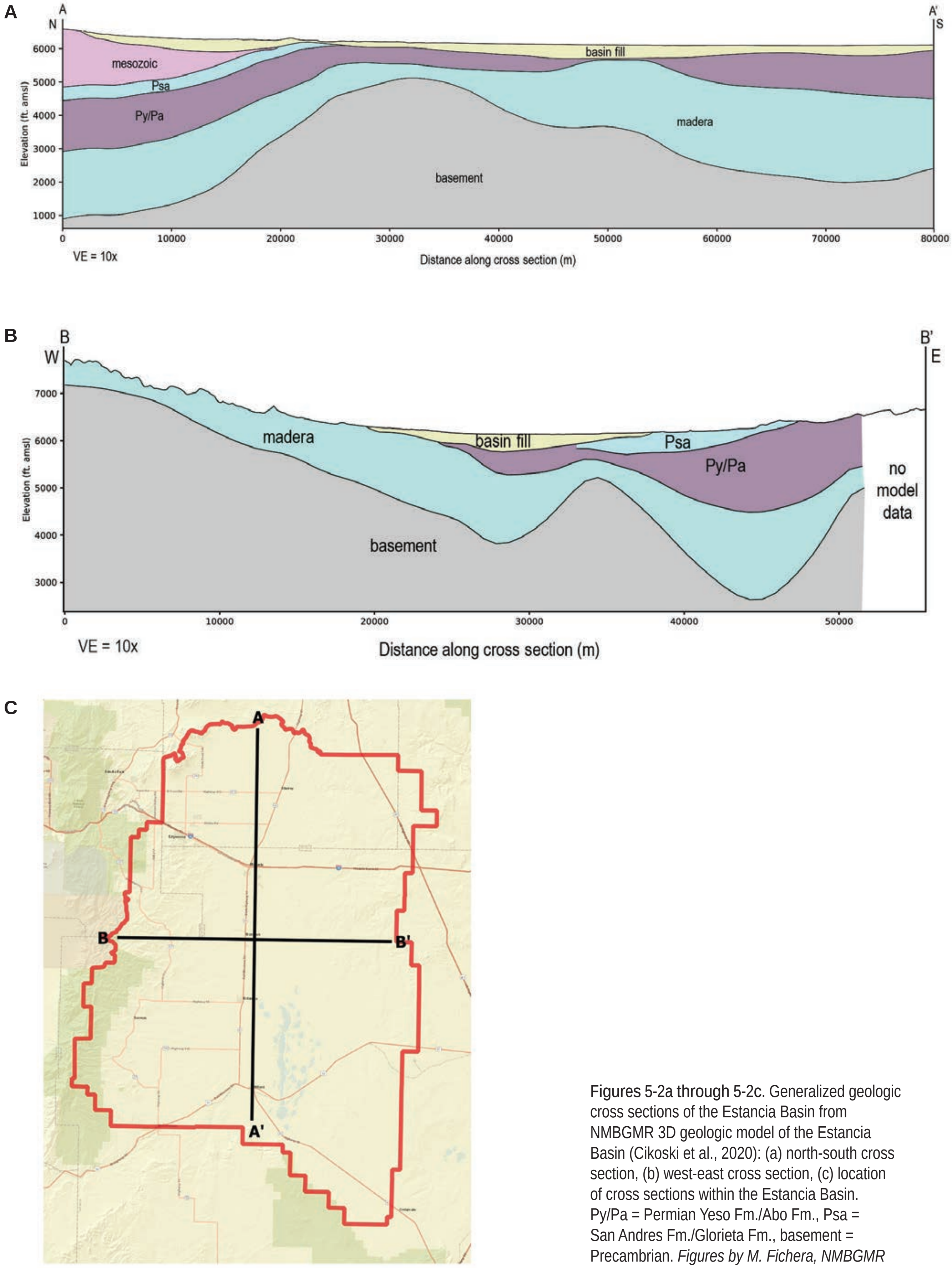


Figure 5-1. Estancia Basin overview showing active monitoring wells and neighboring declared underground water basins.



Figures 5-2a through 5-2c. Generalized geologic cross sections of the Estancia Basin from NMBGMR 3D geologic model of the Estancia Basin (Cikoski et al., 2020): (a) north-south cross section, (b) west-east cross section, (c) location of cross sections within the Estancia Basin. Py/Pa = Permian Yeso Fm./Abo Fm., Psa = San Andres Fm./Glorieta Fm., basement = Precambrian. *Figures by M. Fichera, NMBGMR*

Figure 5-3 is an aquifer map of the Basin based largely on the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) 3D geologic mapping, with modifications by Robert Pine. The 3D model (and therefore the aquifer map) is based on surface geology and the interpretation of driller's logs, and so should be considered an approximation because such logs are generally unreliable from a geologic standpoint. This aquifer map is the starting point for determining monitoring well locations.

WATER RIGHTS AND WATER USE

Currently in the Estancia Basin there are 152,891 acre-feet per year (acre-ft/yr) of irrigation water rights. The New Mexico Office of the State Engineer's (OSE) 2015 water use report (Magnuson et al., 2019) indicates that 65,030 acre-ft were produced for irrigation in the Basin in 2015. The primary crops grown are alfalfa, corn silage, oats, and winter wheat; beans, pumpkins, and sweet corn are also grown. Not all irrigation wells in the Basin are metered; metering was only required in 2002 with the adoption of the administrative guidelines, and thus older wells are not metered. Currently, only 129 out of 1,219 irrigation wells in the Basin are metered, making it difficult to accurately determine or estimate water use.

There are currently 5,245 acre-ft/yr of water rights permitted for municipal use, including use by Mutual Domestic Water Consumer Associations. The majority of these water rights serves the communities of Edgewood (2,000 connections), Moriarty (1,050 connections), Mountainair (587 connections), and Estancia (485 connections) as well as the Entranosa Water and Wastewater Association (3,225 connections), a cooperative that serves numerous developments in the East Mountains, including some located outside of the Basin. There are approximately 6,140 domestic wells in the Basin, although only 5,164 have completion reports. It is not known how many of these domestic wells are currently active. Figure 5-4 shows the distribution of OSE wells.

In July 2001, the State Engineer ordered that the Estancia Basin be closed to new appropriations. An administrative model was developed, and in 2002, administrative guidelines were adopted that defined Critical Management Areas (CMA) that restricted transfers from non-CMA regions into CMAs. These guidelines were revised in 2021 to allow the replacement of wells into deeper formations (i.e., aquifers), a practice normally not permitted by OSE. In addition to the CMAs, the guidelines defined a Poor Quality Area, as seen in Figure 5-4, that restricts well construction so that shallow groundwater with high TDS won't comingle with deeper groundwater of higher quality.

GROUNDWATER MONITORING

As can be seen in Figure 5-1, there are currently no active U.S. Geological Survey (USGS) monitoring wells in the Estancia Basin, though they have taken hundreds of measurements in numerous wells throughout the region over the years. Many of those wells with multiple measurements indicate declining water levels. The NMBGMR has three active continuous monitoring wells in the southern portion of the Basin.

The OSE has collected annual measurements in the Estancia Basin for over 30 years. However, some years were skipped due to staffing issues, some wells may not have been measured in a particular year due to access issues or because they were pumping, and some wells have been replaced over time. The data from this program, which are kept on multiple spreadsheets in the OSE District 1 (Albuquerque) Office, show that water levels have been declining by at least 1 ft/yr in most areas (District 1 staff, personal communication).

The Estancia Basin Water Planning Committee (EBWPC) established a hydrogeologic monitoring program in 2011 to monitor groundwater levels in the Basin. Currently, there are 14 wells in the program, three of which are instrumented for continuous monitoring (Melis, 2022). Seven wells were previously monitored but were discontinued. As of the 2022 report, four of the 14 wells, all completed in the basin fill, showed a clear declining water-level trend, with rates of decline from 0.8 ft/yr to 2.9 ft/yr. Most other well hydrographs were either flat or variable.

Figure 5-5 shows a graph of the average depth to water, and Figure 5-6 shows average well depth of domestic wells drilled in the Basin by year. It can be seen that both well depth and depth to water are steadily increasing over time, though not at the same rate. The linear trend line for depth to water has a slope of approximately 2.2, suggesting a basin-wide average rate of decline of 2.2 ft/yr.

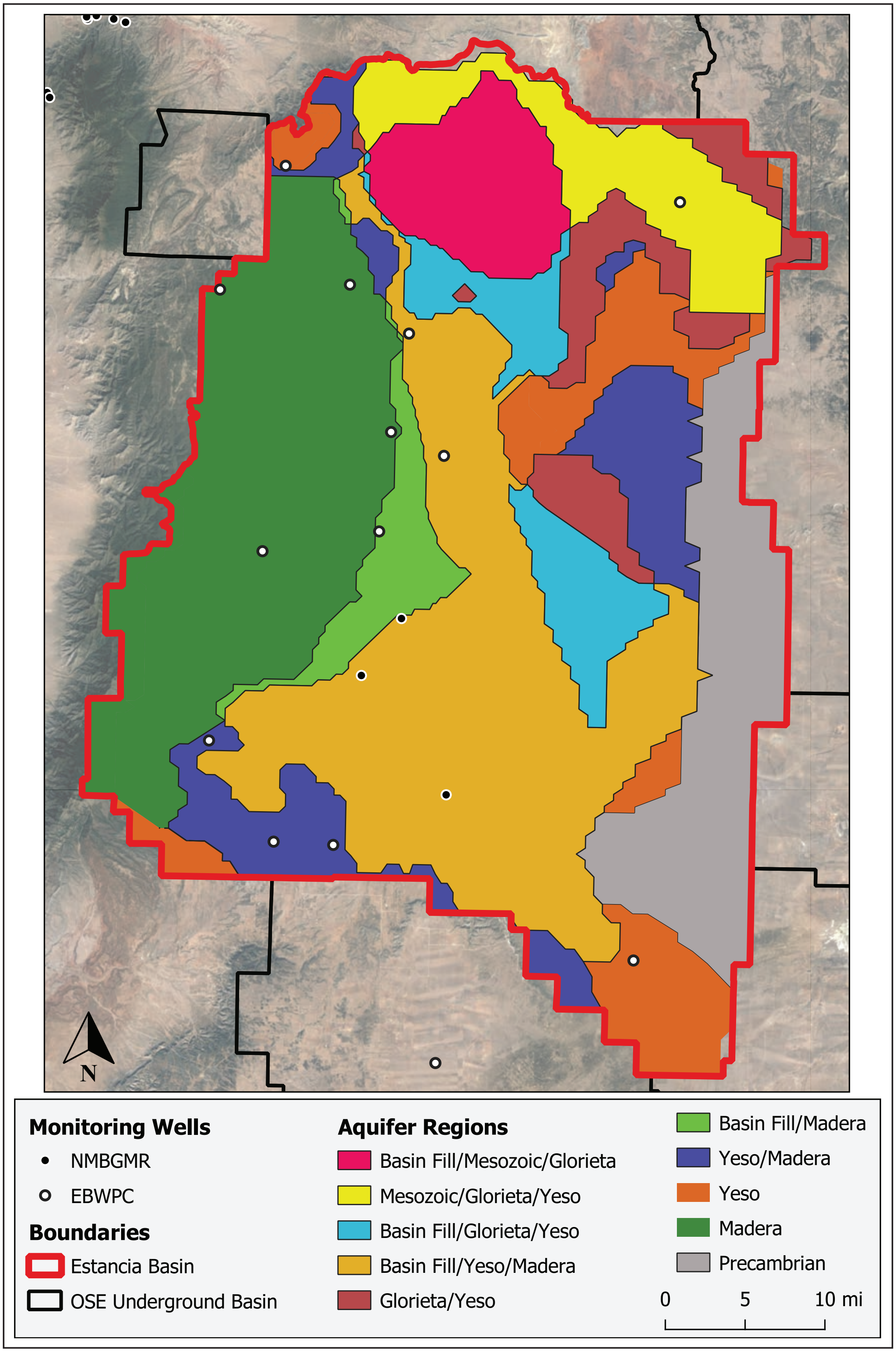


Figure 5-3. Aquifer availability regions in the Estancia Basin based on NMBGMR 3D geologic model of the Basin.

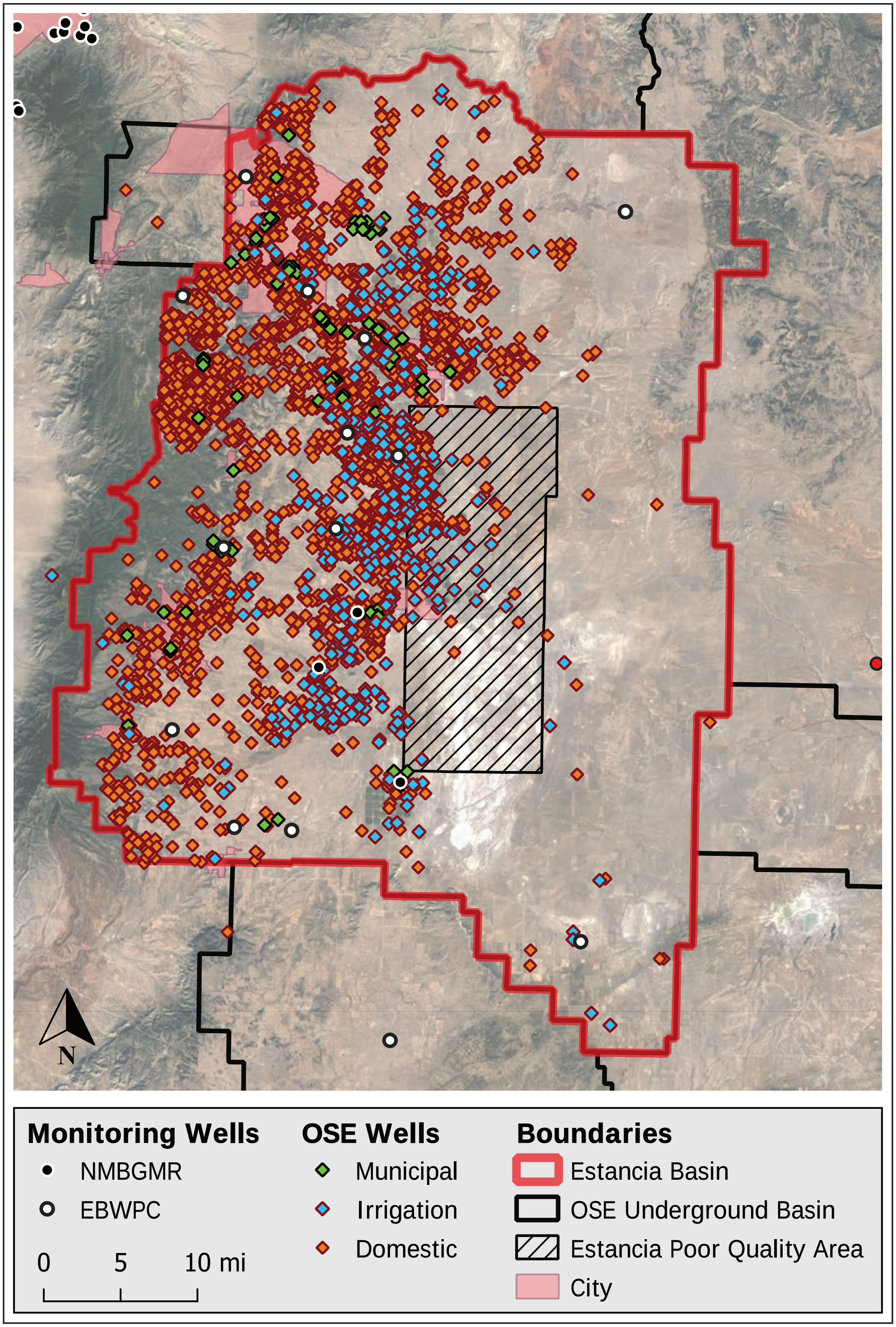


Figure 5-4. Distribution of OSE municipal, irrigation, and domestic wells and OSE-designated Poor Quality Area within the Estancia Basin.

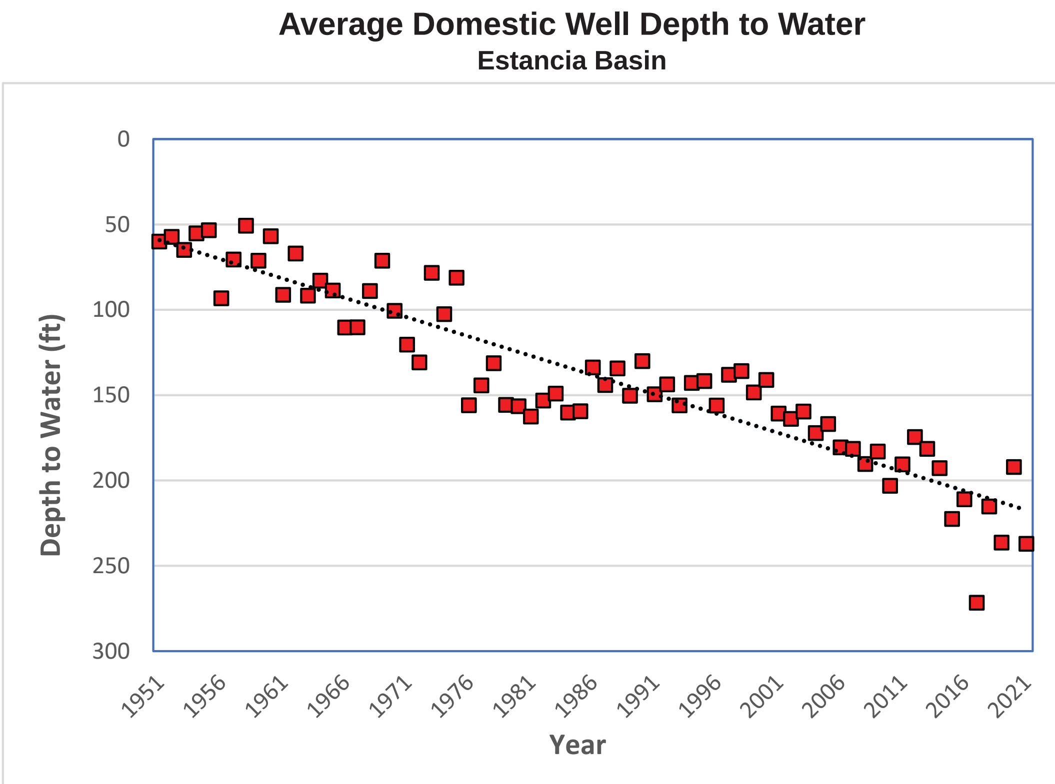


Figure 5-5. Estancia Basin average domestic well depth to water by year with trend line.

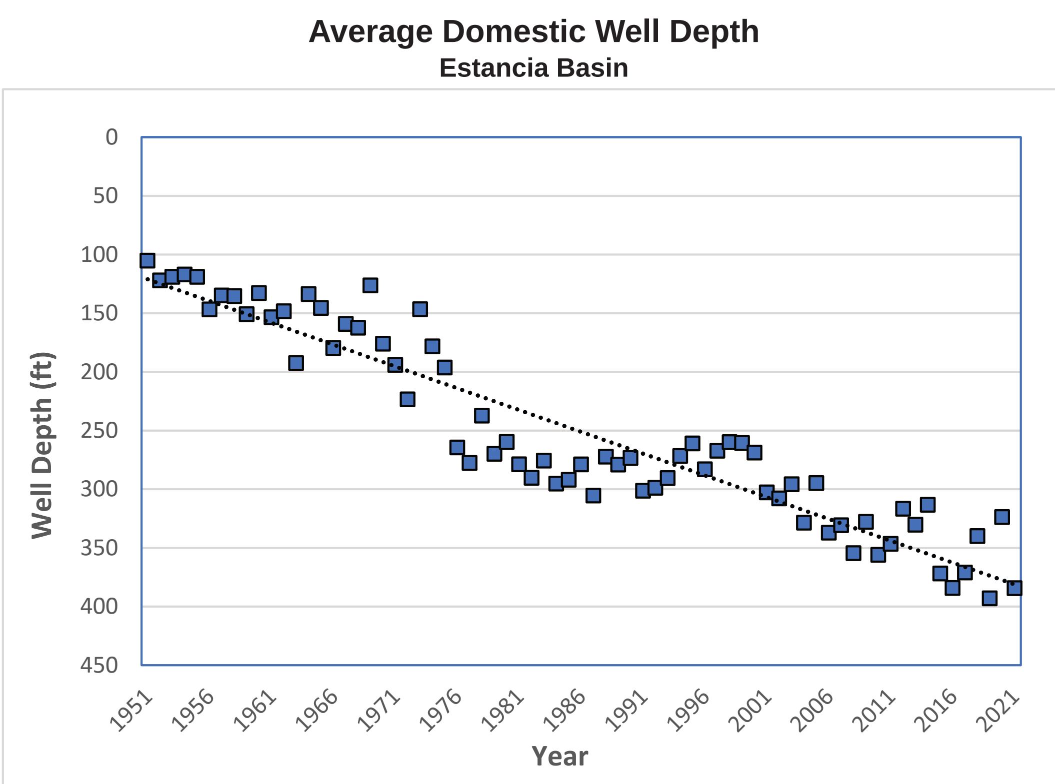


Figure 5-6. Estancia Basin average domestic well depth by year with trend line.

Readers should bear in mind, though, that some areas are not showing a decline, and because there are multiple aquifers in the Basin, some of the increase in well depth is accounted for by an increase in completions in the deeper aquifers.

GROUNDWATER MODELS

The model used by OSE for administration of water rights in the Estancia Basin is the 2001 calibrated Frost and Keyes model, which is an updated version of a model created by Balleau Groundwater Inc. in 1997 (referred to as ESTAN97 by OSE). The modifications in the Frost/Keyes model include changes to some boundary conditions and the addition of some irrigation wells. The model has five layers: Layer 1 = alluvium and playa lake beds, Layer 2 = alluvium, Layer 3 = alluvium and Glorieta/San Andres Formations, Layer 4 = alluvium and Yeso/Abo Formations, and Layer 5 = Madera Group. For water-rights administrative purposes, the model assumes each water right produces its full permitted amount.

LAND SURFACE OWNERSHIP

Figure 5-7 shows the land surface ownership status in the Estancia Basin. The majority of land in the Basin is privately owned, covering 78% of the Basin, and the remainder is 17% state land, 4% U.S. Forest Service, and 1% Bureau of Land Management (BLM). This presents a challenge for siting monitoring wells, but not an insurmountable one.

MONITORING RECOMMENDATIONS

Goals for monitoring the Estancia Basin should include monitoring of high-use and background areas in the most commonly utilized aquifers: the basin-fill aquifer, the Madera Group aquifer, the Mesozoic aquifer(s), the Glorieta Formation aquifer, and the Yeso Formation aquifer. It is unclear if there are high-use areas in the Yeso Formation, but some monitoring is desirable because it is a utilized aquifer. Figure 5-8 shows suggested locations for recommended monitoring wells and their function numbered in order of priority. Estimated costs to install the recommended wells can be found in Table 5-1.

The following locations, in order of priority, were identified for monitoring wells.

Location 1. This is an area of high use within the basin-fill aquifer located on state land. In addition to a considerable amount of irrigation, there is a large concentration of domestic wells. It is unclear what the thickness of the alluvium is in this area, but it is probably around 275 to 300 ft thick based on well logs. Many of the irrigation wells are deeper than 300 ft, but it is not clear which formation they are tapped into based on well log descriptions. Depth to water for most recently drilled domestic wells less than 300 ft deep is typically in the range of 140 to 180 ft. It is recommended that this well be drilled to the bottom of the alluvium at an estimated depth of 300 ft.

Table 5-1. Cost estimates for recommended monitoring wells in the Estancia Basin.

Well Location	Aquifer	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates Low	Cost Estimates High
1	Basin fill	300	50	No	$94,000	$112,000
2	Madera	500	50	No	$131,000	$149,000
3	Basin fill	200	50	No	$75,000	$93,000
3	Madera	350	50	Yes	$113,000	$131,000
4	Basin fill	250	50	No	$84,000	$102,000
4	Glorieta or Yeso	500	100	Yes	$147,000	$165,000
5	Basin fill	225	50	No	$80,000	$98,000
5	Mesozoic	350	50	Yes	$113,000	$131,000
6	Madera	600	100	No	$153,000	$171,000
7	Madera	300	50	No	$94,000	$112,000
8	Glorieta	300	50	No	$94,000	$112,000
TOTAL					$1,178,000	$1,376,000

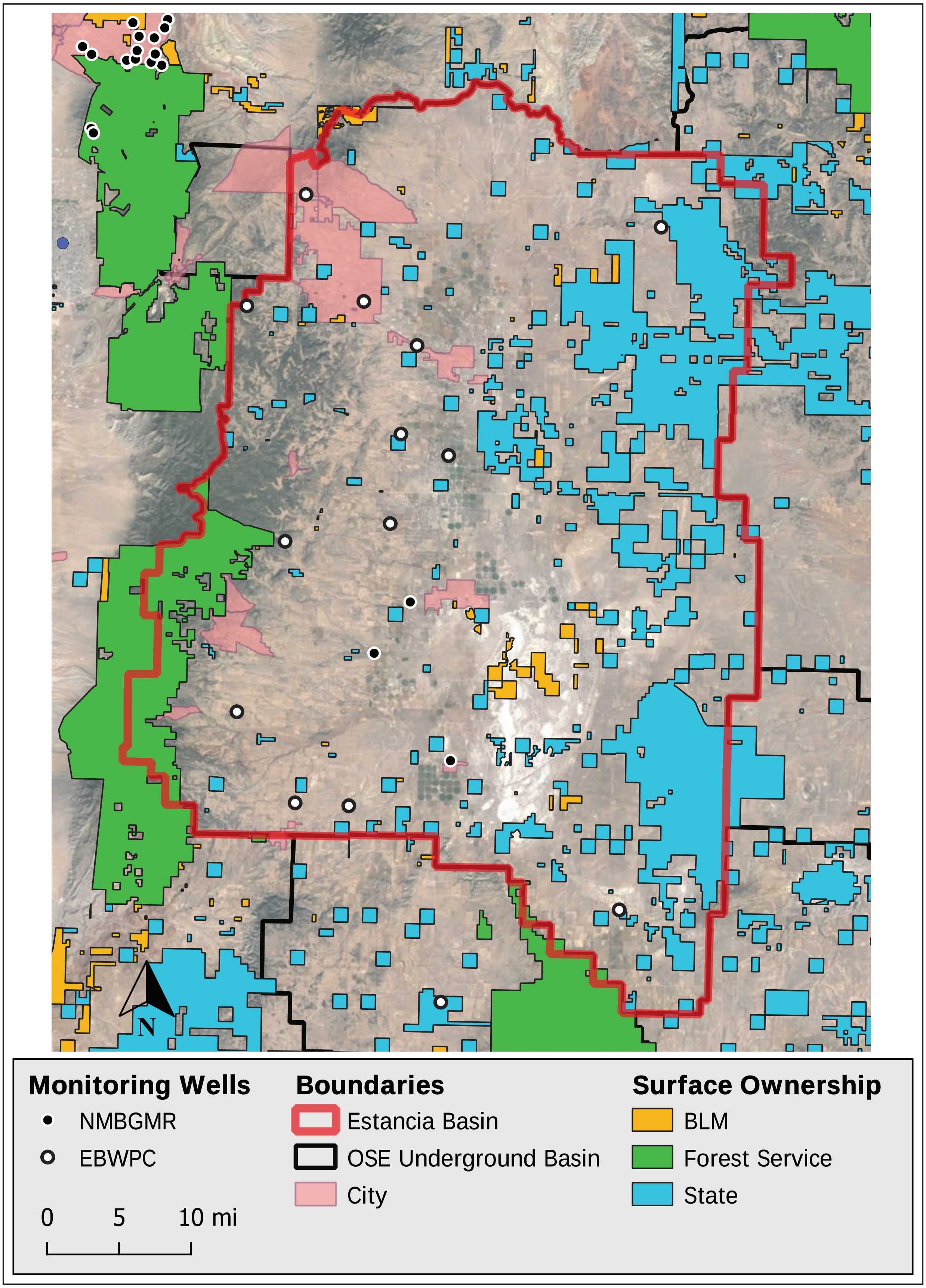


Figure 5-7. Estancia Basin land surface ownership. No color overlay indicates private ownership.

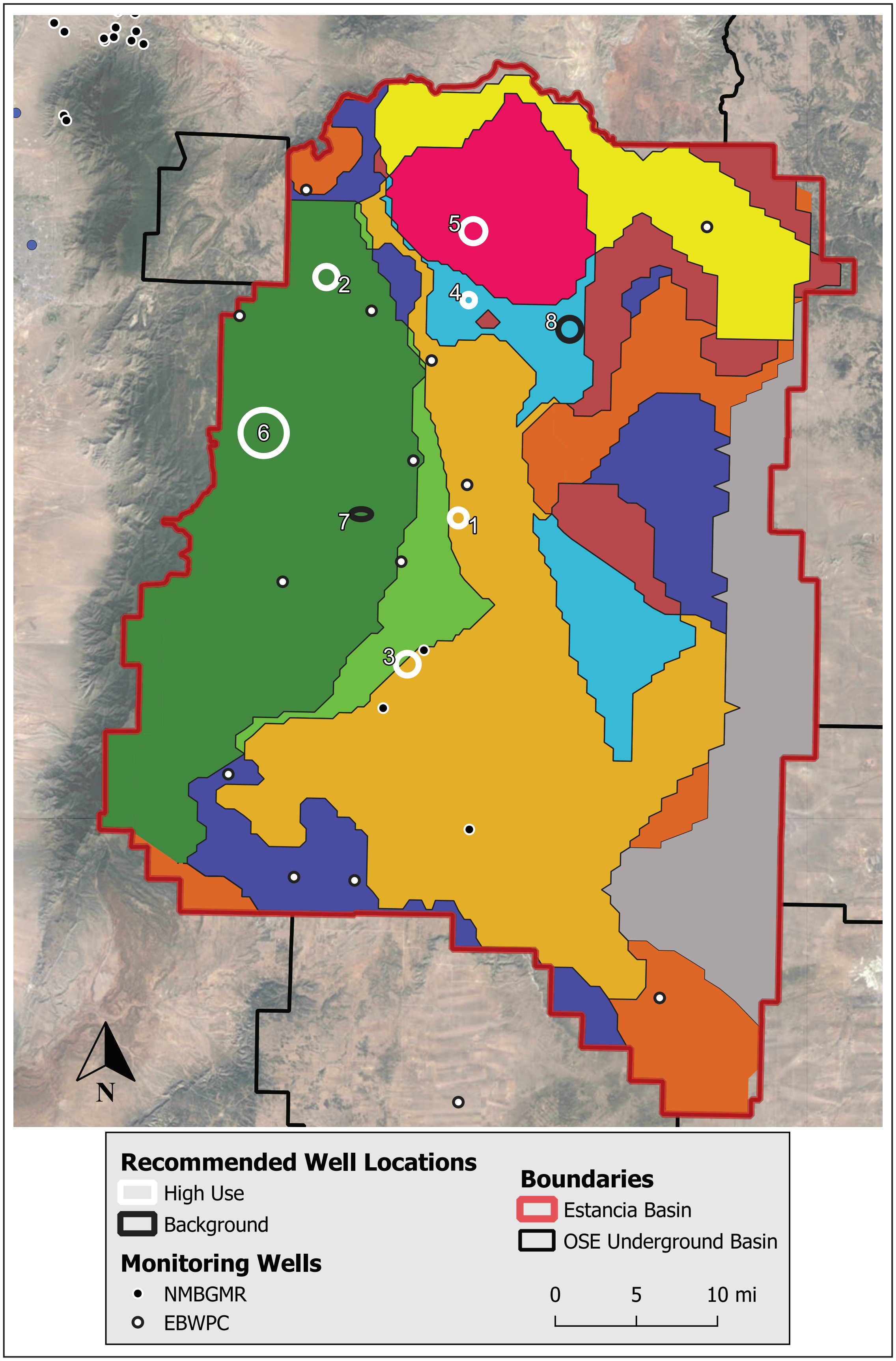


Figure 5-8. Recommended Estancia Basin monitoring well locations and functions. Refer to Figure 5-3 for color coding of aquifer regions.

Location 2. This location is within the town of Edgewood north of Interstate 40 on state land. The primary aquifer is the Madera Group. There are several municipal supply, domestic, and irrigation wells nearby. Most recently drilled wells have depths around 500 ft, with depth to water averaging 380 ft. Recommended well depth is 500 ft.

Location 3. This is an area of high use on state land where wells are completed either in the basin-fill aquifer or in the Madera Group. There are many irrigation and domestic wells in the area in addition to the water supply wells for the town of Estancia. The NMBGMR has continuously monitored a nearby Estancia supply well (WL-0093) since August 2018. The water level in this well has shown a declining trend over time. Recommended for this location is a set of two wells, one completed in the basin-fill aquifer and one in the Madera Formation. It is unclear if the Madera aquifer is artesian in this area or if the aquifers are connected. The alluvium appears to be approximately 200 ft thick in this area, thickening somewhat to the east based on well logs. Estimated depth of the recommended alluvial well is 200 ft and 350 ft for the Madera Group well.

Location 4. This is a high-use area for both the basin fill and the deeper formation, which is either San Andres-Glorieta or Yeso (very difficult to know from the driller's logs). The alluvial depth is approximately 250 ft, with most irrigation wells drilled from 300 to 500 ft. In this location on state land, a basin-fill well drilled to 250 ft and a deeper-formation well drilled to 500 ft are recommended.

Location 5. This is an area of moderate to high use in the northern Basin on state land. The majority of wells appear to be completed in the basin-fill aquifer; some deeper wells are found, though it is unclear if they are completed in the Mesozoic formations or in the San Andres-Glorieta. There are currently no monitoring wells in this area. The thickness of the alluvium appears to be approximately 250 ft. The deepest wells in the area are 450 ft. In this location, a basin-fill well drilled to 250 ft and a deeper-formation well drilled to 450 ft are recommended.

Location 6. This is a high-use area in the Madera Group. There is no irrigation or commercial use, but it is an area with a large number of domestic wells. Well depth generally ranges from around 100 up to 600 ft. Reported depths to water are quite variable, ranging from 135 to 400 ft. There are two parcels of state land in this location. Recommended well depth is 600 ft.

Location 7. This is a low-use area in the Madera Group on state land. There is a low density of domestic wells and some irrigation wells within a couple of miles, but there does not appear to have been any active irrigation here for some years based on historical imagery. There are few well logs in the area, but based on those that exist, the recommended well depth is 300 ft, with an estimated depth to water of 200 ft.

Location 8. This is a low-use area ostensibly tapping into the Glorieta Sandstone located on state land. There are few good driller's logs in the immediate area, but based on what exists, the recommended well depth is 300 ft, with an estimated depth to water of 150 ft.

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Steel tapes with graduated markings are the preferred and most accurate method for measuring depth to groundwater. *Photo by Christi Bode, Moxiecran Media LLC*

CHAPTER 6. LOWER RIO GRANDE BASIN

Robert Pine

The Lower Rio Grande Underground Water Basin (referred to here as the LRG Basin) is located in Doña Ana and Sierra Counties as shown in Figure 6-1. The LRG Basin covers an area of approximately 3,850 mi^2 and contains the municipalities of Anthony, Hatch, Las Cruces, Mesilla, and Sunland Park, as well as the towns of Mesquite, Radium Springs, and Vado, serving a combined population of approximately 152,000 based on the 2020 census (not including the dispersed population). The New Mexico Office of the State Engineer (OSE) published administrative guidelines for the Mesilla Valley, which was designated a Critical Management Area (CMA) and closed to new appropriations (see Fig. 6-1).

GEOLOGY AND HYDROLOGY

The LRG Basin is the southern portion of the Rio Grande rift in New Mexico. It is bordered on the east by the Organ and San Andres Mountains. West of these mountains is a fault-bounded graben forming two parallel north-south-trending basins: the Mesilla Basin, which contains the Rio Grande, and the Jornada del Muerto Basin (see Fig. 6-1; these basin boundaries are approximate). The Mesilla Basin extends from Radium Springs south into Mexico, while the Jornada del Muerto Basin extends from the southern end of the Organ Mountains north beyond the LRG Basin's northern boundary. Separating the two basins is a mostly buried structural block consisting of Tertiary volcanics and Paleozoic formations. The basin fill, which can be as much as 3,500 ft thick in the Jornada del Muerto Basin and 3,000 ft thick in the Mesilla Basin, consists of the Santa Fe Group covered by a thin layer of late Quaternary valley fill alluvium (Hawley and Kennedy, 2004). Along the Rio Grande is a narrow layer of floodplain alluvium, no more than 2 mi wide and about 60 to 80 ft thick (Wilson et al., 1981).

The aquifers in the LRG Basin are found in the Santa Fe Group of the Mesilla and Jornada del Muerto Basins and overlying floodplain deposits along the Rio Grande. Groundwater flow in the Mesilla Basin is generally to the south into Texas. Groundwater flow in the southern Jornada del Muerto Basin is primarily north toward the Rincon Basin in the northern LRG Basin. However, there has been speculation that there is some flow from the Jornada del Muerto Basin into the Mesilla Basin through gaps in the structural blocks separating the two basins (Hibbs et al., 1997). However, the amount of cross-basin flow is not presumed to be significant.

The Santa Fe Group has been vertically subdivided into three lithostratigraphic units based on general lithology, depositional environments, and time of deposition (Hawley and Kennedy, 2004). The upper Santa Fe Group, known as the Camp Rice Formation, consists of sequences of fluvial sand and pebbly sand deposited by the ancestral Rio Grande. It generally ranges in thickness from approximately 350 to 700 ft and is the most hydrologically productive layer of the Santa Fe Group. For this reason, the majority of wells are completed in this formation. The middle Santa Fe Group generally consists of alternating beds of clean sand, silty sand, and silt-clay mixtures, whereas the lower Santa Fe Group is dominated by fine-grain deposits and is the least productive unit. A generalized geologic cross section is shown in Figure 6-2 (the location of the cross section A–A' is shown in Fig. 6-1).

WATER RIGHTS AND WATER USE

Figure 6-3 shows the distribution of irrigation, municipal (including Mutual Domestic Water Consumer Associations [MDWCA]), and dairy wells in the LRG Basin. The most significant use of groundwater is for irrigation, with approximately 2,100 irrigation wells (the exact number of active wells is unclear) with a total permitted diversion of 469,864 acre-feet per year (acre-ft/yr). The Elephant Butte Irrigation District (EBID) manages irrigation water distribution in the Rincon and Mesilla Valleys.

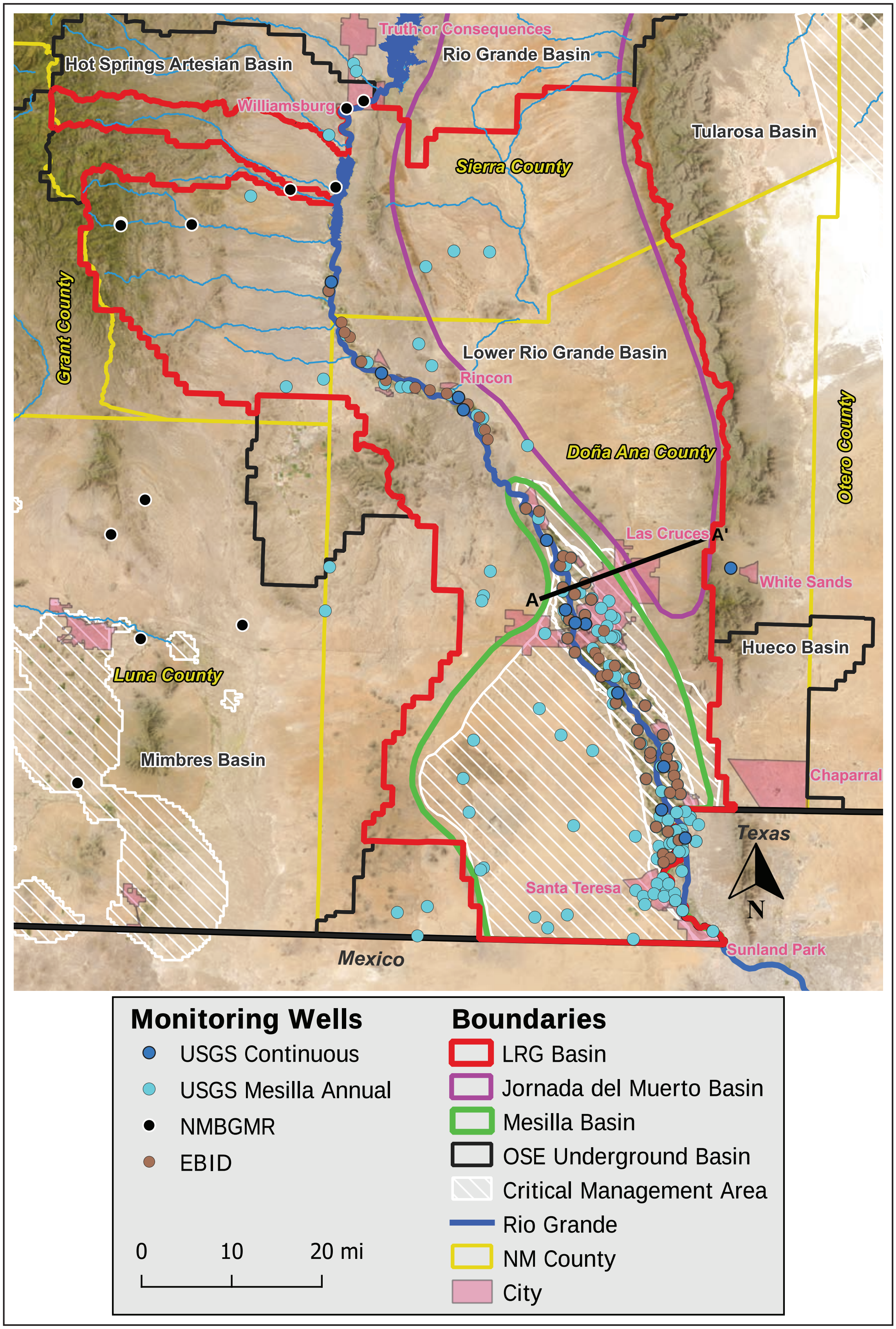

Figure 6-1. Overview of the LRG Basin showing active monitoring wells, Mesilla Valley CMA, neighboring declared underground water basins, and location of cross section in Figure 6-2.

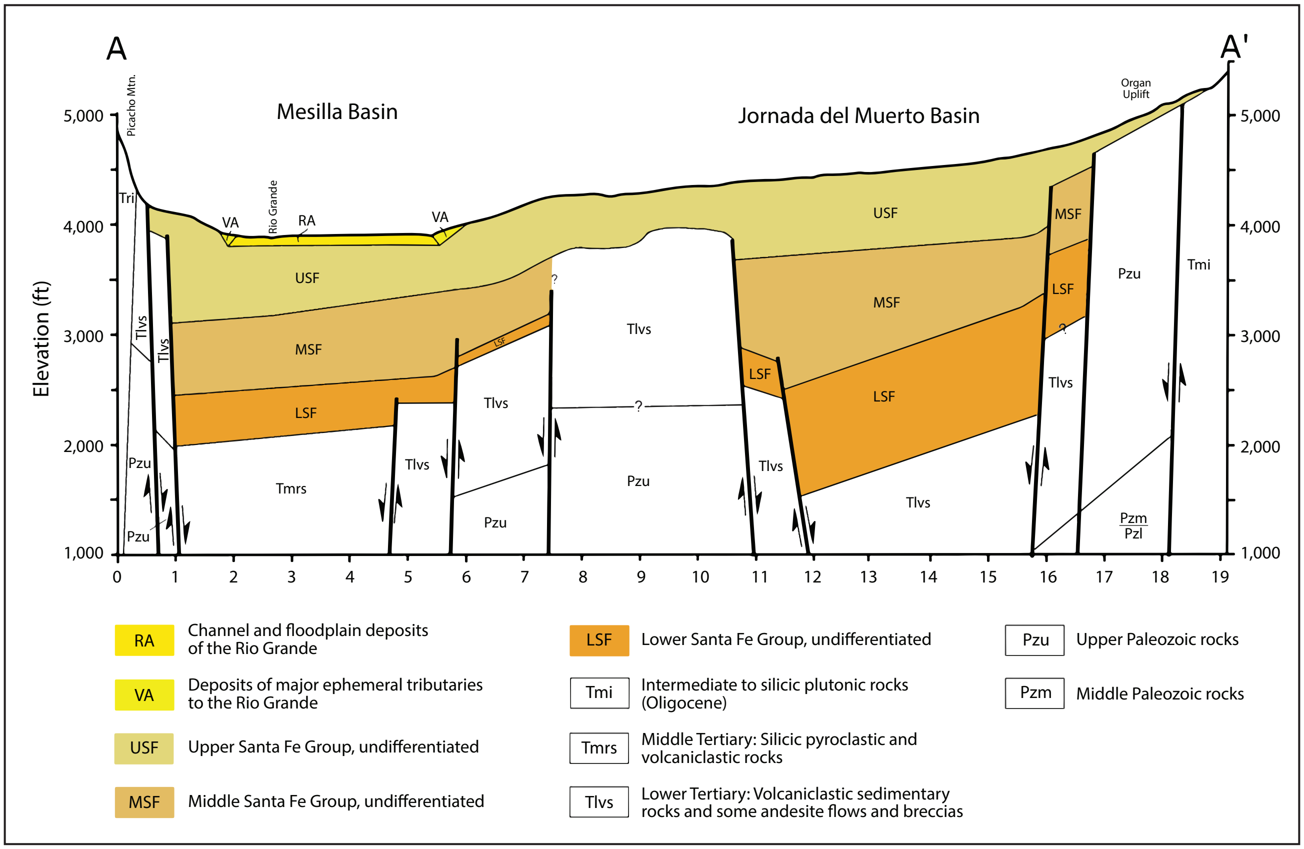

Figure 6-2. Generalized geologic cross section A–A' through the southern portion of the LRG as seen in Figure 6-1 (modified from Hawley and Kennedy [2004]).

There are numerous community water systems in the LRG Basin, all of which rely completely on groundwater for their water source. Many of the water supply wells lie within the Rio Grande corridor, but several are within the southern Jornada del Muerto Basin: Moongate Water Company system, with over 3,000 connections and 3,300 acre-ft/yr of water rights, has eight active wells; the city of Las Cruces has 12 OSE wells with over 3,600 acre-ft/yr of water rights; and the Lower Rio Grande Public Water Works Authority has eight wells (three active) with 1,056 acre-ft/yr of water rights. The LRG Basin also has over 6,200 domestic wells, the majority of which lie within the river corridor.

There are several dairies within the LRG Basin, with combined water rights of over 4,200 acre-ft/yr. These dairy water supply wells all lie within the Rio Grande valley.

GROUNDWATER MONITORING

Figure 6-1 shows the currently active monitoring wells in the LRG Basin. There are two sets of U.S. Geological Survey (USGS) wells: 17 continuously monitored wells, all within 1 mi of the Rio Grande, and 176 Mesilla Basin annual wells that are more broadly distributed, though the majority (approximately 123 or 70%) are within the Rio Grande valley. The EBID owns, manages, and continuously monitors 61 monitoring wells along the river corridor; most of these EBID wells are also listed as USGS wells, though most are annually measured by USGS and the continuous data are not recorded by USGS. The New Mexico Bureau of Geology and Mineral Resources has five Healy Collaborative Groundwater Monitoring Network monitoring wells along Percha Creek in the northwestern portion of the LRG Basin, two of which are the Hillsboro MDWCA supply wells and the other three are in the vicinity of Kingston.

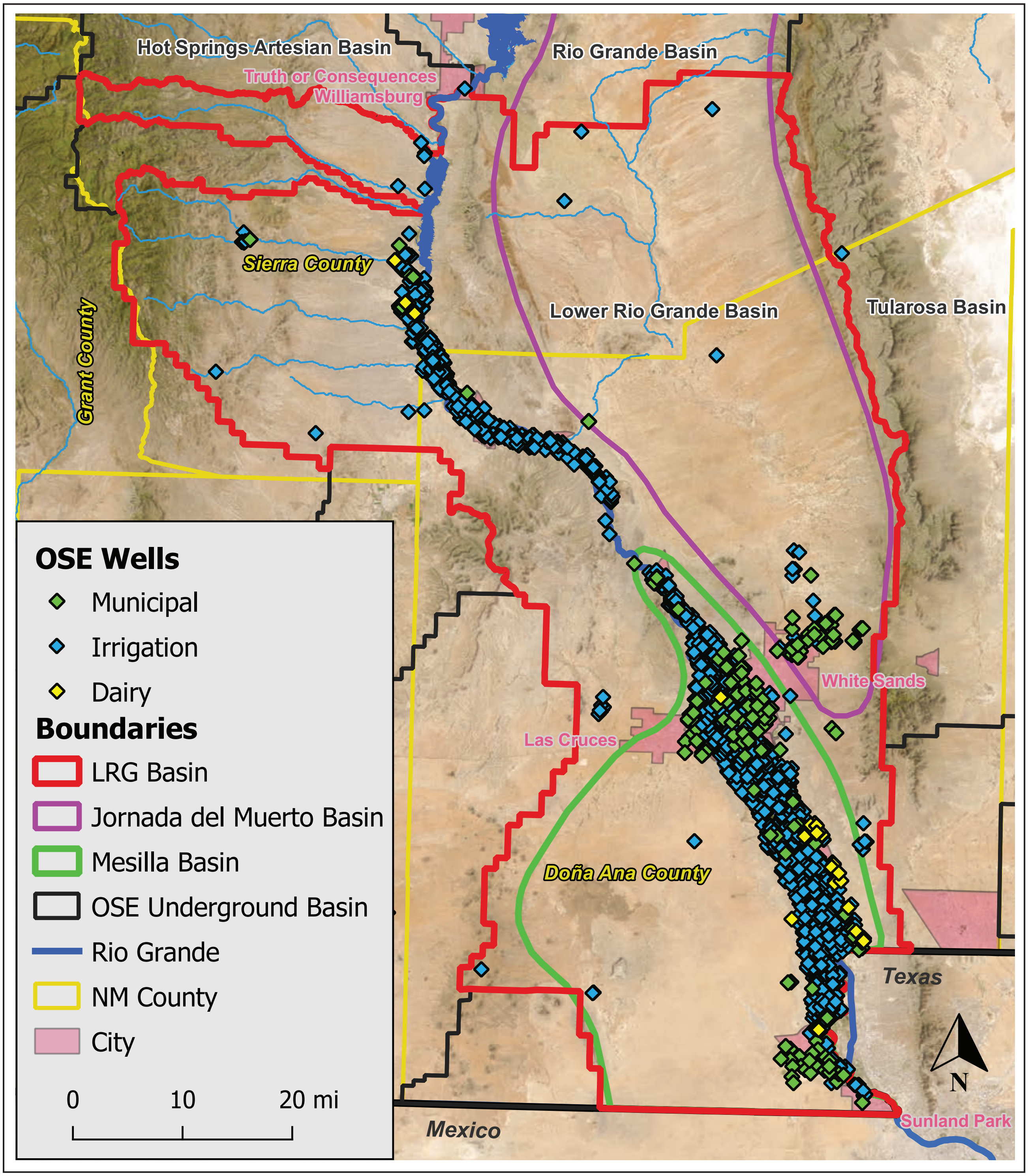

Figure 6-3. Distribution of permitted municipal, irrigation, and dairy production wells in the LRG Basin.

The Rio Grande valley in the LRG Basin is one of the most densely monitored areas in New Mexico, largely due to the state's obligation to deliver water to Texas as part of the Rio Grande Compact. Most monitoring wells in the river valley show seasonal fluctuations in water levels, and several wells have shown a declining trend; for example, the water level in USGS well 321637106444001, located approximately 4.3 mi east of the river, has steadily declined at an average rate of 1.3 ft/yr since 2002.

There are currently no active monitoring wells in the southern Jornada del Muerto Basin despite both the large number of water supply wells in the area and the fact that there have been many wells previously monitored by USGS that have shown steadily declining water levels, as seen in Table 6-1 (see Fig. 6-4 for well locations). On the mesa west of Las Cruces and south of Interstate 10 where the city of Las Cruces has three supply wells (these wells are not currently active), there is one active annual monitoring well that has shown a small declining water-level trend as indicated in Table 6-1.

Table 6-1. Rates of water-level decline in select wells.

USGS Well Number	Depth (ft)	Measurement Interval	Avg. Rate of Decline (ft/yr)
Southern Jornada del Muerto Basin			
322734106432801	572	2009–2012	2.5
322811106393401	560	2009–2012	1.8
322539106412903	1,000	2009–2013	3.2
322529106402701	1,300	1993–2012	2.9
Western Mesilla Basin			
321640106524601	645	2003–2022	0.4

GROUNDWATER MODELS

Several groundwater models of the Mesilla Basin have been created over the years. When the Mesilla Basin administrative guidelines were published in 1999, the groundwater model in use by OSE was a superposition version of a model developed by Frenzel et al. (1992) of the USGS. This was a five-layer MODFLOW model incorporating estimations of evapotranspiration, recharge, and groundwater pumping along with groundwater-surface water interaction.

In 2003, OSE contracted with S.S. Papadopulos & Associates Inc. to create a new groundwater model that would incorporate, among other things, the recent geologic model by Hawley and Kennedy (2004), supplemental irrigation pumping, and refined estimations of farm water budgets. This MODFLOW model was released in 2007 and became the model of choice for OSE analyses. The model includes the Rincon Basin to the north of the Mesilla Basin. Model layers are described in Table 6-2. This model has recently been updated by S.S. Papadopulos & Associates Inc.

LAND SURFACE OWNERSHIP

Figure 6-4 shows land surface ownership within the southern portion of the LRG Basin. There is a considerable amount of Bureau of Land Management (BLM) land in the LRG Basin as well as a significant amount of state land. The northwestern portion of the LRG Basin extends into the Black Range, which is managed by the U.S. Forest Service. In particular, the portion of the Jornada del Muerto Basin where there are several water supply wells has an abundance of road-accessible state and BLM land.

Table 6-2. 2007 Papadopulos Mesilla Basin model layer descriptions.

Layer	Geology	Thickness
1	Rio Grande alluvium within the Rio Grande valley and upper Santa Fe Group outside the valley	70 ft within the valley, increasing to over 300 ft outside of the valley
2	Upper Santa Fe Group sediments in the northern part of the Mesilla Basin and middle Santa Fe Group sediments in the southern part of the LRG Basin	Primarily 130 ft
3	Upper Santa Fe Group sediments in the northern part of the basin (dividing line near or slightly south of La Mesa) and middle Santa Fe Group sediments in the southern part of the LRG Basin	Primarily 200 ft
4	Middle Santa Fe Group	200 ft
5	Middle and lower Santa Fe Group	Ranges from 130 to almost 2,000 ft

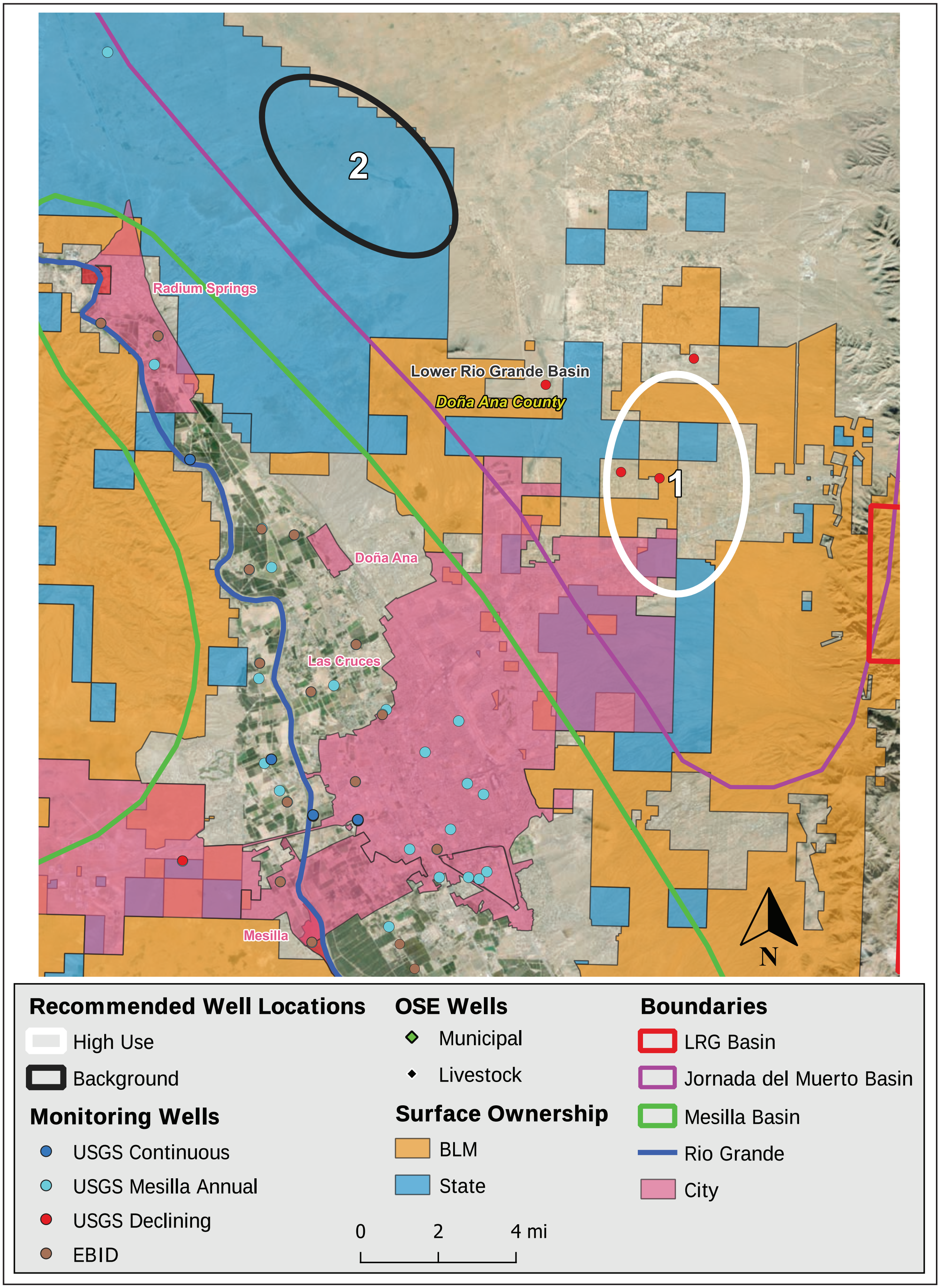

Figure 6-4. Recommended monitoring well locations and land surface ownership in the southern LRG Basin.

MONITORING RECOMMENDATIONS

As seen in Figure 6-1, there are monitoring wells, both annual and continuous, located within the Rio Grande corridor as well as on the mesa west of Las Cruces. Most of the continuous wells are owned by EBID or the city of Las Cruces and other utilities (Lauren Henson, USGS, personal communication), and the annual Mesilla wells have been measured for many years and will most likely continue to be monitored. The area most in need of monitoring in the LRG Basin at this time is the southern Jornada del Muerto Basin where there are several water supply wells. Figure 6-4 shows recommended sites for groundwater monitoring, and estimated costs to install these wells can be found in Table 6-3.

Table 6-3. Cost estimates for recommended monitoring wells in the LRG Basin.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates Low	Cost Estimates High
1	700	100	No	$175,000	$193,000
2	550	100	No	$147,000	$165,000
TOTAL				$322,000	$358,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. This high-use area of the southern Jornada del Muerto Basin has very little irrigation, but contains several water supply wells serving many water systems, including the city of Las Cruces, Moongate Water Company, and the Lower Rio Grande Public Water Works Authority. Because of the importance of this area for water supply and the declining water levels indicated by previous monitoring in this area, it is a high priority to install a monitoring well here. The average depth of the supply wells is 705 ft, with a maximum depth of 1,300 ft. Average depth to water at time of well completion is 407 ft. It is recommended that the monitoring well have a depth of at least 700 ft.

Location 2. This background area is located northwest of Location 1. In order to find an area of the southern Jornada del Muerto Basin that is minimally impacted by pumping, one has to look to the north of the high-use area. There are limitations based on land ownership and road access to the north, but the area selected is one that satisfies all the constraints. The few wells that have been monitored in this area in the past have shown no particular trend. There are two livestock wells in the area with depths of 492 ft and 534 ft and depths to water of 390 ft and 320 ft, respectively, at time of completion. Recommended depth of a monitoring well is 550 ft.

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An irrigation well in the Pecos Valley being equipped with a new meter with telemetry to help track pumping volume, which, when used with groundwater levels, provides a more complete picture of aquifer behavior and trends.

CHAPTER 7. MIMBRES BASIN

Geoffrey C. Rawling

The Mimbres Underground Water Basin (referred to here as the Mimbres Basin or the Basin) lies in southwestern New Mexico in Luna, Grant, and small portions of western Doña Ana and Sierra Counties. The Mimbres Basin was declared on July 29, 1931, by State Engineer Order 1. It covers 4,475 mi^2 and encompasses the topographically closed basin of the Mimbres River drainage within the United States. Major towns in the Basin are Deming (pop. 14,758), Silver City (pop. 9,704), Bayard (pop. 2,116), Columbus (pop. 1,442), and Hurley (pop. 1,256; numbers are from the 2020 census). Irrigated agriculture, mining, and ranching are the major economic activities in the Basin, all heavily dependent on groundwater, as is the public and domestic water supply.

There are several special classifications and restricted areas for groundwater development in the Basin, as defined by the New Mexico Office of the State Engineer (OSE; Fig. 7-1). The southern two-thirds of the Basin are defined as the Deming–Columbus Administrative Area (DCAA). In the DCAA, estimated drawdowns in wells are limited to 2.5 ft/yr; this value is used to assess the impact of new appropriations on existing water rights. The Critical Management Area (CMA) is a defined region based on modeling studies, which predict that drawdowns will exceed 2.5 ft/yr over the 40-year planning period if all water rights and declarations are fully exercised. This area is more restrictively regulated. The Closed Area is closed to new groundwater appropriations. Wells are limited to less than 230 ft in depth in the Order 46 Restriction Area in order to not have wells drawing from deeper subartesian water-bearing units and the shallow unconfined aquifer at the same time.

GEOLOGY AND HYDROLOGY

The Mimbres Basin consists of rugged fault-block mountains bounding low-relief plains formed on structurally down-dropped basins filled with Cenozoic sediments and sedimentary rocks, and lesser amounts of volcaniclastic and volcanic rocks (Clemons and Mack, 1988). The basin-fill units host the aquifer system. North- to northwest-trending basin axes with sediment thicknesses of 400 to more than 4,000 ft are separated by saddles of shallow bedrock (Fig. 7-2).

An upper, poorly consolidated basin-fill unit with thickness ranging from 300 to 1,000 ft can be distinguished from a lower unit as much as 3,280 ft thick composed of conglomerate, sandstone, and mudstone. The lower unit is usually correlated with the well-indurated Gila Group (also referred to as the Gila Conglomerate), which is widely exposed at the northern margins of the Mimbres Basin (Hawley et al., 2000). Quaternary near-surface deposits across the Basin are unconsolidated and can have saturated thicknesses up to 100 ft. The Mimbres Basin aquifer is unconfined, with local zones of partial confinement and subartesian conditions. Many irrigation wells have multiple screens and access more than one water-bearing zone.

Wells are completed in the following units, in decreasing order of abundance: the upper basin fill, the lower basin fill/Gila Group, and Paleozoic carbonate rocks in upland areas of the northern part of the Basin (Hanson et al., 1994; Hawley et al., 2000; Finch et al., 2008). Wells in the upper basin fill can be many hundreds of feet deep and very productive, with yields of up to 1,000 gallons per minute (gpm), or even higher if they tap very transmissive gravel layers, interbedded fractured basalts, and/or volcanic scoria layers (e.g., near Columbus).

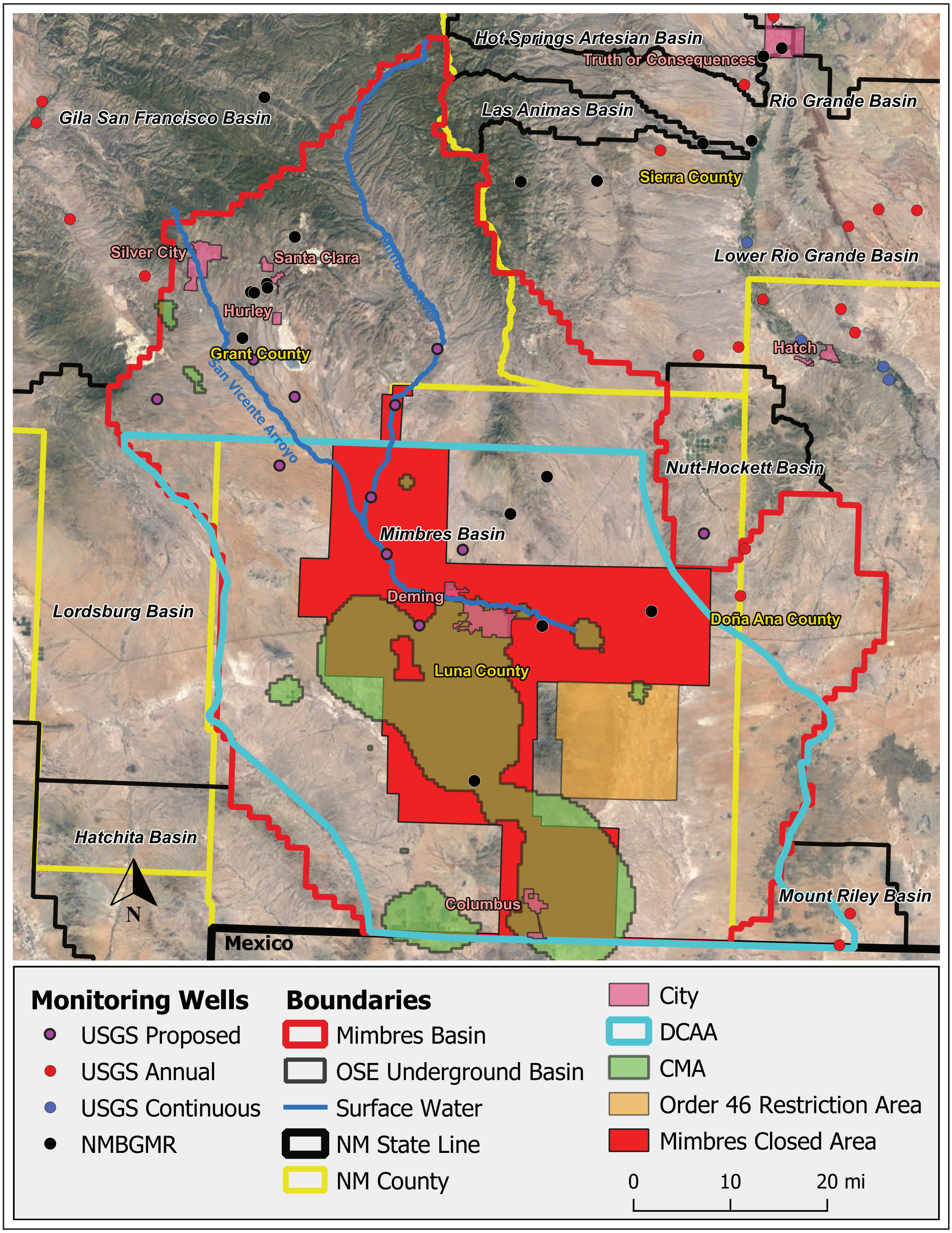


Figure 7-1. Overview of the Mimbres Basin as defined by OSE, showing OSE regions of groundwater regulation, locations of active monitoring wells, and proposed USGS monitoring wells.

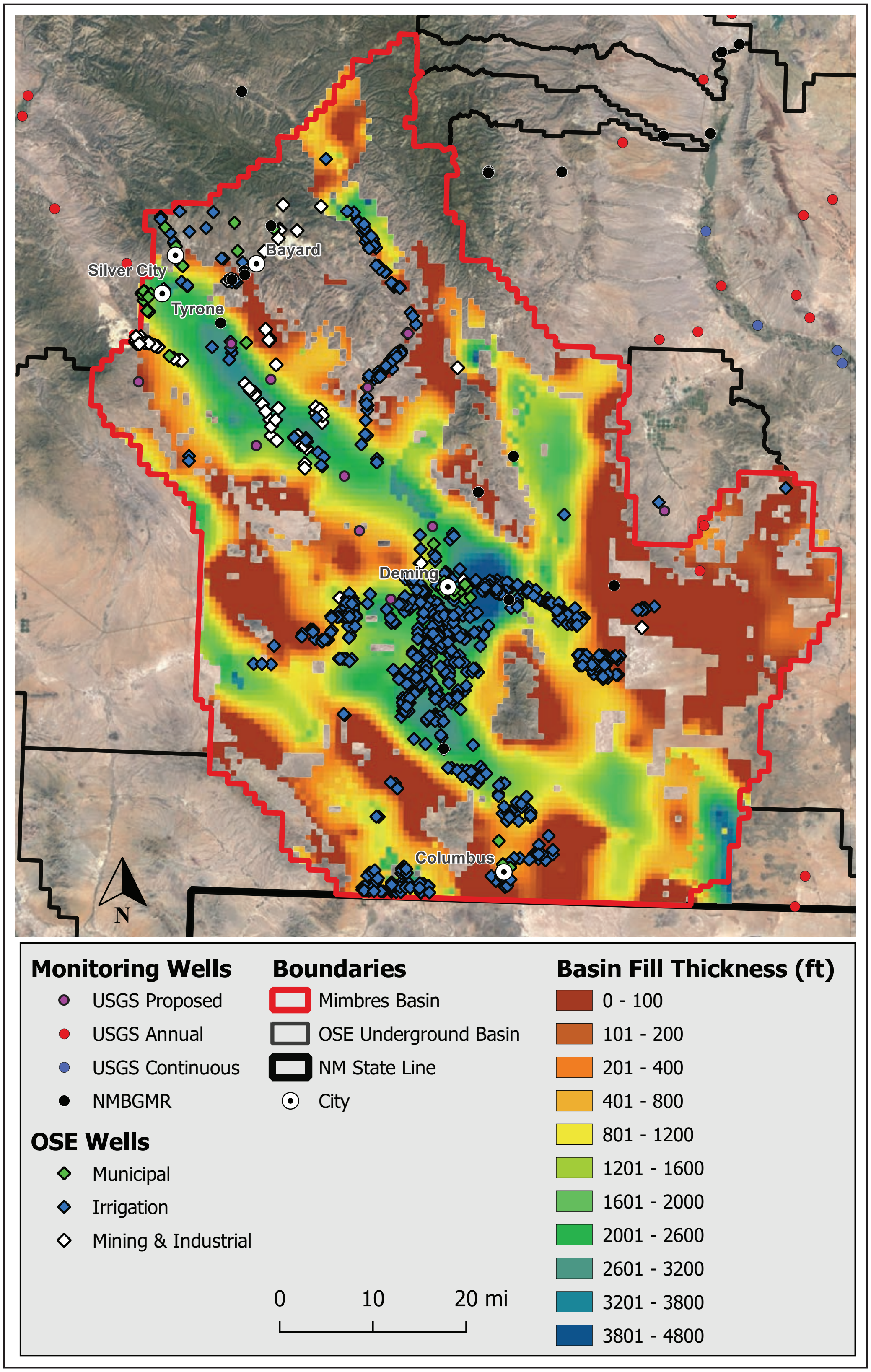


Figure 7-2. Thickness of the basin fill, including the Gila Group (Heywood, 2002). Geology in regions outside the basin fill (uncolored) consists of lithified bedrock such as Paleozoic carbonate rocks. Wells owned by mining companies and the municipalities of Silver City, Deming, and Columbus are shown, in addition to example hydrograph wells shown in Figures 7-3a through 7-3g.

In general, aspects of basin-fill aquifer quality, such as transmissivity and well yield, can be expected to decrease with increasing depth, as one progresses south in the Basin, and as one moves toward the basin floor from bounding and intrabasin mountain ranges (Hawley et al., 2000). Quaternary terrace deposits along the Mimbres River can yield hundreds of gallons per minute where they are saturated.

The Gila Group is only extensively developed for groundwater in the northern part of the Basin. Wells in this unit in the Woodward well field southwest of Silver City yield 400 to 1,500 gpm. As with the younger basin fill, aquifer quality decreases with depth. High yields are dependent on intersecting fractured zones.

Paleozoic carbonate rocks of the Lake Valley Limestone and overlying Oswaldo Formation are exploited in the northern part of the Basin (Finch et al., 2008). Yields depend on intersecting cavernous porosity and fracture zones. Water levels in these rocks may be hundreds of feet below the water table in the basin-fill aquifer (e.g., southeast of Silver City), indicating a lack of good hydraulic connection between the two. Groundwater in these units discharged to springs prior to extensive development.

Recharge comes from infiltration of the Mimbres River and mountain front recharge along the northern margins of the Basin. Small amounts of perennial flow in San Vicente arroyo derived from urban irrigation, leakage, and treated effluent discharge from Silver City infiltrate upstream of the Mimbres River confluence (Fig. 7-1). Intermittent drainages that head in intrabasin and basin-bounding mountains may contribute small amounts of recharge (Hanson et al., 1994; Finch et al., 2008). Groundwater pumping and evapotranspiration from playas are the main discharges; the latter has largely been replaced by the former since groundwater pumping for irrigated agriculture began in 1908.

WATER RIGHTS AND WATER USE

Major classes of permitted water rights in the Basin include those related to mining in the Silver City and Tyrone areas (648 acre-feet per year [acre-ft/yr]), the town of Silver City (895 acre-ft/yr), the city of Deming (6,340 acre-ft/yr), the village of Columbus (2,304 acre-ft/yr), and the town of Bayard (397 acre-ft/yr). There are 171,237 acre-ft/yr of permitted water rights for irrigation from 1,000 wells, 10,228 acre-ft/yr of permitted water rights from 4,228 domestic wells, and 567 acre-ft/yr of permitted water rights from 567 stock wells (Fig. 7-2).

GROUNDWATER MONITORING

Figures 7-3a through 7-3g show hydrographs of several USGS wells across the Mimbres Basin showing water-level declines (well locations are shown in Fig. 7-4). Well 321049107582801 (230 ft deep), located 17 mi southwest of Deming, declined 24 ft at an average of 1.3 ft/yr from 1958 to 1982, but has remained relatively stable since then (Fig. 7-3a). The decline at well 320906107482901 (depth unknown), located 9 mi south of Deming, was 2.1 ft/yr over the same time interval, for a net decline of 96 ft (Fig. 7-3b). Water levels have continued to decline in this area up to the present (Rawling, 2022). Wells 320330107455501 (200 ft deep; Fig. 7-3c), 320058107452001 (depth unknown), and 320202107454001 (108 ft deep; Fig. 7-3d) are located 14 to 17 mi south of Deming in the heavily irrigated central portion of the Mimbres Basin (Fig. 7-2). Water levels in these wells have declined 0.6 to 1.1 ft/yr from the late 1950s to the early 2000s, for net declines of 27 to 40 ft.

Near Columbus, wells 315153107370801 (628 ft deep; Fig. 7-3e) and 315100107363301 (529 ft deep; Fig. 7-3f) have declined 100 ft from 1955 to 1982 and 78 ft from 1952 to 1982, respectively, for average decline rates of 3.7 and 2.6 ft/yr. Both wells remained relatively stable up to 2012, but Rawling (2022) documented renewed declines in this area since then.

West of Columbus and the Tres Hermanas Mountains, wells 314731107513001 (440 ft deep; Fig. 7-3g) and 314709107503101 (depth unknown) declined 100 ft from 1955 to 2003 and 79 ft from 1964 to 2003, respectively, for decline rates of about 2 ft/yr for both wells. There are few water-level measurements in this area after 2012 with which to determine any further declines (Rawling, 2022).

Areas of water-level decline are widespread in the Mimbres Basin; rates of decline in some areas have approached 2 ft/yr since 1980 (Fig. 7-4).

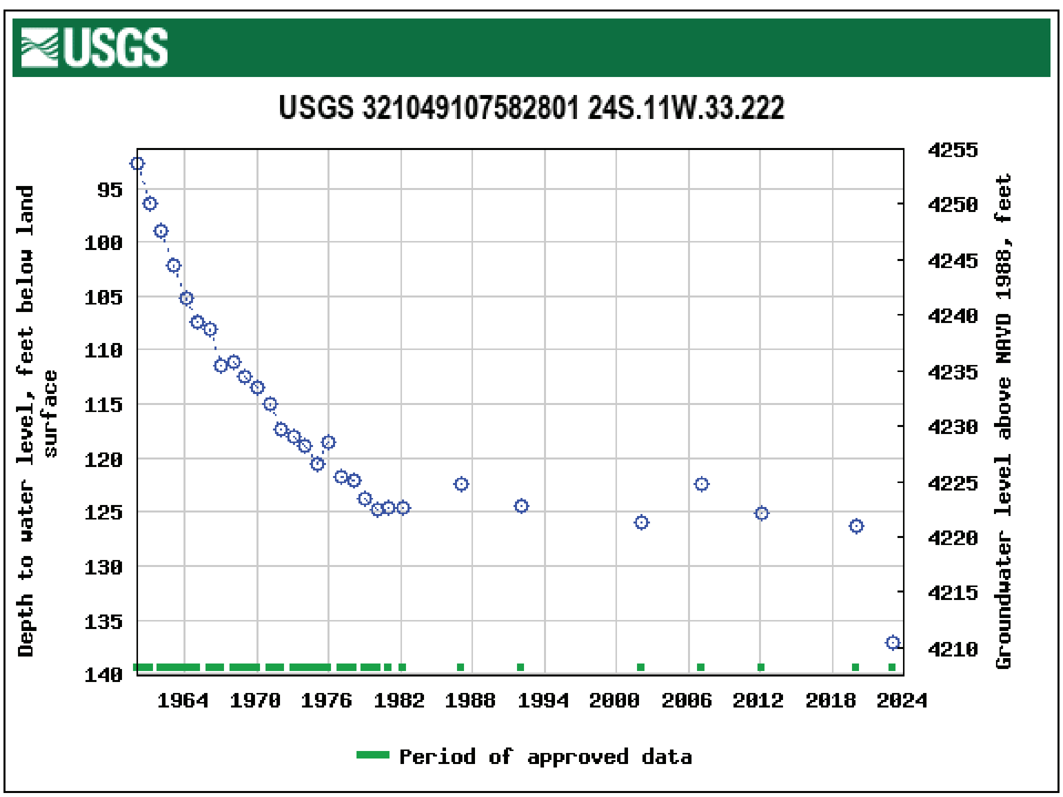
As of November 2022, the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has 11 wells that are monitored in the Basin; nine are measured annually and two are measured continuously with data recorders. The U.S. Geological Survey (USGS) is planning to begin annual monitoring of 30 to 40 additional wells starting in 2024 (permission has been granted by all owners).

GROUNDWATER MODELS

Several groundwater models have been constructed for the Mimbres Basin or portions of the basin. Hanson et al. (1994) created a basin-wide 2D model of the basin-fill aquifer, with zones of uniform hydraulic conductivity corresponding to structural zones in the Basin. Results from this model of the time period 1930 to 1985 indicated that most of the water pumped from the Basin came from storage, with lesser but still significant amounts from reductions in evapotranspiration. Johnson (2000) created a model of the northern Mimbres Basin in order to evaluate a water rights application by the town of Silver City, which was later used as part of a study to project the impacts of groundwater development in the Basin (Johnson et al., 2002). Finch et al. (2008) developed a 3D calibrated groundwater flow model and defined four major hydrogeologic regions in the Basin based on hydrologic properties and groundwater flow patterns. Thickness and stratigraphy of the basin fill and regional geologic structure were identified as the major controls on the hydrogeologic regions.

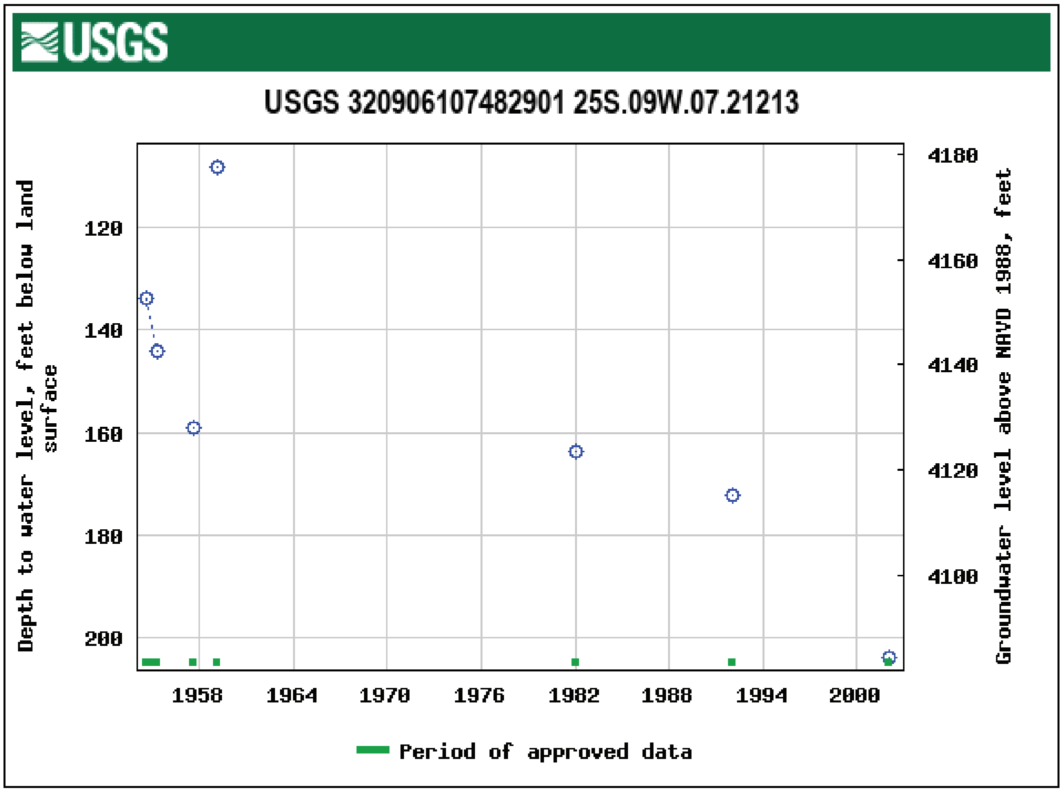
Cuddy and Keyes (2011) developed the 3D groundwater flow model that OSE currently uses to administer groundwater rights in the Mimbres Basin. Prior to the current model and guidelines, Mimbres Basin groundwater rights were administered using a model developed in the 1970s. Improvements include better delineations of the subsurface basin geometry based on the geophysical work of Heywood (2002), more detailed characterization of the subsurface basin geology, and an improved estimate of the pumping history in the Basin based on interpretation of irrigated acreage from Landsat imagery. The basin fill-bedrock boundary is defined as a no-flow condition, and the bedrock is not simulated in the model. This is in contrast to the model of Finch et al. (2008), who place significant importance on groundwater flow in the bedrock. Figure 7-5 shows an example cross section through the model grid showing the subdivision of the basin fill into three layers, with the base of Layer 1 defined as 200 ft below the predevelopment water table, and deeper layers having variable thickness below Layer 1 (Cuddy and Keyes, 2011).

A

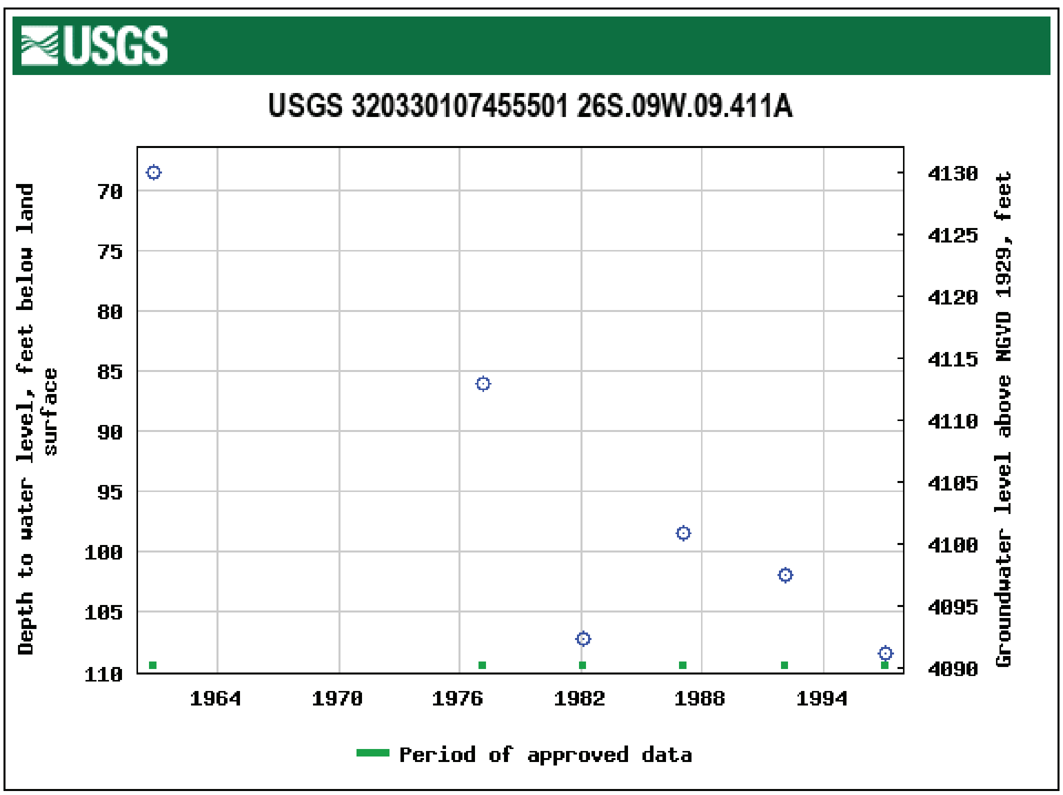


Figures 7-3a through 7-3g. Hydrographs of select wells in the Mimbres Basin. Locations are shown in Figure 7- 4.

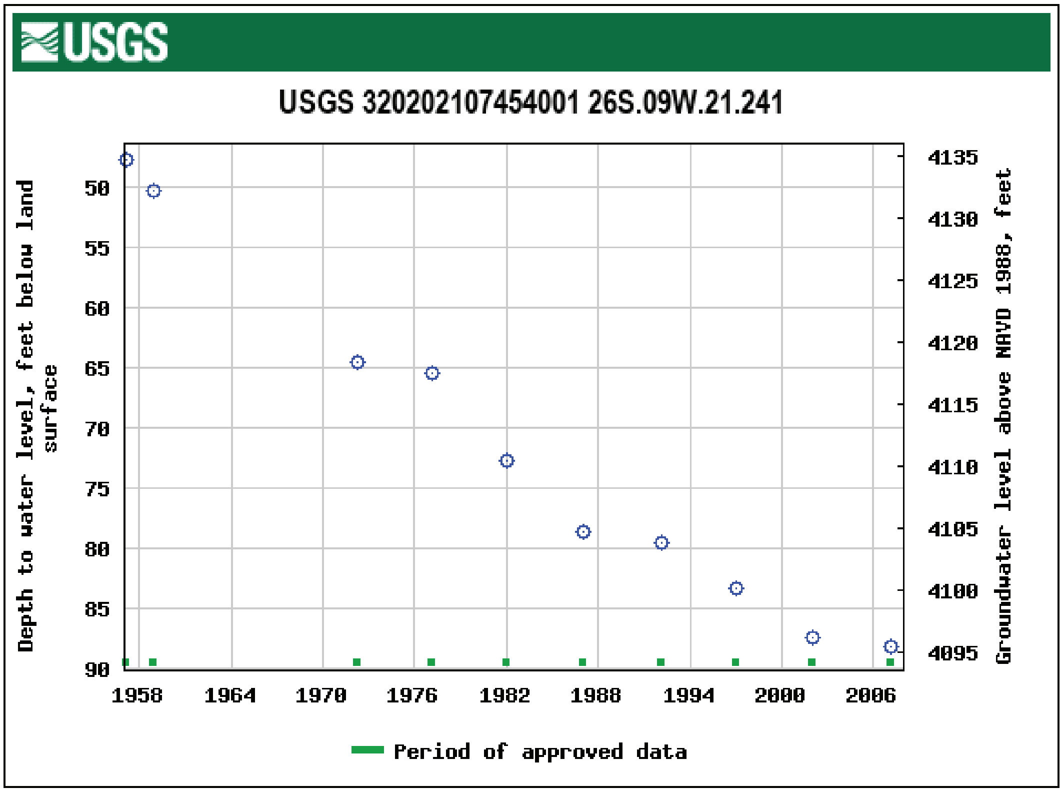
B


USGS
USGS 320906107482901 25S.09W.07.21213
Depth to water level, feet below land surface
120
140
160
180
200
Groundwater level above NAVD 1988, feet
4180
4160
4140
4120
4100
1958
1964
1970
1976
1982
1988
1994
2000
Period of approved data

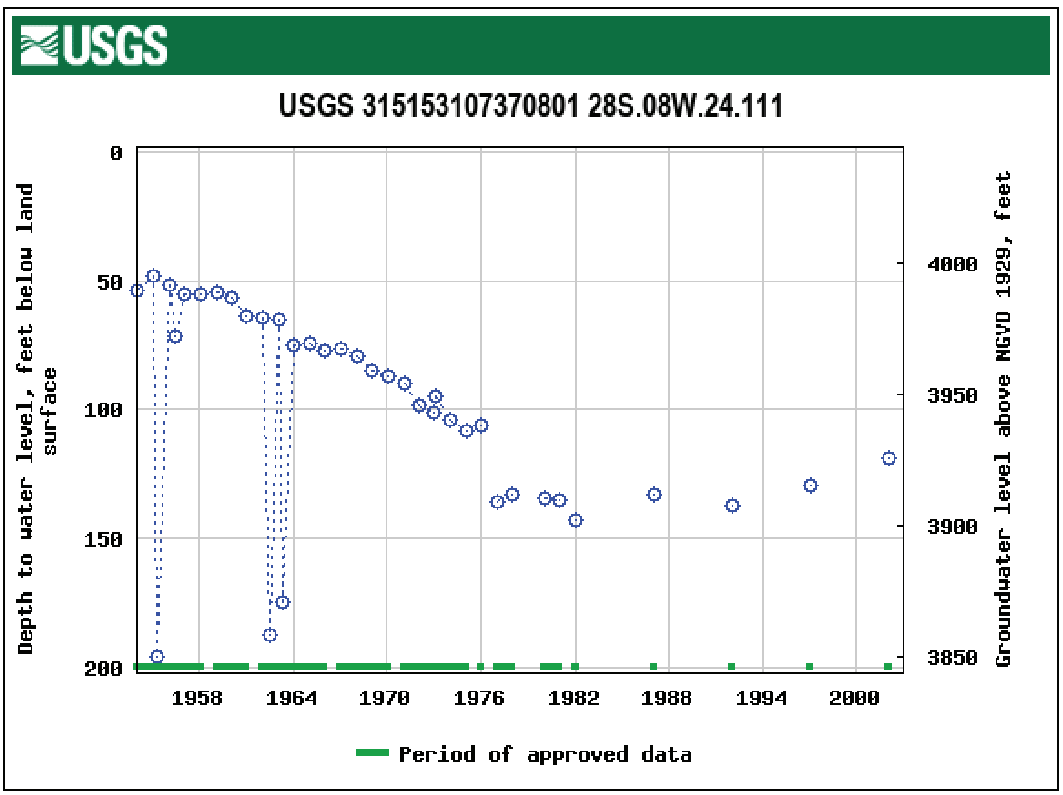
C


USGS
USGS 320330107455501 26S.09W.09.411A
Depth to water level, feet below land surface
70
75
80
85
90
95
100
105
110
Groundwater level above NGVD 1929, feet
4130
4125
4120
4115
4110
4105
4100
4095
4090
1964
1970
1976
1982
1988
1994
Period of approved data

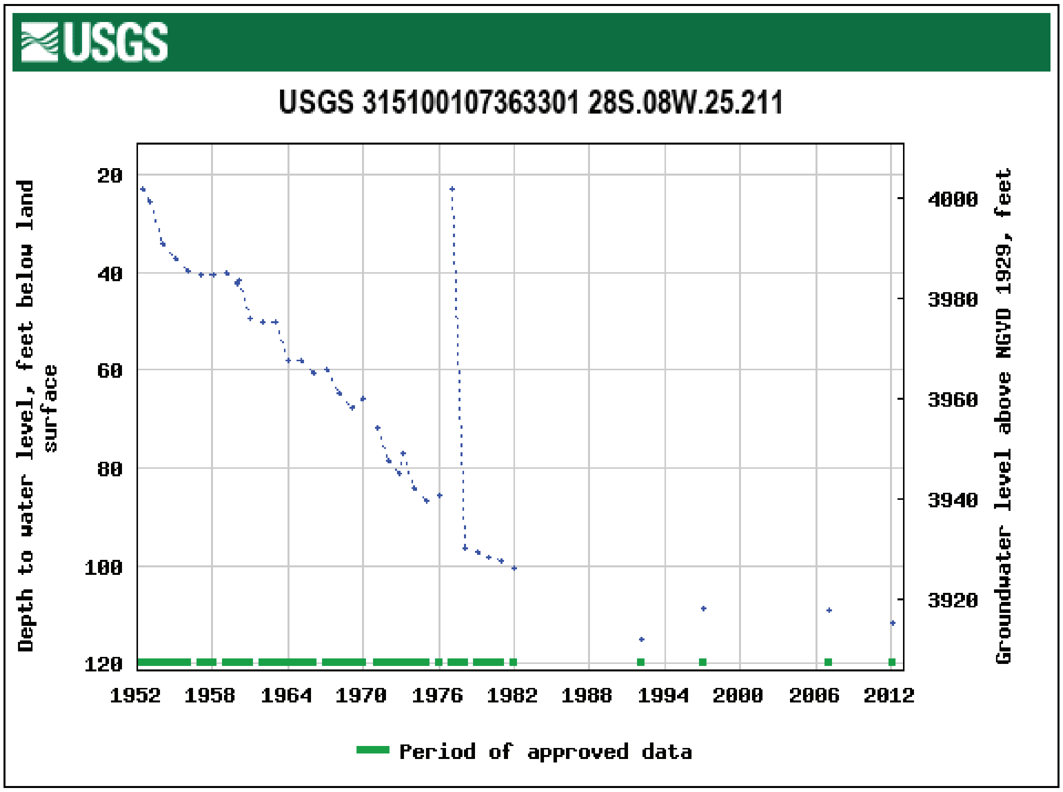
D


USGS
USGS 320202107454001 26S.09W.21.241
Depth to water level, feet below land surface
Groundwater level above NAVD 1988, feet
50
55
60
65
70
75
80
85
90
4135
4130
4125
4120
4115
4110
4105
4100
4095
1958
1964
1970
1976
1982
1988
1994
2000
2006
Period of approved data

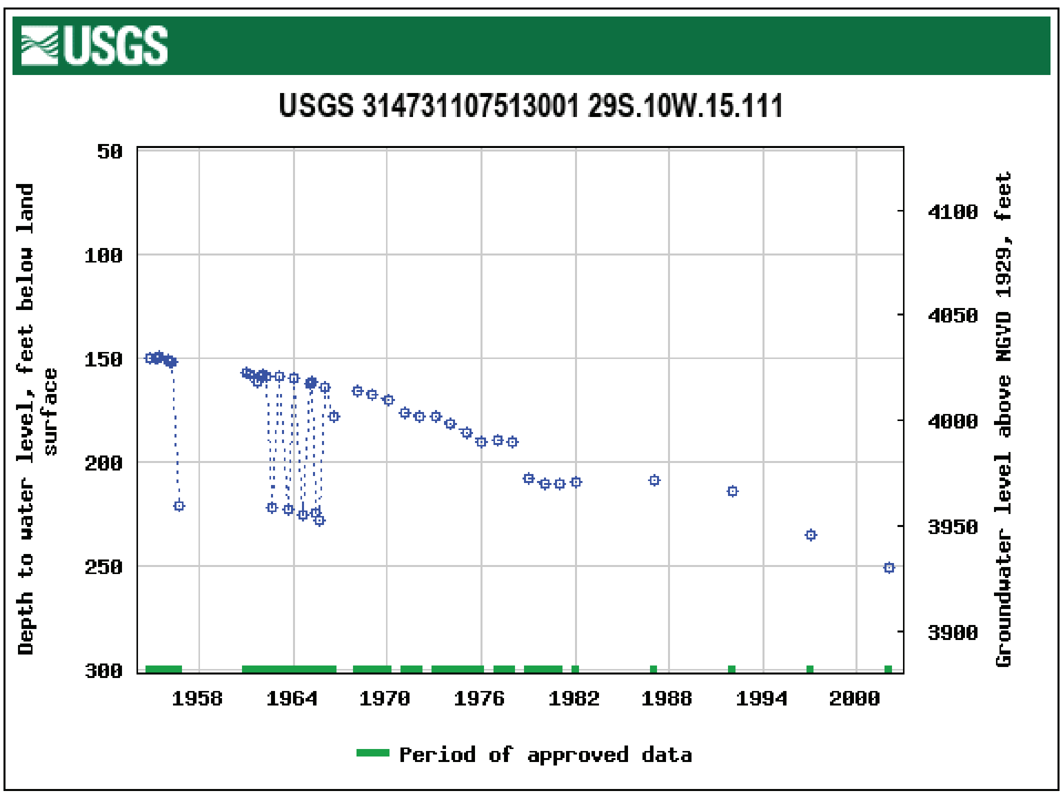
E


USGS
USGS 315153107370801 28S.08W.24.111
Depth to water level, feet below land surface
Groundwater level above NGVD 1929, feet
0
50
100
150
200
4000
3950
3900
3850
1958
1964
1970
1976
1982
1988
1994
2000
Period of approved data

F


USGS
USGS 315100107363301 28S.08W.25.211
Depth to water level, feet below land surface
Groundwater level above NGVD 1929, feet
20
40
60
80
100
120
4000
3980
3960
3940
3920
1952
1958
1964
1970
1976
1982
1988
1994
2000
2006
2012
Period of approved data

G


USGS
USGS 314731107513001 29S.10W.15.111
Depth to water level, feet below land surface
Groundwater level above NGVD 1929, feet
50
100
150
200
250
300
4100
4050
4000
3950
3900
1958
1964
1970
1976
1982
1988
1994
2000
Period of approved data

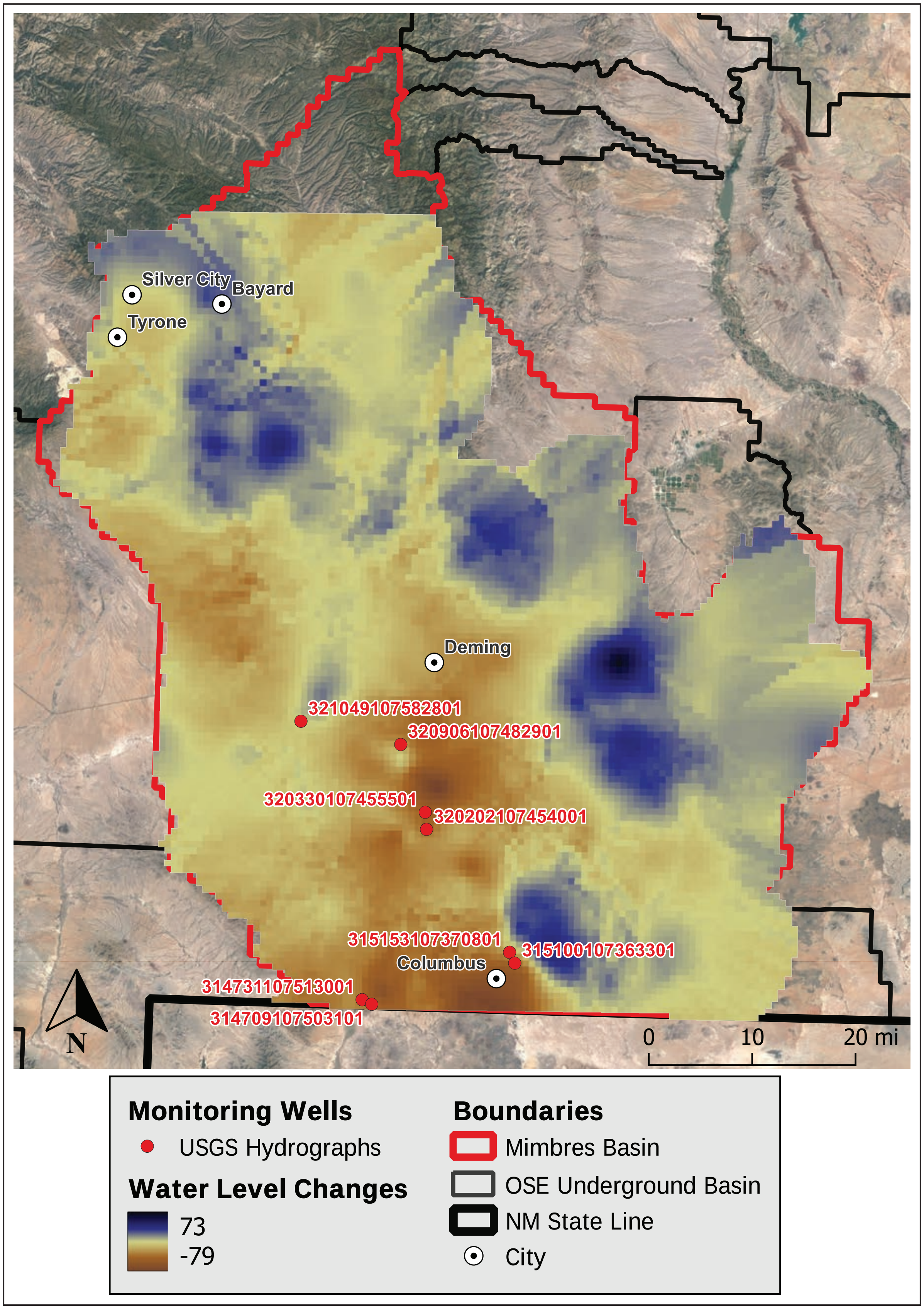


Figure 7-4. Interpolated water-level changes over the period 1980–2020 (Rawling, 2022). The largest declines correspond to an average decline rate of almost 2 ft/yr.

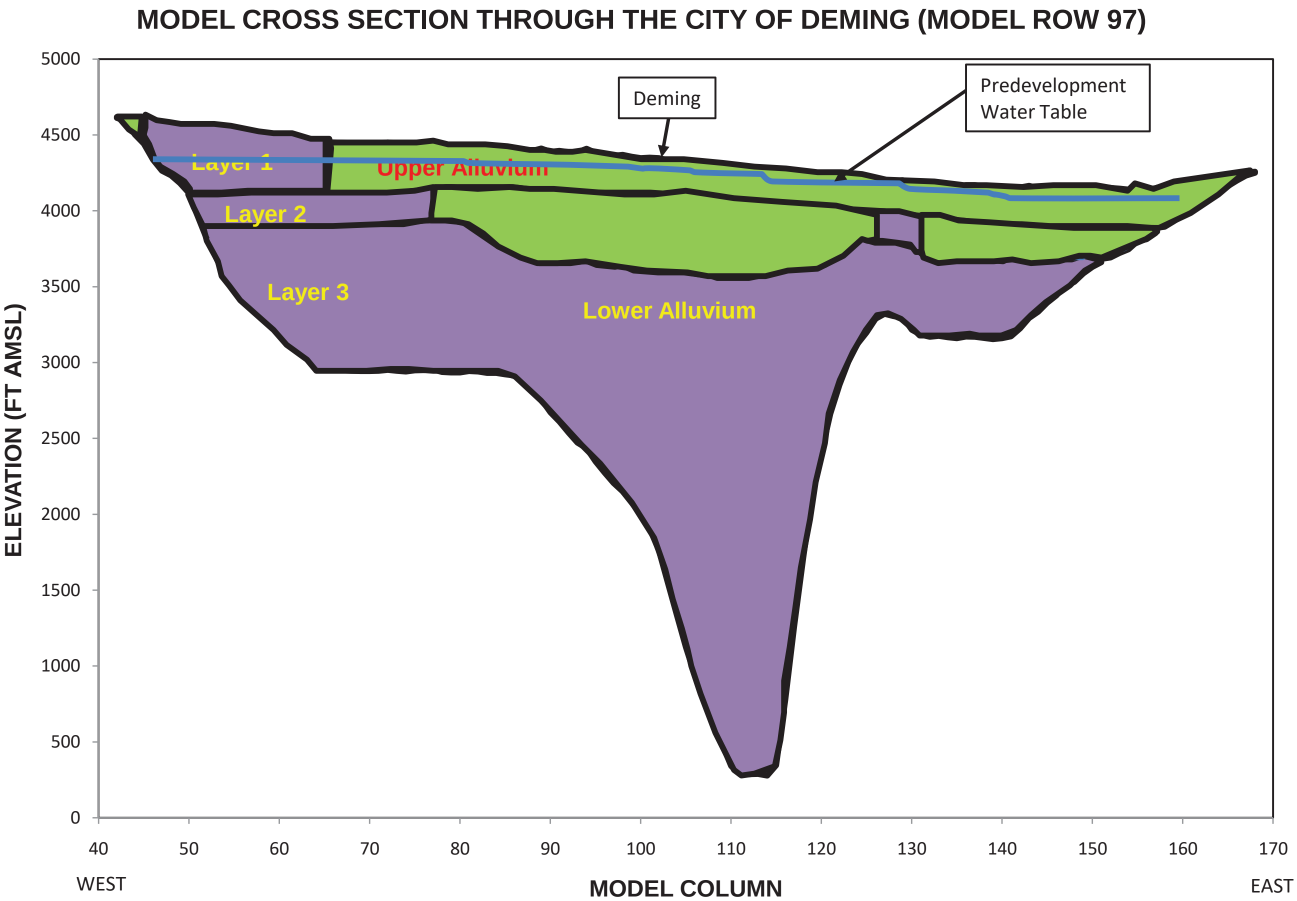


Figure 7-5. Cross section through the groundwater model grid of Cuddy and Keyes (2011, fig. 5) along an east-west line through Deming.

LAND SURFACE OWNERSHIP

The Mimbres Basin is a mix of private, state, and federal land (Bureau of Land Management [BLM] and U.S. Forest Service). U.S. Forest Service land is confined to the mountainous northern margin of the Basin (Fig. 7-6). Central Luna County around and south of Deming, where there is abundant irrigation, is almost entirely private land, as is the region around Columbus. These are two areas of concern and where monitoring wells should be established. There are a few parcels of state and BLM land in these areas, however, and those could be targeted as monitoring well sites. These areas are accessible via the many unimproved roads in the Basin.

MONITORING RECOMMENDATIONS

Goals for groundwater monitoring in the Mimbres Basin should include monitoring water levels in 1) high-use and background areas in the basin-fill aquifer in the central and southern parts of the Basin in the CMA, where irrigation demand and water level declines are the greatest, and 2) background areas in the Gila Conglomerate in the northern part of the Basin, where it (along with subjacent bedrock) is the aquifer for municipal wells and mining water supply. This area is of secondary importance because there are numerous monitoring sites already in this region. Recommended well locations are shown in Figure 7-6. Estimated costs to install these wells can be found in Table 7-1.

Table 7-1. Cost estimates for recommended monitoring wells in the Mimbres Basin.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates Low	Cost Estimates High
1	200	20	No	$77,000	$95,000
2	600	20	No	$152,000	$170,000
3	480	20	No	$129,000	$147,000
4	350	20	No	$105,000	$123,000
5	550	20	No	$142,000	$161,000
6	450	20	No	$124,000	$142,000
TOTAL				$729,000	$838,000

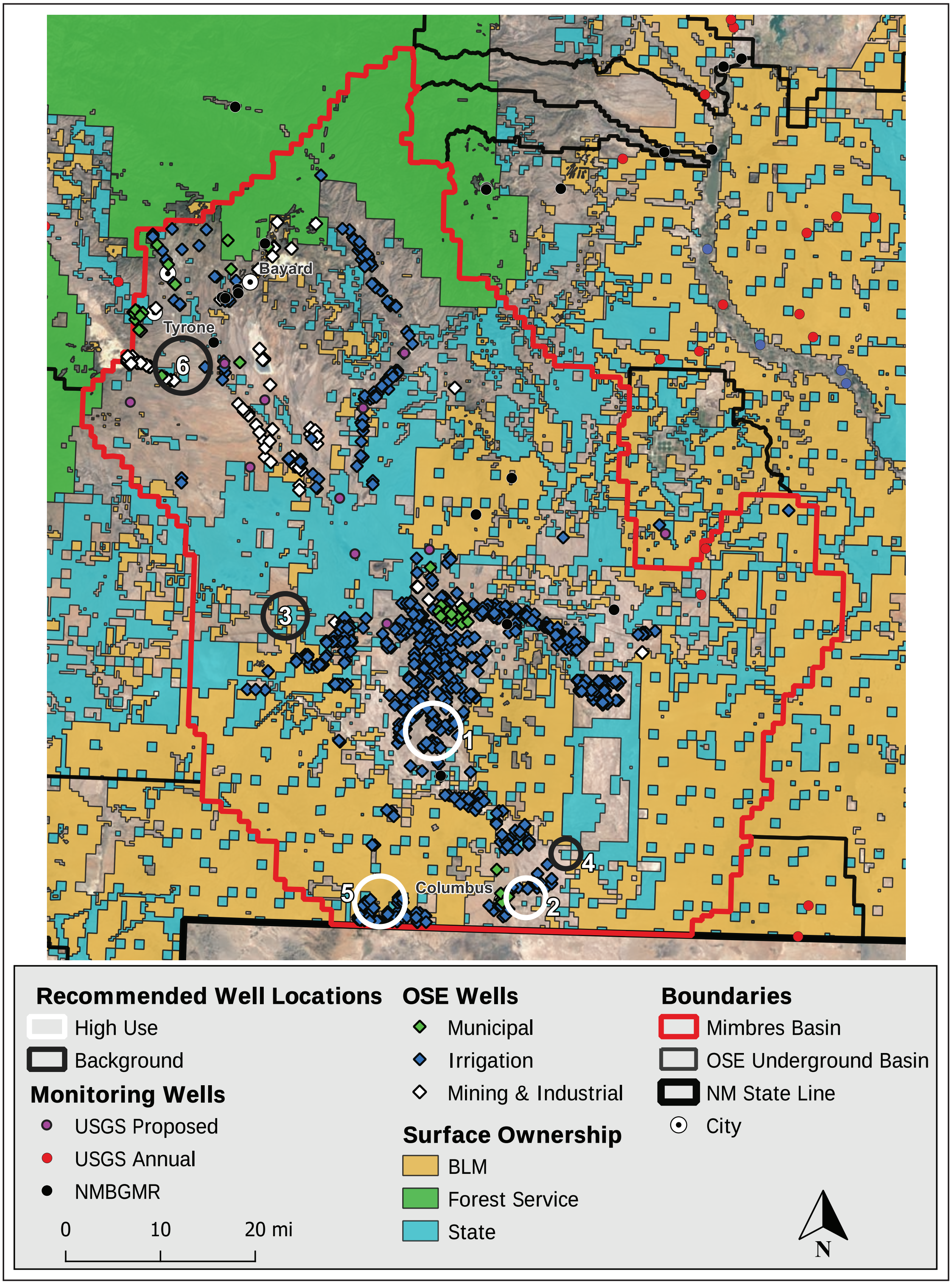


Figure 7-6. Land surface ownership status in the Mimbres Basin and recommended locations of monitoring wells. Numbers indicate recommended priority of the wells.

The following locations, in order of priority, were identified for monitoring wells.

Location 1. This is an area of high use south of Deming. Water levels here have declined over 40 ft in the past 40 years. The basin fill thickness is approximately 2,600 ft. Depths of irrigation and domestic wells in the area vary from less than 200 to over 1,000 ft. A suggested monitoring well depth is 200 ft, the average of recorded depths of wells in the area. This is deeper than most domestic wells but less than the average irrigation well depth. The nearby NMBGMR monitoring well is 200 ft deep and is measured annually. There is state land in this area. This is the highest-priority area for monitoring.

Location 2. This high-use area is northeast of Columbus. Water levels here have dropped almost 40 ft in the past 40 years. The basin-fill aquifer is relatively thin at 205 ft. A suggested monitoring well depth for the basin-fill aquifer is no more than 200 ft. Few wells have recorded depths here; they average 700 ft, and thus are in Gila Group and/or bedrock beneath the basin fill. If monitoring of the bedrock beneath the basin fill is desired, a recommended depth is 500 to 700 ft. The proposed location is a small area of BLM land.

Location 3. This background area is west of Deming at the margin of the high-use area with many irrigation and domestic wells. Water levels here have remained stable or risen a few feet over the past 40 years (Fig. 7-3a; Rawling, 2022). A suggested monitoring well depth is 480 ft, the average of recorded depths of wells in the area. The basin fill thickness is approximately 1,000 ft.

Location 4. This lower-use area is 6 mi northeast of Location 3 and serves as a background area for the Columbus region. Water levels here have risen more than 20 ft since 1980 (Fig. 7-4; Rawling, 2022). The thickness of the basin fill is approximately 450 ft. There are few wells here with recorded depth data. The suggested monitoring well depth is 300 to 400 ft.

Location 5. This high-use area is proposed as a second monitoring site in the southern part of the Basin. There is much active irrigation in this area near Hermanas and the international border. The site is on BLM land. The basin fill is 580 ft thick here, and water levels have declined 33 ft over the past 40 years. There is a huge range in recorded well depths, from 350 to 2,100 ft. A recommended monitoring well depth is 550 ft.

Location 6. This site is proposed for a background well in the northern part of the Mimbres Basin. Between the existing NMBGMR monitoring sites and the additional wells the USGS is planning to monitor, there will be 13 monitoring sites in the northern Basin in 2023, five of which are possibly completed in the Gila Group (OSE and USGS well records are not definitive). If an additional monitoring site is needed, Location 6 is proposed east of the Tyrone Mine. Numerous mining-related and municipal wells are within 10 mi of this well to the northwest and north. At this site the basin fill is over 1,500 ft thick. Water levels have declined just a few feet here in the past 40 years, but water-level change values in this region are not particularly reliable due to sparse data (Rawling, 2022). There are few wells here with recorded depth data. The recommended depth is 400 to 500 ft.

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Groundwater levels can be monitored using acoustic devices with telemetry, as shown here.

CHAPTER 8. NUTT-HOCKETT BASIN

Robert Pine

The Nutt-Hockett Underground Water Basin (referred to here as the Nutt-Hockett Basin or the Basin) lies in a sparsely populated region to the west of the town of Hatch within Luna, Sierra, and Doña Ana Counties. It consists primarily of the Uvas valley, which lies some 500 ft above the Rio Grande valley and is bordered to the east by the Sierra de las Uvas and to the west by the Good Sight Mountains (Fig. 8-1). It is approximately 252 mi^2 in area. The northern boundary was arbitrarily fixed by the New Mexico Office of the State Engineer (OSE) and does not necessarily represent a hydrologic or topographic boundary.

GEOLOGY AND HYDROLOGY

The Basin is part of the Rio Grande rift. The dominant aquifer is found in the upper hydrostratigraphic unit of the Santa Fe Group, in particular the Camp Rice Formation (Clemens, 1979; Hawley and Lozinsky, 1992). The Camp Rice Formation consists of ancestral Rio Grande channel sand and gravel deposits with interbedded silty clay. The Camp Rice Formation overlies the Rincon Valley Formation of the Santa Fe Group (corresponding to the middle hydrostratigraphic unit of the Santa Fe Group). The Santa Fe Group appears to be as much as 1,000 ft thick in the deepest parts of the Uvas valley. The relative thickness of the two Santa Fe Group units is unclear.

The Santa Fe Group overlies Tertiary andesite flows that emerged from vents in the Sierra de las Uvas on the eastern side of the Basin and near Nutt Mountain on the northwestern side of the Basin. These flows likely form a semi-impermeable floor to the Santa Fe Group aquifer in the valley. A generalized stratigraphic column can be found in Figure 8-2 (it does not distinguish between the Camp Rice Formation and the Rincon Valley Formation).

The valley aquifer is quite productive. Contouring of groundwater elevations by Clemens (1979) suggests that groundwater in the southern part of the valley flows from the mountains into the valley and then to the north and finally to the east toward the Rio Grande north of the Sierra de las Uvas. He indicated a groundwater mound in the center of the southern valley, which he speculated was caused by recharge from a deeper artesian aquifer. It is not known if this mound is present today. Groundwater may also be entering the Basin across the northern boundary from the northwest of Nutt Mountain, but it probably then flows toward the Rio Grande. The only other possible source of direct recharge to the Santa Fe Group in the Basin would be from infiltration from large rainfall events at the margins of the valley.

No aquifer test results have been located for the Santa Fe Group in the Nutt-Hockett Basin, but there are test results available from the Mesilla Valley. Hawley and Kennedy (2004) summarize much of this data and report a horizontal hydraulic conductivity range from 43 ft/d to 110 ft/d, with a median of 70 ft/d, for the upper 200 ft of Mesilla basin fill (i.e., upper Santa Fe Group). No values were given for storage coefficient, but a study by Wilson et al. (1981) reports results from 10 multi-well aquifer tests in the Santa Fe Group, all with calculated storage coefficients between 0.0004 and 0.002. The low values are likely attributable to interbedded clay layers in the geologic profile.

WATER RIGHTS AND WATER USE

There is no surface water irrigation in the Nutt-Hockett Basin. There are approximately 43,000 acre-feet per year (acre-ft/yr) of irrigation water rights currently permitted in the Nutt-Hockett Basin in 46 water rights; OSE's 2015 water use report (Magnuson

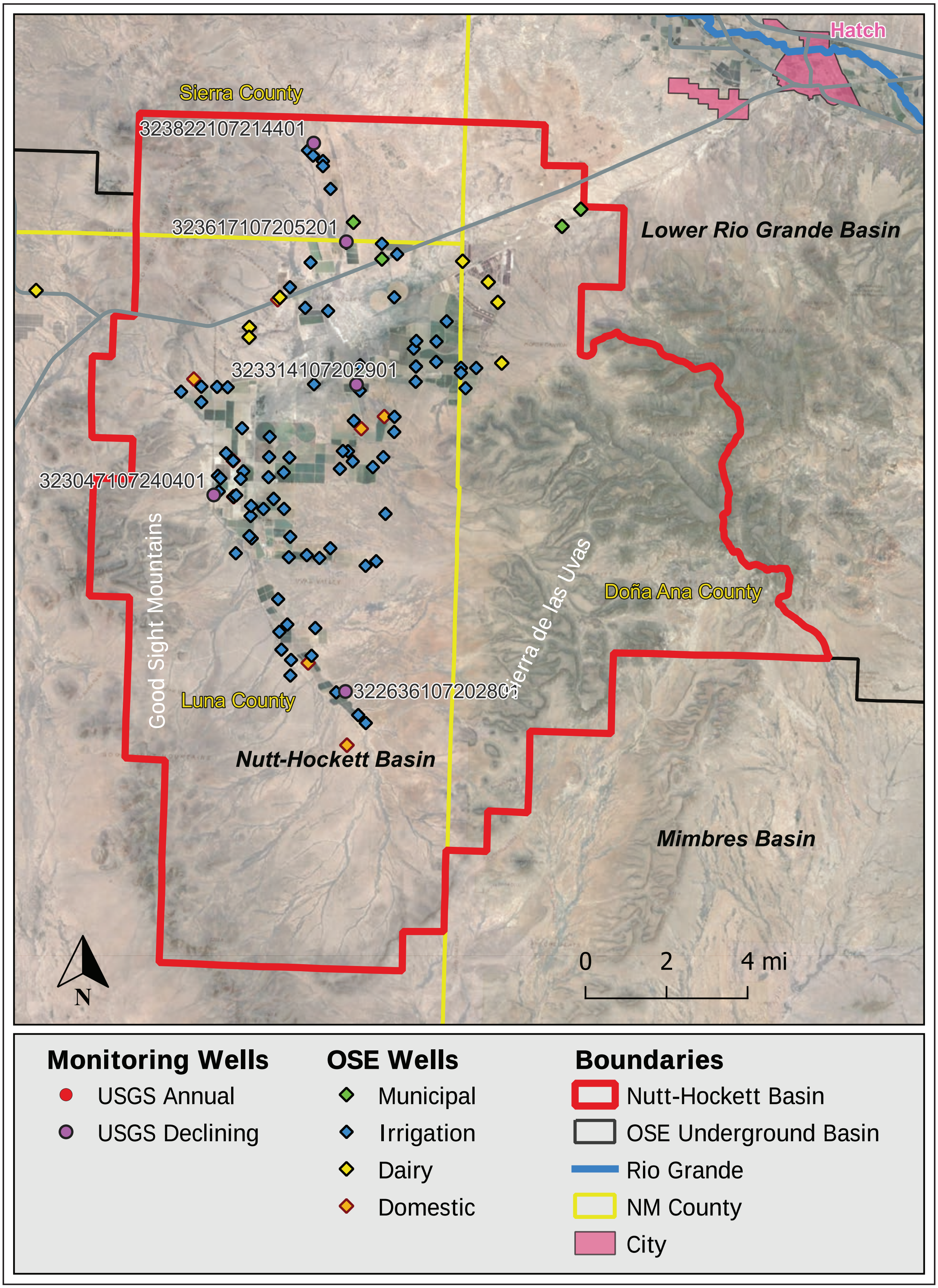

Figure 8-1. Overview of the Nutt-Hockett Basin, including OSE wells, active monitoring wells, and neighboring declared underground water basins.

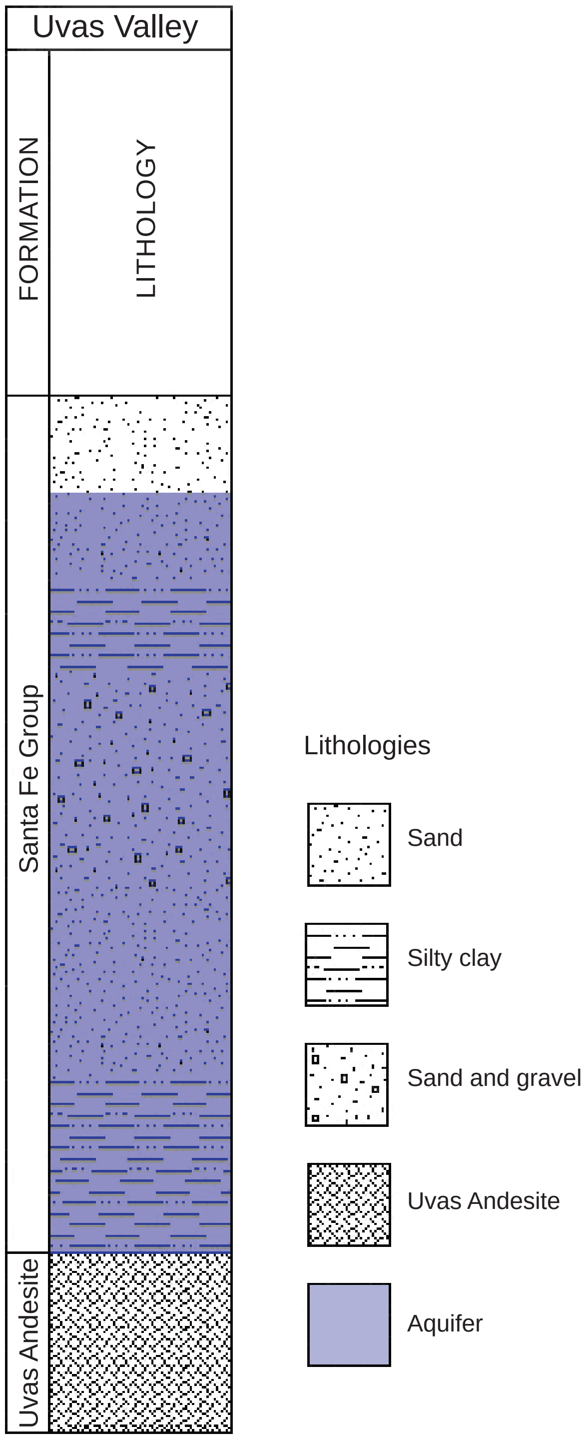

Figure 8-2. Generalized stratigraphic column of the Uvas valley within the Nutt-Hockett Basin.

et al., 2019) states that there were 34,024 acre-ft/yr of irrigation withdrawals that year in the Basin (79% of the permitted amount). Meter records for 2020 indicate that of those irrigators that reported quarterly usage, approximately 61% of the permitted amount was diverted. A wide variety of crops are grown, including cotton, onions, pinto beans, watermelon, and chile.

The village of Hatch, located in the Rincon Valley along the Rio Grande, has its four municipal supply wells (one of which is inactive) within the Nutt-Hockett Basin, which has much better water quality than in the valley; wells in the valley have total dissolved solids (TDS) concentrations typically well over 1,000 mg/L (Stringam et al., 2016), whereas, for example, Hatch supply well NH-299 POD3 had a TDS of 326 mg/L in October 2019 (NMED Drinking Water Bureau, n.d.).

There are three dairies in the Nutt-Hockett Basin with a total of 910 acre-ft/yr of water rights from eight wells. One of these dairies, Las Uvas Valley Dairies, filed for bankruptcy in 2017 and is no longer operating. At its peak, it was the largest dairy in New Mexico and one of the largest dairies in the United States. In addition to its 797 acre-ft/yr of water rights for dairy use, it has 427 acre-ft/yr of irrigation rights in the Basin. The case is not yet settled, and the fate of the dairy and associated water rights is not known at this time.

GROUNDWATER MONITORING

As seen in Figure 8-1, there are no active U.S. Geological Survey (USGS) or New Mexico Bureau of Geology and Mineral Resources (NMBGMR) monitoring wells located in the Nutt-Hockett Basin. There had been monitoring in the Basin by USGS in the past, with several wells showing significant declines in water level over time. Table 8-1 lists some of these monitoring results, with rates of decline ranging from 2.1 to 3.8 ft/yr (starting and ending water levels were selected to ensure results during periods of non-irrigation); see Figure 8-1 for well locations.

Up until 2012, OSE had been collecting water-level data from various production wells on a 5-year basis, but this apparently has not been done since. Furthermore, when data were last collected in 2012,

Table 8-1. Water-level changes in select wells in the Nutt-Hockett Basin.

USGS Well Number	Initial Water Elevation (ft)/Date	Final Water Elevation (ft)/Date	Water-Level Decline (ft)	Average Rate of Decline (ft/yr)
323822107214401	4,383.39/1-23-74	4,302.40/1-13-97	81.0	3.5
323617107205201	4,418.16/1-12-67	4,321.96/1-24-92	96.2	3.8
323314107202901	4,382.16/1-23-74	4,322.04/1-10-02	60.1	2.1
322636107202801	4,437.66/1-5-65	4,324.76/1-30-07	112.9	2.7
323047107240401	4,399.06/2-1-71	4,333.63/1-23-92	65.4	3.1

the collection period was mid-March when irrigation was active, which suggests the results are of limited use for determining regional groundwater flow or background levels.

GROUNDWATER MODELS

To the author's knowledge, there are no existing groundwater models that include the Nutt-Hockett Basin.

LAND SURFACE OWNERSHIP

There is a considerable amount of both state land and Bureau of Land Management (BLM) land in the Nutt-Hockett Basin, which should facilitate the siting of new monitoring wells and access to existing wells. Figure 8-3 shows this public land.

MONITORING RECOMMENDATIONS

Given the hydrogeologic parameters described above for the Santa Fe Group, year-round true background groundwater monitoring in the Nutt-Hockett Basin is not possible due to the wide distribution of irrigation wells and the resulting widespread seasonal cone of depression caused by pumping of these wells. Background water levels can be monitored during the winter after irrigation pumping has ceased and groundwater levels recover. Despite this, it is recommended to locate some monitoring wells as far from high-production areas as possible. Figure 8-3 shows recommended locations for siting monitoring wells in the Nutt-Hockett Basin. Estimated costs to install these wells can be found in Table 8-2.

Table 8-2. Cost estimates for recommended monitoring wells in the Nutt-Hockett Basin.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
				Low	High
1	600	100	No	$156,000	$175,000
2	500	100	No	$138,000	$156,000
3	500	100	No	$138,000	$156,000
TOTAL				$432,000	$487,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. High-use area located near several irrigation wells and the Hatch water supply wells. The irrigation wells in this area are generally between 500 and 1,000 ft deep, with static depth to water ranging from 200 to 250 ft. Recommended well depth is at least 600 ft.

Location 2. High-use area located farther south than Location 1. Irrigation wells in this area generally range from 300 to 700 ft deep, with static depth to water ranging from 200 to 250 ft. Recommended well depth is at least 500 ft.

Location 3. Background location. There are two permitted stock wells located within this area, one of which was drilled in 1940 to a depth of 297 ft and had been monitored by OSE sporadically until 2012 (water level at 283 ft below ground surface). Recommended well depth is 500 ft.

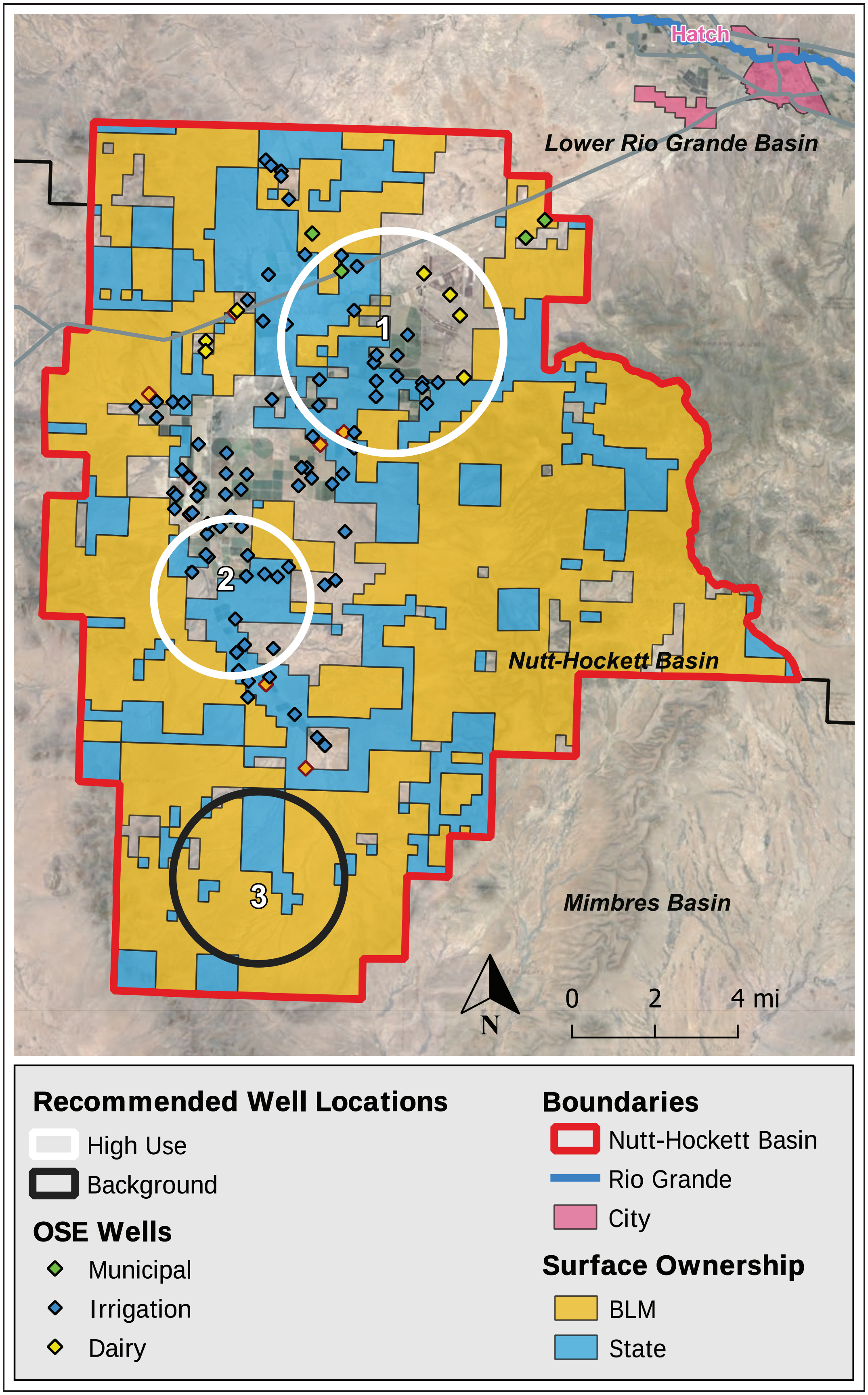

Figure 8-3. Land surface ownership in the Nutt-Hockett Basin and recommended monitoring well locations. No color indicates private land.

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CHAPTER 9. ROSWELL AREA

Robert Pine

The project area is contained within the Roswell-Artesian Underground Water Basin (referred to here as the Roswell-Artesian Basin or the Basin) located in Chaves and Eddy Counties as shown in Figure 9-1. The project area covers an area of approximately 2,123 mi^2 and contains the municipalities of Artesia, Dexter, Hagerman, and Roswell, serving a combined population of approximately 62,000. The New Mexico Office of the State Engineer (OSE) published administrative guidelines (OSE, 2005) for the Roswell-Artesian Basin with the central portion being closed to new appropriations and a small area around Dexter and Hagerman designated a Critical Management Area (CMA). Transfers are not permitted into the CMA from outside the CMA.

GEOLOGY AND HYDROLOGY

The Roswell project area lies to the east of the Sacramento Mountains, which rise more than 5,500 ft above the valley floor in the south and more than 8,000 ft in the north around Sierra Blanca peak. The Sacramento Mountains' crest is primarily made up of the lower Permian Yeso Formation in the south and Tertiary-Cretaceous volcanics, intrusive igneous, and Cretaceous sedimentary rocks that make up Sierra Blanca (Newton et al., 2012). As one moves east from the crest and down the Pecos slope that leads to the Pecos River corridor, the middle Permian San Andres Formation becomes the dominant outcropping formation.

A carbonate layer within the San Andres Formation forms the artesian aquifer within the Pecos River corridor. The boundaries of the confining layer were mapped by Welder (1983) and are shown approximately on Figure 9-2. The aquifer in the San Andres Formation exists to the west of this boundary but is unconfined. East of the Pecos River, the carbonate aquifer does not appear to extend more than a mile or two. When first tapped, the carbonate aquifer produced many flowing artesian wells. Due to the lowering of the potentiometric surface from pumping, there are few flowing wells today. However, the aquifer can still yield up to 1,000 gallons per minute (gpm) in some wells.

Within the Pecos River corridor, the San Andres Formation is overlain by the Permian Grayburg, Queen, and Seven Rivers Formations of the Artesia Group (Welder, 1983), which forms an aquitard for the artesian aquifer. The thickness of the confining layer is highly variable, increasing in thickness from west to east up to the river and then decreasing in thickness as one moves east from the river.

Above the confining bed are alluvial deposits of clay, silt, sand, and gravel, which contain the shallow aquifer. The shallow alluvial aquifer was mapped by Welder (1983) and is shown approximately on Figure 9-2, although, based on well depths, it seems likely that the shallow aquifer extends farther north than indicated by Welder. According to Welder, shallow wells are very productive, with 8-inch wells producing up to 500 gpm. Figure 9-3 is a generalized east-west geologic cross section in the Roswell area.

WATER RIGHTS AND WATER USE

The primary consumptive use of groundwater in the Roswell project area is irrigated agriculture. Based on OSE's 2015 water use report (Magnuson et al., 2019), in Chaves County there were 54,291 irrigated acres, of which only 122 acres were irrigated by surface water only and 862 acres were irrigated with surface water and groundwater combined.

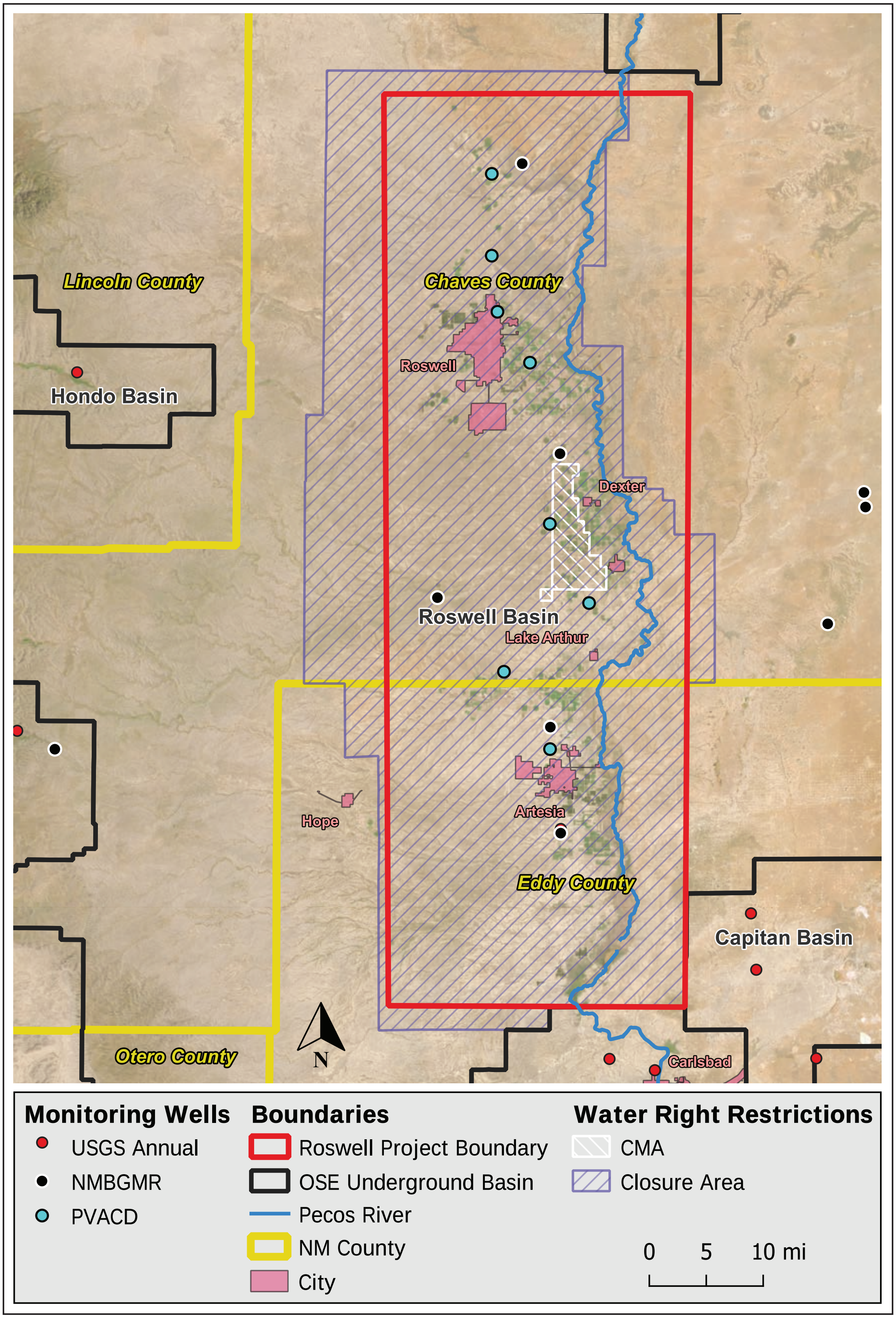

Figure 9-1. Overview of the Roswell project area, including active monitoring wells, OSE restricted areas, and neighboring declared underground water basins.

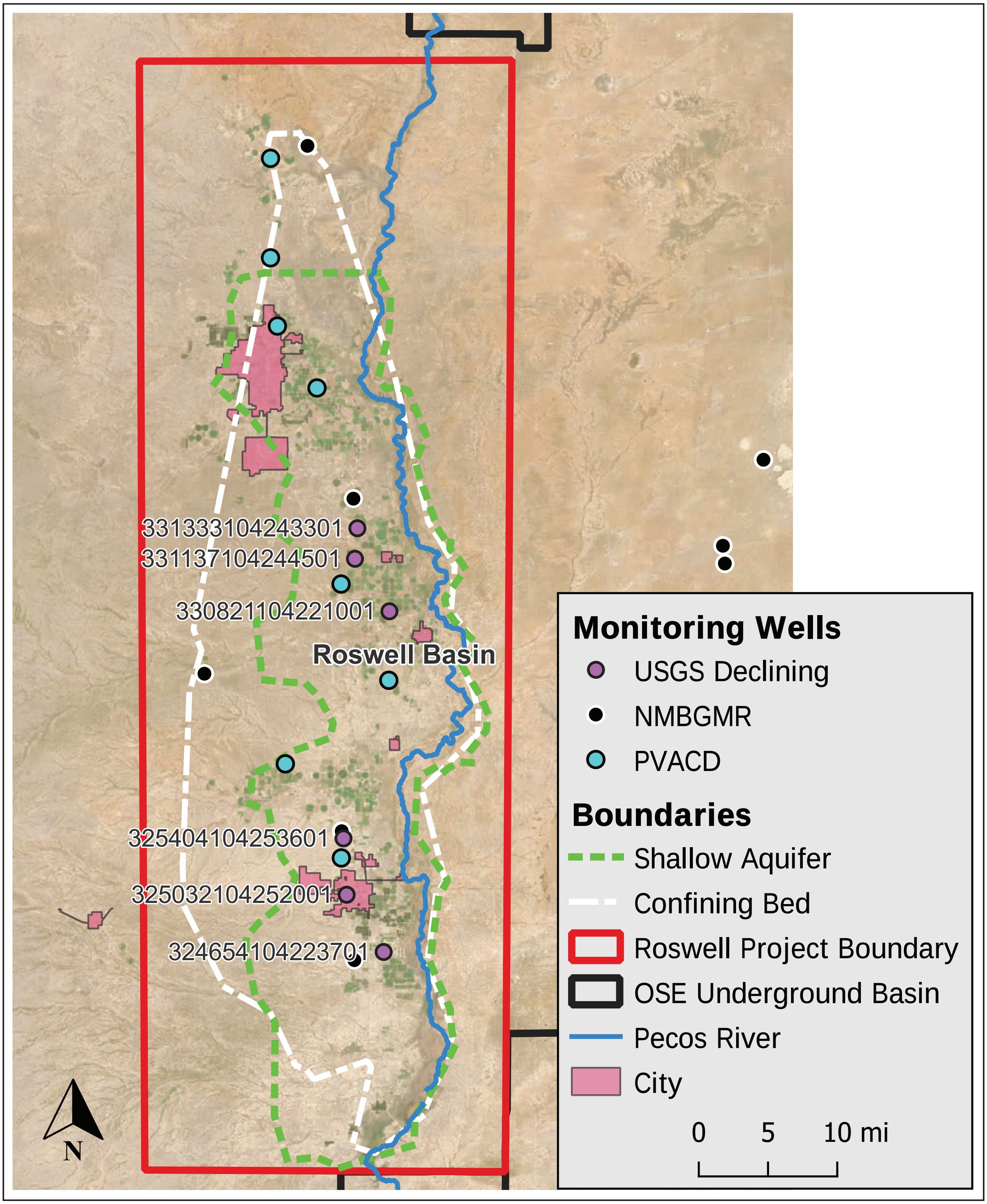

Figure 9-2. Approximate location of confining layer and shallow aquifer in the Roswell project area (based on Welder [1983]).

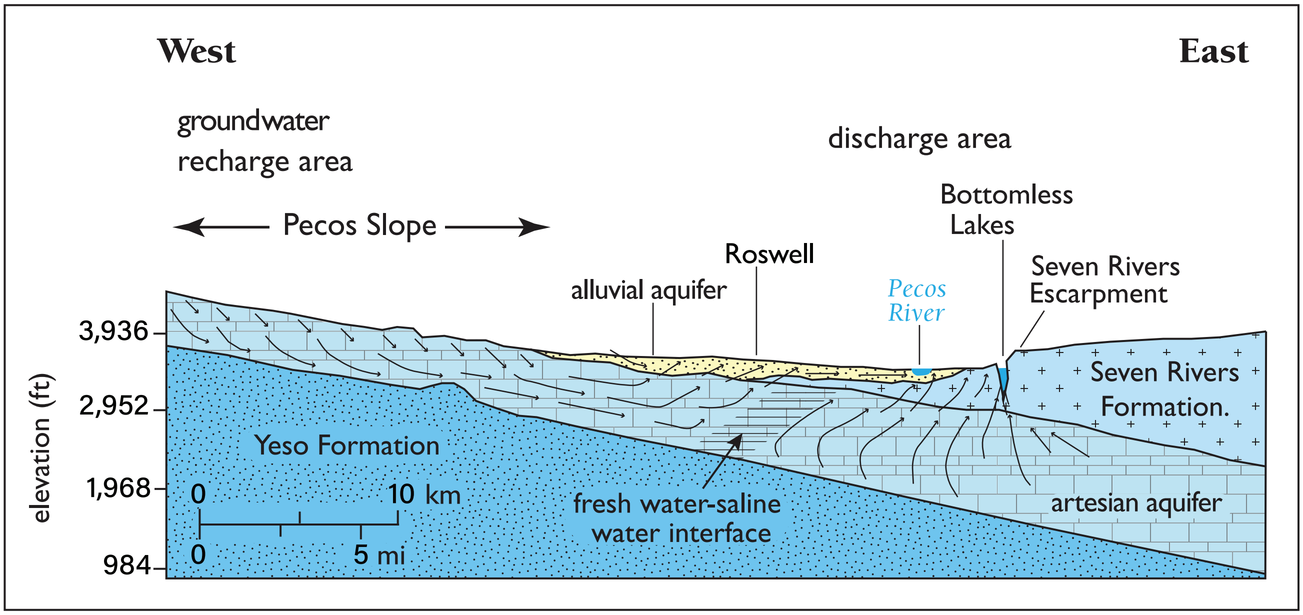

Figure 9-3. Generalized east-west geologic cross section in the Roswell project area (from Land [2003]).

The reason the vast majority of irrigation water rights in the Roswell-Artesian Basin are groundwater rights, despite the Pecos River flowing through the valley (compared with the Carlsbad Basin to the south, where only 1.6% of the irrigated acreage is groundwater only), is that the relatively shallow artesian aquifer, discovered in 1891, became the preferred source of irrigation water in the area. The Pecos Valley Artesian Conservancy District (PVACD), created in 1932, manages irrigation of approximately 130,000 acres in the Roswell area from both the artesian and the shallow aquifers. Of the total diversions in 2016, approximately 70.5% were from the artesian aquifer and approximately 27% were from the shallow aquifer (Stewart, 2016).

In addition to irrigation, there are approximately 1,527 acre-feet per year (acre-ft/yr) of groundwater rights for dairies and 20,048 acre-ft/yr for municipal and mutual domestic use. There are approximately 16,000 acre-ft/yr of permitted domestic use, 1,622 acre-ft/yr of livestock water rights, and 1,900 acre-ft/yr of combined domestic/livestock water rights in the Roswell project area (mostly from the shallow aquifer). Figure 9-4 shows the location of irrigation and municipal wells in the Roswell region. There is considerable groundwater production from both the artesian and the shallow alluvial aquifers.

GROUNDWATER MONITORING

Currently, the U.S. Geological Survey (USGS) has no active groundwater monitoring in the Roswell project area. There are several wells in the Basin previously monitored by OSE with time-series data that were provided to USGS. While many wells have not shown much of a trend, others have shown a steady decline in some areas. Table 9-1 lists some of these wells and their average rate of decline; location of these wells can be seen in Figure 9-2.

Table 9-1. Select rates of water-level decline in previously monitored wells in the Roswell project area.

USGS Well Number	Well Depth (ft)	Aquifer	Measurement Period	Average Rate of Decline (ft/yr)
331137104244501	152	Shallow	1940–1979	1.7
331333104243301	385	Artesian	1955–2015	0.85
330821104221001	185	Shallow	1938–2005	0.84
325404104253601	212	Shallow	1950–1979	2.6
325032104252001	140	Shallow	1939–1984	2.1
324654104223701	840	Artesian	1912–1984	1.6

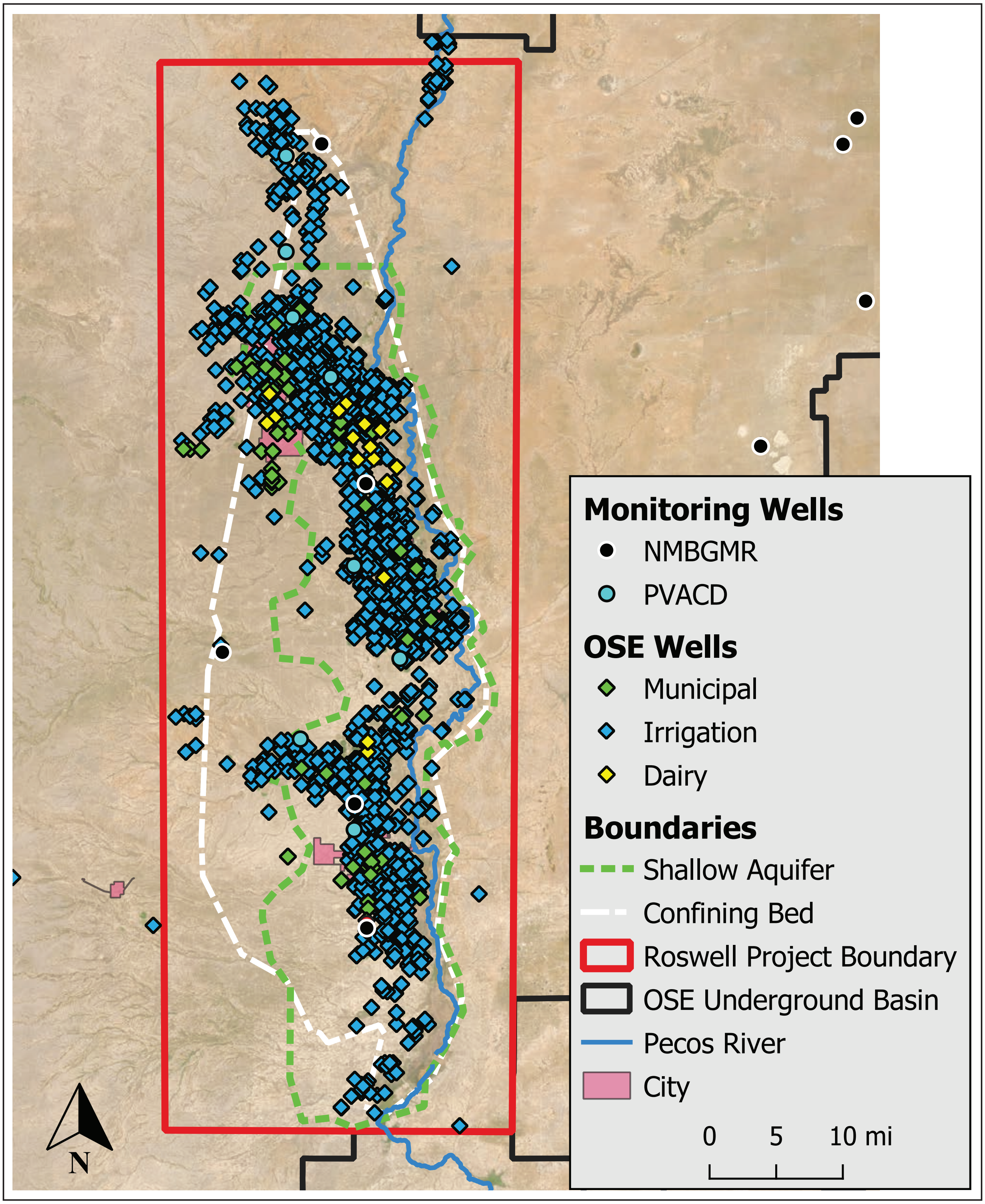

Figure 9-4. OSE municipal, irrigation, and dairy wells in the Roswell project area.

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has three active monitoring wells in the region, only one of which is continuously monitored. These wells can be seen in Figures 9-1 and 9-2.

The OSE District 2 staff have been measuring a set of wells in the Basin since at least 2011. However, the data are kept in multiple spreadsheets and there is no indication of the OSE well number, so the well completions are unknown, though one might infer which aquifer the wells are completed in by the water level. The NMBGMR has sorted through the data and made them available through their online Hydroviewer app (**https://hydroviewer-dot-waterdatainitiative-271000.appspot.com**). Some wells have been measured annually while others have not. Over the period of measurement, most of these wells have not shown an appreciable decline in water level.

The PVACD has 10 dedicated monitoring wells now instrumented for continuous water-level measurement. All appear, based on depth, to be monitoring the artesian aquifer (well logs are not available for these wells). Water levels in these wells do not appear to be dropping over time, but it should be noted that during irrigation season, water levels may drop 100 ft or more from static levels (see Fig. 1-4).

GROUNDWATER MODELS

The OSE utilizes a calibrated groundwater model originally created in 1995 by Daniel B. Stephens and Associates. This model has had subsequent revisions, and the current superposition version dates from 2004 and is sometimes referred to as the SKL Model. It is a three-layer model, with the upper layer representing the shallow aquifer, the middle layer representing the semi-confining layer, and the lower layer representing the carbonate aquifer.

LAND SURFACE OWNERSHIP

Figure 9-5 shows land surface ownership within the Roswell project area. There is a mix of state, federal (Bureau of Land Management [BLM] and some U.S. Fish and Wildlife), and private land. Public land is not abundant but is sufficient for siting monitoring wells. There is also some city-owned property that is not shown in Figure 9-5.

MONITORING RECOMMENDATIONS

Figure 9-5 shows recommended locations for groundwater monitoring. Because the artesian aquifer has 10 PVACD continuously monitored wells, only one additional artesian monitoring well is recommended for this aquifer. Estimated costs to install these wells can be found in Table 9-2.

Table 9-2. Cost estimates for recommended monitoring wells in the Roswell project area.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
				Low	High
1	225	25	No	$78,000	$96,000
2	250	75	No	$86,000	$104,000
3	100	20	No	$55,000	$73,000
4	350	120	Yes	$115,000	$133,000
TOTAL				$334,000	$406,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. Shallow aquifer, high use. This location is a 1.25-mi^2 parcel of state land with road access just to the west of an area of high irrigation around Dexter and Hagerman. The irrigation wells in this area utilize water from both the shallow and artesian aquifers. The anticipated well depth is approximately 225 ft, with an estimated depth to water of 150 ft based on well logs in the area.

Location 2. Shallow aquifer, high use. This location is north of Artesia where there is a considerable amount of irrigation and contains two deep monitoring wells. There is currently a well nest consisting of a deep PVACD well and a shallow NMBGMR well located approximately 8 mi to the south of this location; however, this location is still recommended due to the considerable amount of irrigation from the shallow aquifer taking place north of Artesia. There is a mix of state, BLM, and city land in this area with road access. Recommended well depth is 250 ft, with an estimated depth to water of 100 ft based on well logs in the area.

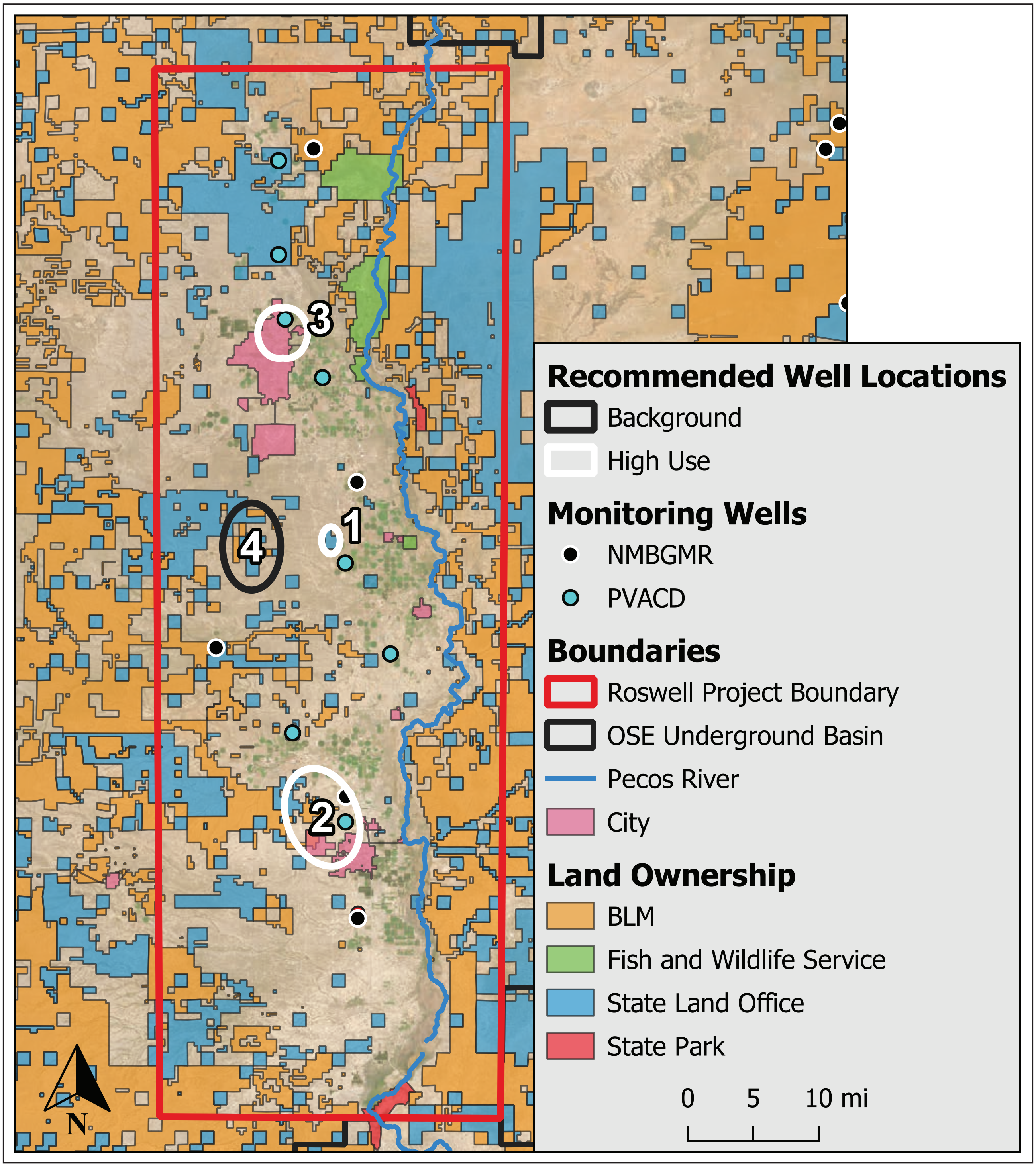

Figure 9-5. Recommended monitoring well locations and land surface ownership in the Roswell project area.

Location 3. Shallow aquifer, high use. This location is within the city of Roswell, which is surrounded by a considerable amount of irrigation. It is hoped that the city could provide a secure location for the well. Based on recent well logs, recommended well depth is 100 ft, with estimated depth to water of 60 ft.

Location 4. Artesian aquifer, low use. This location is approximately 6 mi west of Location 1 in an area with little irrigation. The majority of PVACD artesian monitoring wells are in areas with high irrigation use, so this well would provide static water levels with less direct impact from irrigation. The recommended depth of this well is 350 ft, and depth to water is 200 ft based on recent well logs in the vicinity. It is assumed that this well will require an artesian completion.

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CHAPTER 10. SOUTHERN LEA COUNTY

Robert Pine

For this study, southern Lea County is defined as the portion of Lea County from Township T18S south to the Texas border (T26S). This area is approximately 2,100 mi^2 and includes portions of the Capitan, Lea County, and Carlsbad Underground Water Basins and all of the Jal Underground Water Basin (see Fig. 10-1). On average, it receives less than 14 in. of annual precipitation, most of which falls in the summer months. The area includes the cities of Eunice, Hobbs, and Jal.

GEOLOGY AND HYDROLOGY

Southern Lea County is contained within the Delaware Basin, a sedimentary basin covering approximately 12,000 mi^2 in southeastern New Mexico and western Texas that contains layers deposited in the Permian, Triassic, Tertiary, and Quaternary periods. The Delaware Basin is well known for its rich oil reserves, which provided approximately $2.8 billion in revenue for the state of New Mexico in FY2020 (Palmer, 2021). Southern Lea County contains three aquifers in common use: a mostly confined aquifer found within the Santa Rosa Formation (referred to here as the Santa Rosa aquifer), a shallow aquifer found within the Pecos Valley alluvium (referred to here as the PVA aquifer), and the High Plains aquifer found within the Ogallala Formation. The High Plains aquifer, which is closed to new appropriations, is found within the Lea County Underground Water Basin and is fairly well monitored, and so is not included in this analysis.

The Santa Rosa Formation is the lower portion of the Triassic Dockum Group. It is bounded below by the Dewey Lake Formation of the Permian Ochoa Series and bounded above by the Chinle Formation of the Dockum Group. It is primarily sandstone with some shale and is fairly distinguishable in a gamma log (Powers, 2014), of which there are many in this region due to the oil and gas industry. Within southern Lea County, the Santa Rosa aquifer is primarily confined. However, in the western portion of this region the formation is at or near the surface and is unconfined. Additionally, there is a collapse feature in the region known as the Monument Draw Trough that parallels the Carlsbad Basin-Capitan Basin boundary and was formed by dissolution of underlying evaporites, with over 1,000 ft of vertical dislocation in the Jal Basin and to the southwest of Eunice. Within these collapse features, there is a high likelihood of fracturing within the Santa Rosa Formation and overlying Chinle Formation, and so there is a reasonable probability that the Santa Rosa aquifer is in direct communication with the overlying shallow aquifer; however, this has never been verified. The collapse feature is shown in Figure 10-2, which includes a mapping of the elevation of the top of the Permian Rustler Formation (the Rustler mapping was used instead of the Santa Rosa because there are more data points for the Rustler Formation). The collapse features can be seen as the black and dark-gray regions (circled in yellow), indicating a much deeper depth of the Rustler Formation. There are very little aquifer test data available for the Santa Rosa aquifer in this region.

The Santa Rosa Formation shallows to the west, is intermittently at or near the surface west of the Monument Draw Trough, and eventually disappears completely as one moves farther west. This region where the Santa Rosa Formation is at or near the surface is likely a recharge zone for the aquifer. The Santa Rosa Formation continues well to the north of southern Lea County, and so this western region does not represent the entirety of the aquifer recharge zone.

The Cenozoic Pecos Valley alluvium, or PVA (misnamed because the ancestral Pecos River never existed anywhere near this region), overlies the majority of southern Lea County.

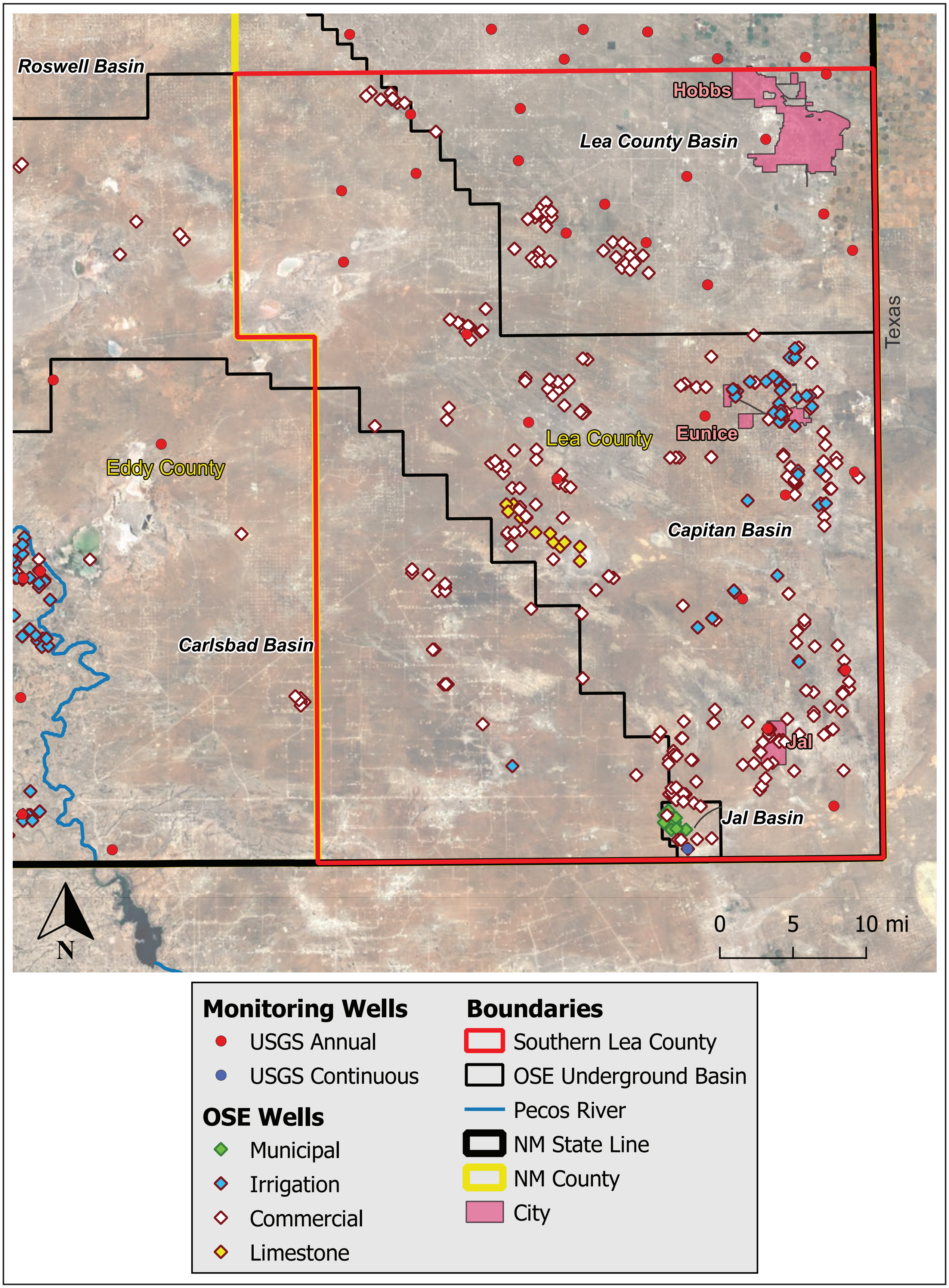

Figure 10-1. Overview of southern Lea County showing OSE wells, active monitoring wells, and neighboring declared underground water basins.

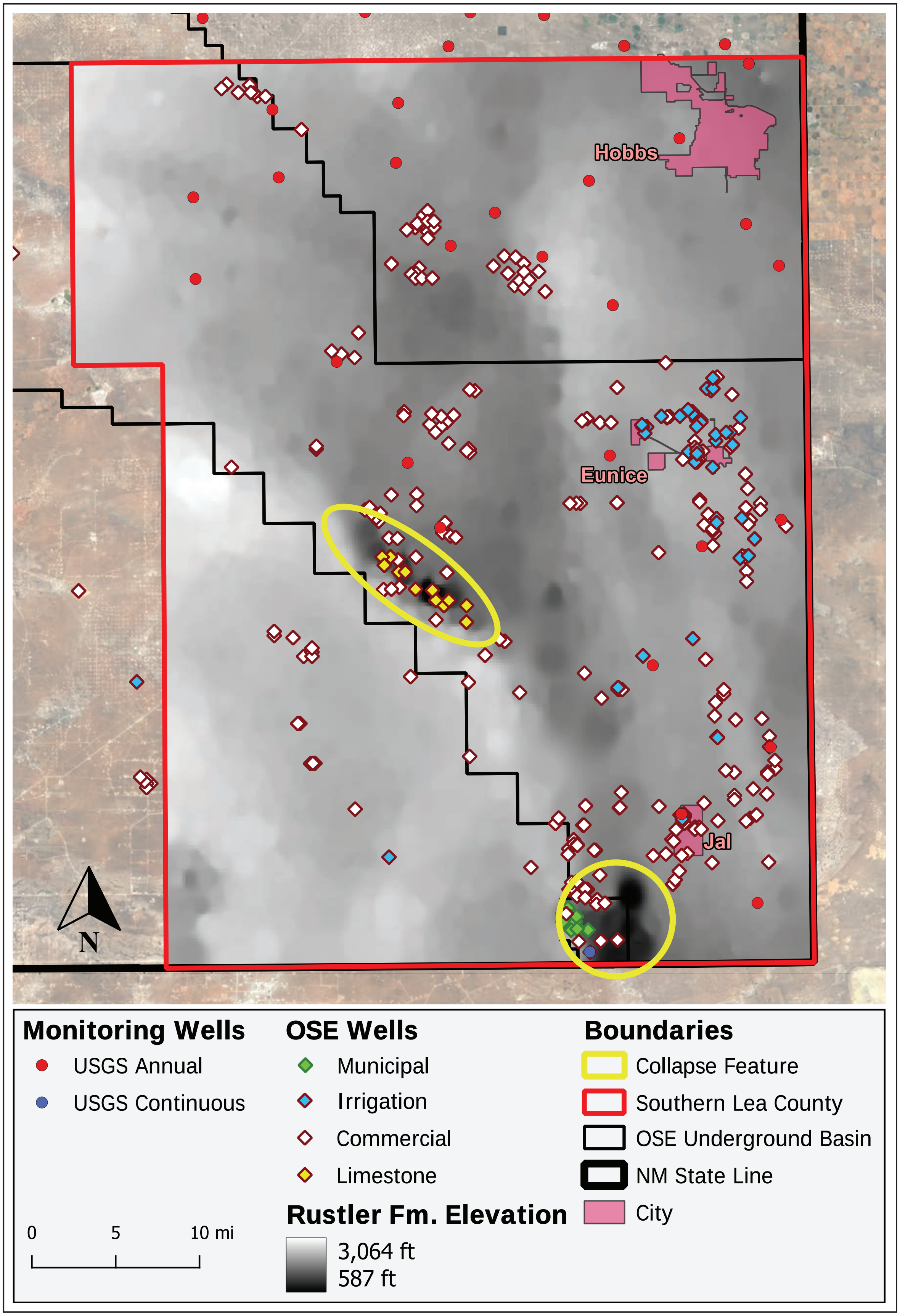

Figure 10-2. Top of Rustler Formation elevation showing the Monument Draw Trough collapse features.

It consists of clay, silt, sand, and gravel, with a commonly occurring shallow caliche layer (Meyer et al., 2012). The thickness of the PVA outside of the trough is on average less than 100 ft, but can be hundreds of feet thick within the deeper portions of the trough. There is some debate as to whether the two deep portions of the PVA aquifer are continuous, with flow from approximately north to south. The author believes this is the case, though there are insufficient data to make a definitive determination. The aquifer does not extend much beyond the Carlsbad Basin-Capitan Basin boundary to the west of the trough but is continuous to the east beyond the state line.

There have been several aquifer tests, both single-well and multi-well, in the PVA within the Jal Basin. Results for specific yield have been difficult to interpret and somewhat controversial, with values on the low side suggesting a high fines content. Drilling logs have not shown a high fines content, though in all cases wells were drilled with mud, which makes it difficult to recover fines in drill cuttings. The PVA aquifer is likely recharged through infiltration from significant rainfall events in drainages throughout its coverage. Therefore, monitoring of PVA aquifer recharge with wells is not practicable.

In addition to the Santa Rosa and PVA aquifers, the deeper Permian Rustler Formation and Capitan Limestone are also water bearing but are not being utilized in southern Lea County at this time, and they have poorer water quality than the Santa Rosa or PVA aquifers. Therefore, they are not included in this analysis. A generalized stratigraphic column of the upper Delaware Basin geology is shown in Figure 10-3.

WATER RIGHTS AND WATER USE

There are relatively few irrigation water rights in southern Lea County within the Santa Rosa or PVA aquifers. There are a total of 1,093 acre-feet per year (acre-ft/yr) of irrigation water rights, most of which are in and around the city of Eunice (203 acre-ft/yr are for the Eunice golf course). In contrast, there are currently over 17,000 acre-ft/yr of commercial water rights, the majority of which are to supply water for oil and gas well drilling.

The shallow aquifer within the PVA is the highest-quality aquifer in the region, in particular within the northern and southern troughs. The southern trough in and around the Jal Basin is the sole source of drinking water supply for the city of Jal, with several supply wells located within the Jal Basin. Although the Jal Basin was closed to new appropriations by the New Mexico Office of the State Engineer (OSE) in 2013, there recently have been applications for new appropriations to tap into the PVA aquifer just outside the basin boundary to the north and to the southwest. Just south of the Jal Basin in Texas, the city of Midland installed a well field in 2012 with 44 production wells tapping the PVA aquifer that are capable of producing 20 million gallons per day. Recently, Limestone Basin Properties received approval of 12 commercial applications (one well each) in the PVA aquifer in the northern trough, for a total of 1,700 acre-ft/yr as shown in Figures 10-1 and 10-2.

The Santa Rosa aquifer in southern Lea County is not currently used for municipal drinking water supply (though there are a few domestic wells tapped into it), but it has recently been targeted for commercial use by the oil and gas industry to supply water for hydraulic fracturing, which on average can consume 4 million gallons of water per well according to the American Petroleum Institute (API, 2021). Within the Lea County Basin (T19S and T20S), three applications from the L&K Ranch (L-14552, L-14553, and L-14554) were recently approved for 1,722 acre-ft/yr of commercial use from 30 wells producing from the Santa Rosa aquifer. Southern Lea County was temporarily closed to new appropriations in 2020 due to the large number of applications for new commercial rights, in part due to the L&K Ranch and Limestone Basin Properties applications.

GROUNDWATER MONITORING

There are currently few active monitoring wells within southern Lea County in the Santa Rosa or PVA aquifers. There are five annual U.S. Geological Survey (USGS) Santa Rosa aquifer monitoring wells, eight annual USGS PVA aquifer monitoring wells, and one continuous PVA aquifer monitoring well located at the southern end of the Jal Basin within the trough. Within the deeper portions of the trough, there are no Santa Rosa aquifer monitoring wells. Any monitoring by OSE has been ad hoc.

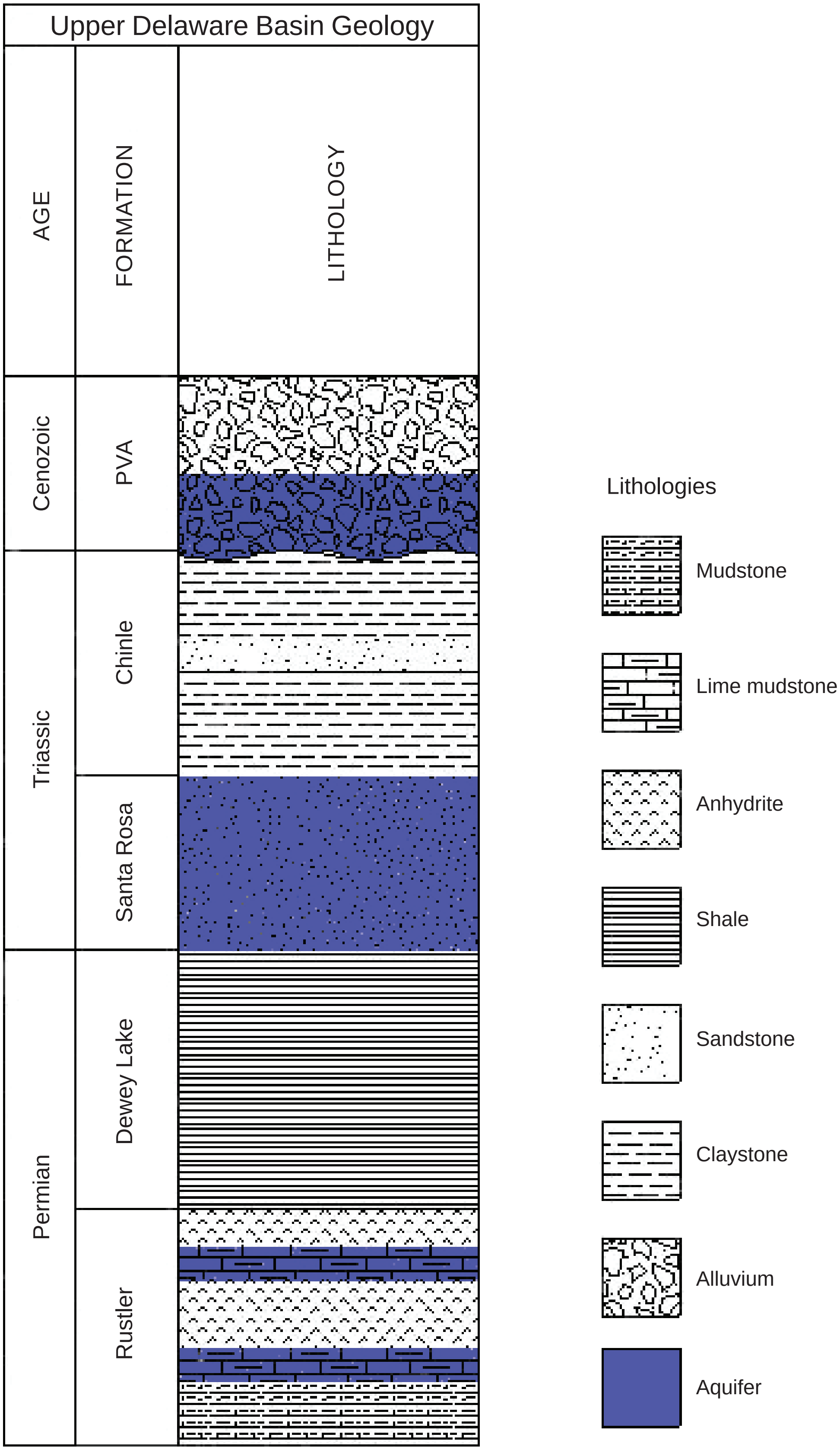

Figure 10-3. Generalized stratigraphic column of the upper Delaware Basin.

GROUNDWATER MODELS

Various models have been constructed in this region, primarily by consultants on behalf of their clients. The OSE has recently been developing a model to evaluate water rights in southern Lea County, but it is a work in progress because needed hydrogeologic and water-level data for the region are still lacking. At this time, neither this model nor any other model of the region is considered adequate to function as an administrative model.

LAND SURFACE OWNERSHIP

There is a considerable amount of both state land and Bureau of Land Management (BLM) land in southern Lea County as seen in Figure 10-4, which should facilitate the siting of new monitoring wells. Not all of this area is accessible by existing roads, so potential sites are more limited than appears in the figure.

MONITORING RECOMMENDATIONS

Goals for monitoring southern Lea County should include monitoring of high-use areas, background water levels, and aquifer interaction within the trough. Until the recharge zone is better defined, monitoring recharge west of the trough is not practicable. Figure 10-4 shows recommended monitoring well locations and functions. Estimated costs to install these wells can be found in Table 10-1.

The following locations, in order of priority, were identified for monitoring wells.

Location 1. High-use PVA aquifer. There are no active USGS wells located in the northern portion of the Jal Basin. The northern Jal Basin is the location of the water supply wells for the city of Jal and several recently approved commercial wells. Water levels appear to have been declining here for some time, so there is a need for continuous monitoring. The estimated depth of the PVA ranges in this area from approximately 550 to 800 ft based on gamma logs. The current depth to water ranges from 250 to 300 ft. Recommended well depth is to the bottom of the PVA, which is estimated to be 800 ft.

Location 2. High-use PVA aquifer. This area is within the northern trough where many commercial wells are located, including the recently approved Limestone Basin Properties wells. The thickness of the PVA in this area ranges from a few hundred feet to well over 1,000 ft. The average depth of the pending Limestone wells is 1,090 ft, and average depth to water in recently drilled wells is approximately 300 ft. Estimated depth of the recommended well is 1,000 ft.

Location 3. High-use Santa Rosa aquifer. This area is located in the vicinity of the L&K Ranch wells. The Santa Rosa Formation in this area is approximately 200 ft thick and lies approximately between the depths of 1,200 and 1,400 ft based on gamma logs from oil and gas wells. Estimated well depth is 1,400 ft.

Table 10-1. Cost estimates for recommended monitoring wells in southern Lea County.

Well Location	Aquifer	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
					Low	High
1	PVA	800	100	No	$98,000	$162,000
2	PVA	1,000	100	No	$113,000	$188,000
3	PVA	1,400	200	Yes	$170,000	$272,000
4	PVA	400	100	No	$67,000	$112,000
4	Santa Rosa	1,080	200	Yes	$145,000	$230,000
5	PVA	200	100	No	$52,000	$87,000
6	Santa Rosa	1,000	200	Yes	$134,000	$214,000
TOTAL					$779,000	$1,265,000

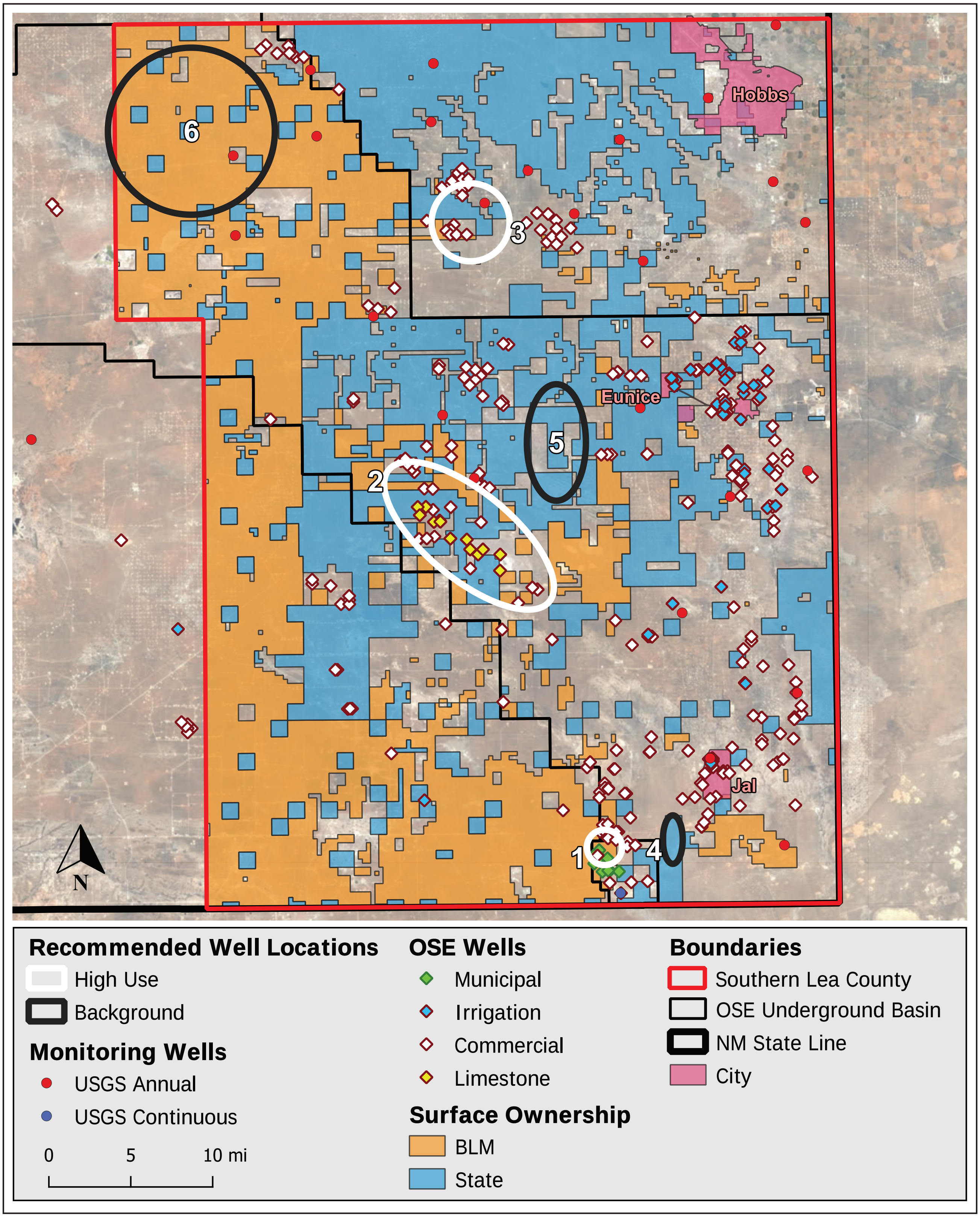

Figure 10-4. Recommended monitoring well locations and land surface ownership in southern Lea County.

Location 4. Background PVA and Santa Rosa aquifers. There are limited areas for background wells around the Jal Basin due to its small size, but the best location would be in the northeastern portion of the trough. Although the Santa Rosa aquifer within the Jal Basin is closed to new appropriations, two commercial Santa Rosa wells (CP-1687 PODs 1 and 2) just east of the Jal Basin and a little north of the Texas state line were recently approved. One of these wells was drilled under an exploratory permit and was a good producer, probably because of fracturing of the formation due to its proximity to the trough. More new Santa Rosa aquifer wells in this area might be expected if the temporary closure is not made permanent. Therefore, of secondary interest is a monitoring well in the Santa Rosa aquifer in the same location as a PVA aquifer monitoring well (it may or may not serve as a background Santa Rosa aquifer well). Based on nearby gamma logs, the depth to the top of the Rustler Formation in this area is approximately 1,700 ft and the thickness of the Dewey Lake Formation is 620 ft. Therefore, the Santa Rosa Formation should be approximately between 880 and 1,080 ft below ground surface. The thickness of PVA in this area is unclear but estimated to be approximately 400 ft. Depth to water is estimated to be approximately 100 ft.

Location 5. Background PVA aquifer. This area within the PVA aquifer is east of the northern trough where there is less permitted diversion than in surrounding areas. It will likely be impacted by surrounding production but much less so than the high-use areas. Thickness of the PVA in this area appears to be approximately 200 ft based on gamma logs. Depth to water is estimated to be approximately 50 ft based on a few nearby wells.

Location 6. Background Santa Rosa aquifer. Due to the large uncertainty in hydraulic parameters for estimating a recommended distance from production wells, it is best to just try and locate background wells as far from existing and proposed pumping wells as possible. This location is at least 10 mi from any Santa Rosa aquifer high-production area. In the selected area, the Santa Rosa aquifer lies approximately between 800 and 1,000 ft below ground surface (based on gamma logs), and so the estimated depth of the recommended well is 1,000 ft. The existing USGS monitoring well within this location taps a shallow aquifer.

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CHAPTER 11. TAOS AREA

Sara Chudnoff

The Taos project area (Fig. 11-1) is located in north-central New Mexico in Taos County and within the Rio Grande Underground Water Basin. It encompasses 155 mi^2 and is bordered approximately on the north, east, and south by the Sangre de Cristo Mountains and on the west by the Rio Grande. Within the study area are the Taos Pueblo and the communities of Taos, Ranchos de Taos, Arroyo Seco, Arroyo Hondo, and Talpa.

GEOLOGY AND HYDROLOGY

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) has published reports on the geology and hydrogeology of the northern (Rawling, 2005; Johnson et al., 2009) and southern (Johnson et al., 2016) parts of the study area. In addition to the work done by NMBGMR, Glorieta Geoscience Inc. and the U.S. Bureau of Indian Affairs (BIA) published three papers in 2004 with the New Mexico Geological Society (Drakos et al., 2004a, 2004b, 2004c) on their hydrogeologic work in the southern San Luis Basin, which extends throughout the study area.

The area falls within the Rio Grande rift's northernmost basin, the San Luis Basin, which is flanked by the Tusas Mountains to the west and the Sangre de Cristo Mountains to the east. There are four distinct aquifers in this region: two in the alluvial fan deposits, one in the Servilleta Formation (Aqua Azul aquifer), and one in the Santa Fe Group (Barroll and Burck, 2006). In general, groundwater moves from east to west (toward the Rio Grande). Along the eastern side of the Rio Grande rift there are many springs where there has been downcutting into the aquifer.

The shallow alluvial aquifer is composed of Quaternary to Tertiary alluvial fan deposits. The shallow aquifer, springs, and streams throughout the region are all interconnected. Underlying the alluvial deposits is the Tertiary Servilleta Formation, which is basalt interbedded with sediments. Underlying the Servilleta Formation is the Tertiary Santa Fe Group comprising the Chamita and Tesuque Formations (see Fig. 11-2). Faults throughout the region act as a conduit of flow (upward, downward, and horizontally) as well as inhibit flow (Bauer et al., 1999; Rawling, 2005). Generally speaking, the shallow aquifer is defined as the alluvial deposits and Servilleta Formation and the deeper aquifer is defined as the Santa Fe Group and older formations (Rawling, 2005).

WATER RIGHTS AND WATER USE

Figure 11-3 shows New Mexico Office of the State Engineer (OSE) wells in the Taos area. There are over 7,000 OSE wells throughout the study area; of those, 5,705 have either a permitted water right or a domestic/livestock water right, for a total of approximately 18,000 acre-feet per year (acre-ft/yr). Of the OSE wells, 94% are permitted for domestic and livestock use (total diversion of 14,421 acre-ft/yr) and the remaining 6% are permitted for commercial, sanitary, municipal, mutual domestic, and irrigation use (total diversion of 3,680 acre-ft/yr). For an agriculturally rich area, the reason so little groundwater is diverted for irrigation is because there are 55 acequias providing surface water to the farmers in the region.

The Abeyta Settlement (hereafter Settlement) is a multi-party agreement that adjudicated Taos Pueblo's water rights within the Rio Hondo and Rio Pueblo de Taos stream systems. As part of the Settlement, OSE, in cooperation with the Taos Technical Committee, developed a groundwater flow model that roughly encompasses the study area proposed here.

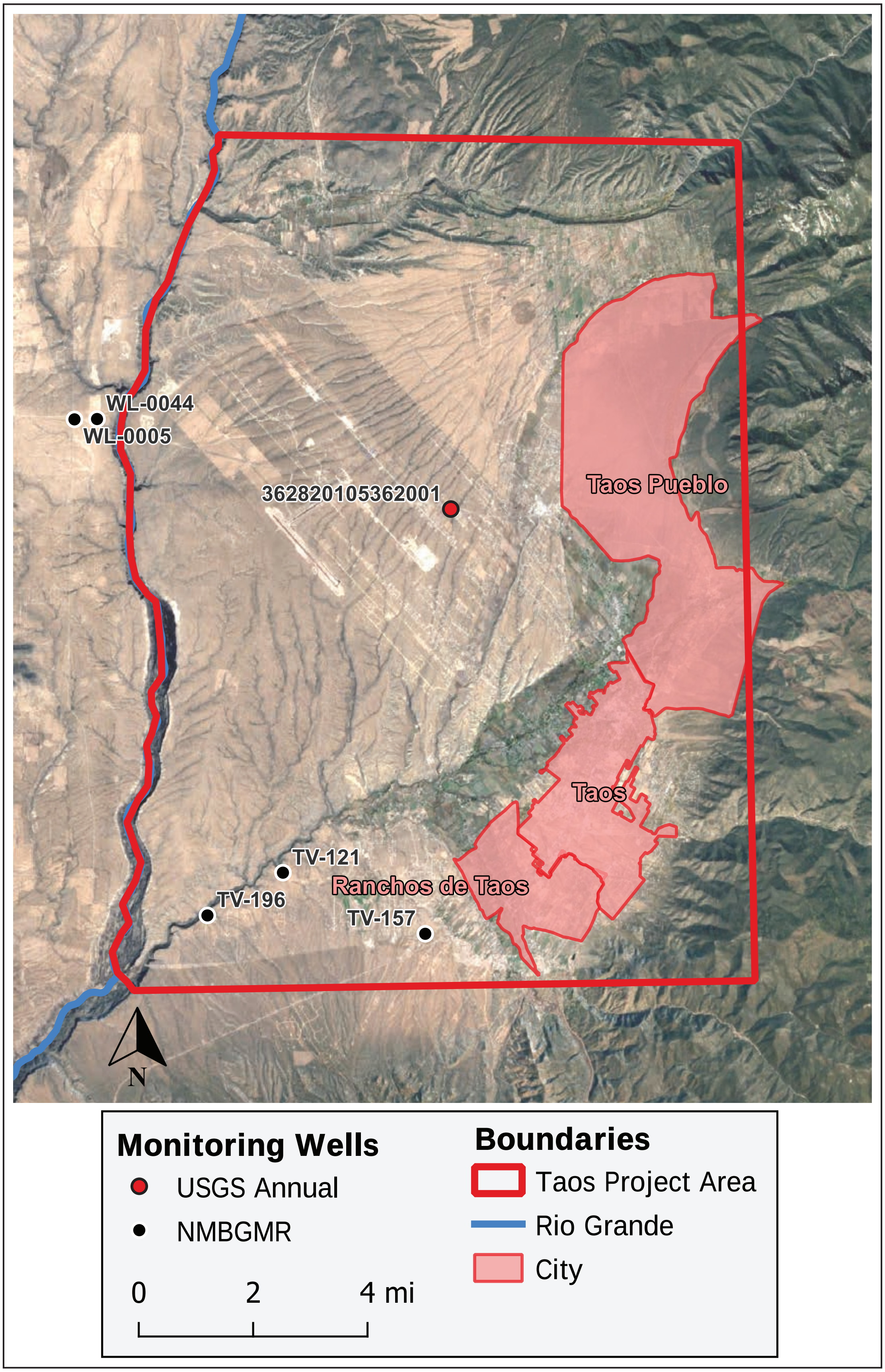


Figure 11-1. Overview of Taos project area, including active monitoring wells.

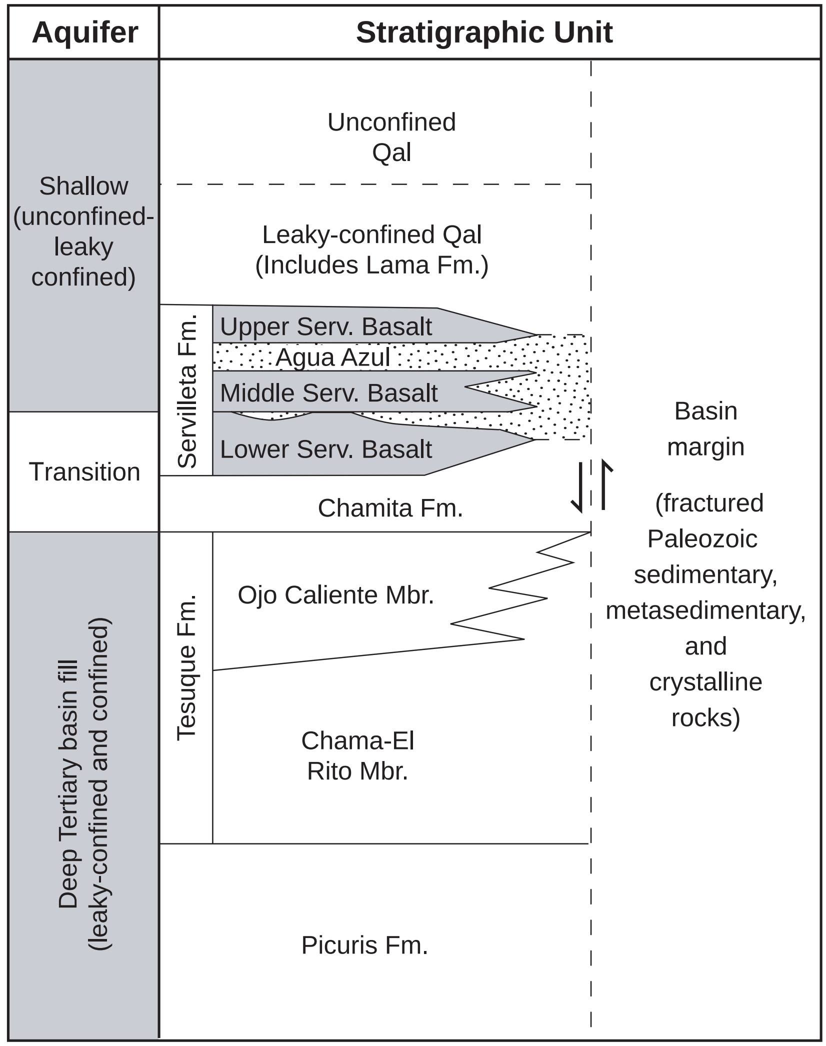


Figure 11-2. Generalized geologic stratigraphic column of the Taos area (from Drakos et al. [2004b]).

The purpose of the model was to provide a tool for the adjudication Settlement negotiations and to “administer the wells subject to the Settlement Agreement” (Barroll and Burck, 2006). Two large outcomes of this Settlement were the El Prado Water and Sanitation District and the town of Taos moving their municipal wells away from Taos Pueblo’s Buffalo Pasture (wetlands) and into the deeper aquifer (Santa Fe Group) in order to mitigate impacts on the shallow aquifer.

As of August 2022, non-Pueblo water rights have also been adjudicated, and the region is essentially closed to any new appropriations (personal communication, Ramona Martinez, OSE District 6 Water Rights Manager, August 2022). At the time of this report, domestic wells have not been adjudicated and the OSE District 6 Water Rights Office is still issuing domestic permits.

GROUNDWATER MONITORING

Generally, there is a lack of good groundwater-level time-series data in the Taos area. Active groundwater-level monitoring wells within the project area can be seen in Figure 11-1. The U.S. Geological Survey (USGS) has only one active monitoring site (USGS 362820105362001) with an unknown depth (indicated as being completed in the alluvial aquifer). The site has been manually measured since 1983 at inconsistent time intervals, the most recent being January 27, 2022. The NMBGMR has three monitoring sites (TV-157, TV-121, and TV-196) within the region that are monitored every 12 hours by a pressure transducer. The three wells were drilled in the late 1990s and early 2000s and have known completion information.

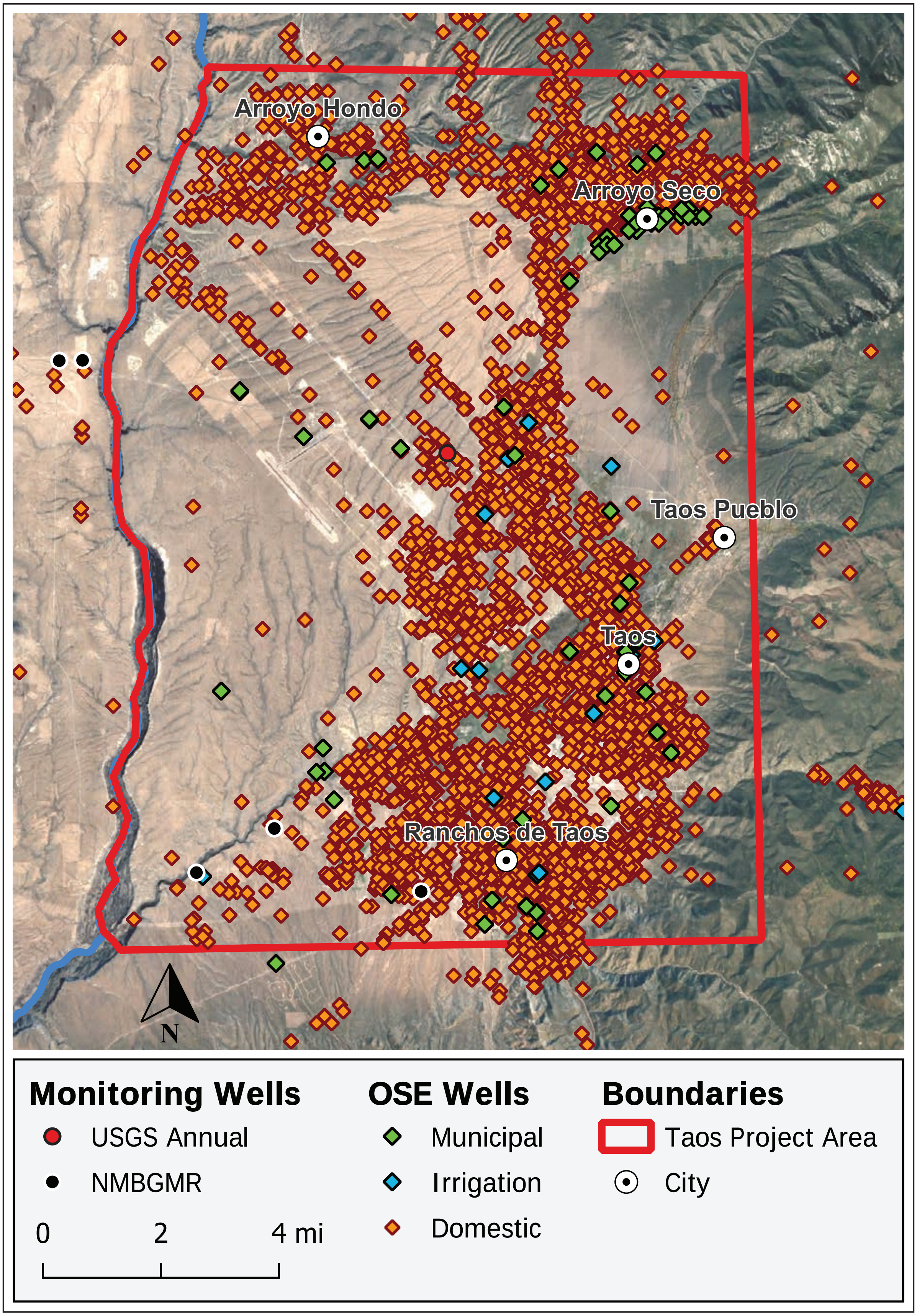


Figure 11-3. OSE wells in the Taos project area.

Two of the three wells (TV-121 and TV-196) are completed in the Servilleta Formation and have pumping test information that is available in Drakos et al. (2004b). As part of the Settlement, parties are required to take water-level measurements; however, the measurements are not readily available. Hydrographs for wells USGS 362820105362001, TV-121, TV-157, and TV-196 can be seen in Figures 11-4a through 11-4d. Water levels in TV-157 have been slowly declining since 2012. The USGS well 362820105362001 has shown a significant drop in water level starting around 2014. The other two wells have not shown any notable trend.

GROUNDWATER MODELS

In 2006, the OSE Hydrology Bureau finalized their Taos groundwater model. This model was developed in conjunction with a technical committee made up of state and federal entities, consultants, and BIA. The model was developed to aid in the adjudication of the Settlement. Table 11-1 is a list of the model layers and geologic description (from Barroll and Burck [2006]).

Table 11-1. Taos groundwater model layer description.

Layer	Geologic Description	Thickness (ft)
1, 2	Youngest alluvial fan deposits derived from Sangre de Cristo Mountains	20, 30
3	Youngest alluvial fan deposits derived from Sangre de Cristo Mountains, northern basin	50 up to 700
4	Reworked alluvial fan materials and other basin-fill deposits, including poorly to well-sorted silts, sands, and gravels	<100 up to 550
5	Pliocene Servilleta basalt flows and interbedded sediments	400
6, 7	Miocene Santa Fe Group sediments composed of fluvial, eolian, and lacustrine clays, silts, sands, and gravels	500 up to 1,700

A

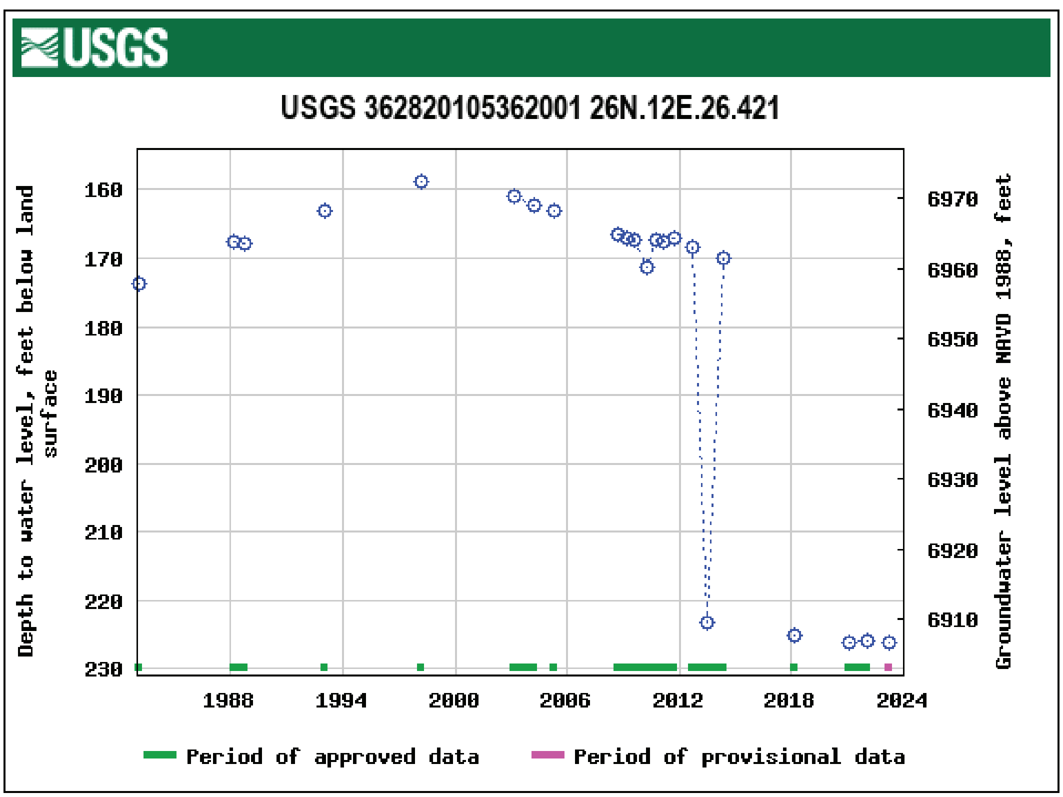
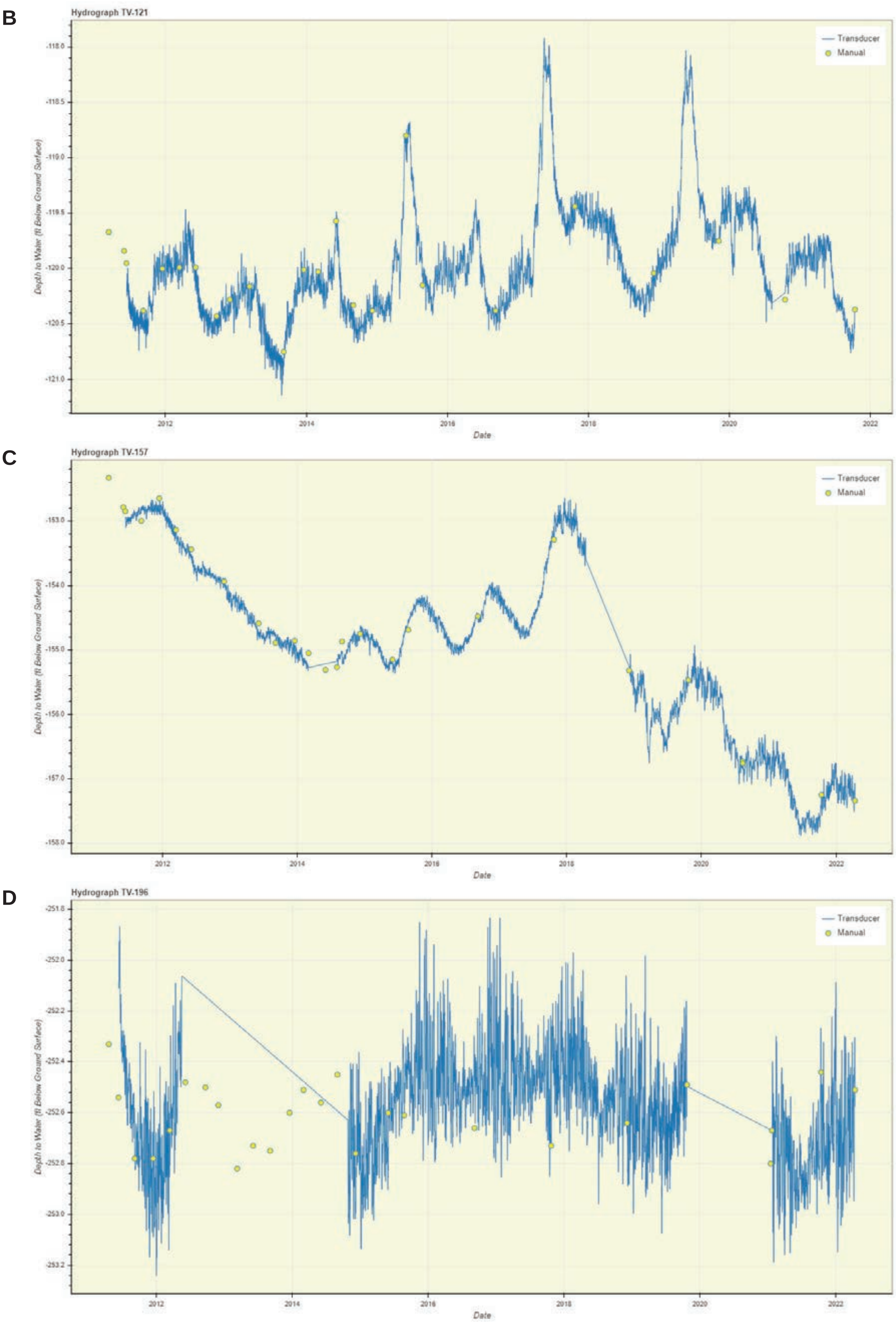


Figure 11-4a. Hydrograph of currently active USGS 362820105362001 (see Fig. 11-1 for location).



Figures 11-4b through 11-4d. Hydrographs from three Taos area wells: (b) NMBGMR well TV-121, (c) NMBGMR well TV-157, and (d) NMBGMR well TV-196 (see Fig. 11-1 for locations).

LAND SURFACE OWNERSHIP

Within the study area, most of the land is either privately owned or owned by Taos Pueblo. However, as shown in Figure 11-5, there is federally owned land within the study area managed by the U.S. Forest Service and property owned by local government agencies (county, municipalities, and school districts). Many of these entities have a vested interest in groundwater conditions, and it may therefore be feasible to work with them to gain access to existing monitoring wells or to get access agreements for installing monitoring wells and conducting continuous monitoring.

MONITORING RECOMMENDATIONS

The primary aquifers utilized in the study area are the alluvium and the Servilleta and Santa Fe Formations. A number of studies were completed in the past that included the installation of wells into the Servilleta and Santa Fe Formations for monitoring. The status of monitoring at most of these wells is currently unknown. Recharge to all aquifers in the region originates in the mountains and subsequently flows through the shallow alluvial aquifer before moving into the Servilleta and Santa Fe Formation aquifers via faults. The majority of production wells in the study area are less than 250 ft deep and are completed in the alluvium; therefore, any new monitoring wells are recommended to be completed in the alluvial aquifer. Because of the high density of domestic and non-domestic wells in the region, baseline monitoring will be difficult. Figure 11-5 shows proposed monitoring locations. Estimated costs to install these wells can be found in Table 11-2.

Table 11-2. Cost estimates for recommended monitoring wells for the Taos area.

Well Location	Depth (ft)	Screen Length (ft)	Artesian	Cost Estimates	
				Low	High
1	200	50	No	$98,000	$116,000
2	350	50	No	$107,000	$125,000
3	300	50	No	$79,000	$97,000
TOTAL				$284,000	$338,000

The following locations, in order of priority, were identified for monitoring wells.

Location 1. High-use alluvial aquifer. This site is in an area of dense wells and near wetlands on Taos Pueblo. This well can be used to monitor the shallow aquifer that feeds springs and wetlands in the area. Most of the domestic wells drilled in the last 10 years in this area are between 160 and 220 ft deep, with depth to water averaging around 100 ft. A dedicated monitoring well in this area should be drilled to at least 200 ft.

Location 2. High-use alluvial aquifer. This area is located in the northeastern portion of the project region where there is a fairly high density of domestic wells, as well as water supply wells for several mutual domestic water systems. Studies in the area have shown that water in shallow wells (<300 ft) near the foothills of the northwestern portion of the study area is relatively young and responds to drought (Rawling, 2005). Well depths in the area mostly range from 150 to 350 ft, with some being shallower or deeper. Recommended well depth is 350 ft.

Location 3. High-use alluvial aquifer. This area is near Ranchos de Taos where there is a high density of domestic wells, as well as supply wells for the town of Taos and several mutual domestic water systems. Depths of wells in this area range between 25 and 960 ft, likely due to wells being completed in formations other than the alluvial aquifer. Typically, domestic wells are drilled until sufficient water is encountered (sometimes the first water). Most of the shallow wells in this region are between 100 and 400 ft, so a dedicated monitoring well in this area should be drilled to 300 ft.

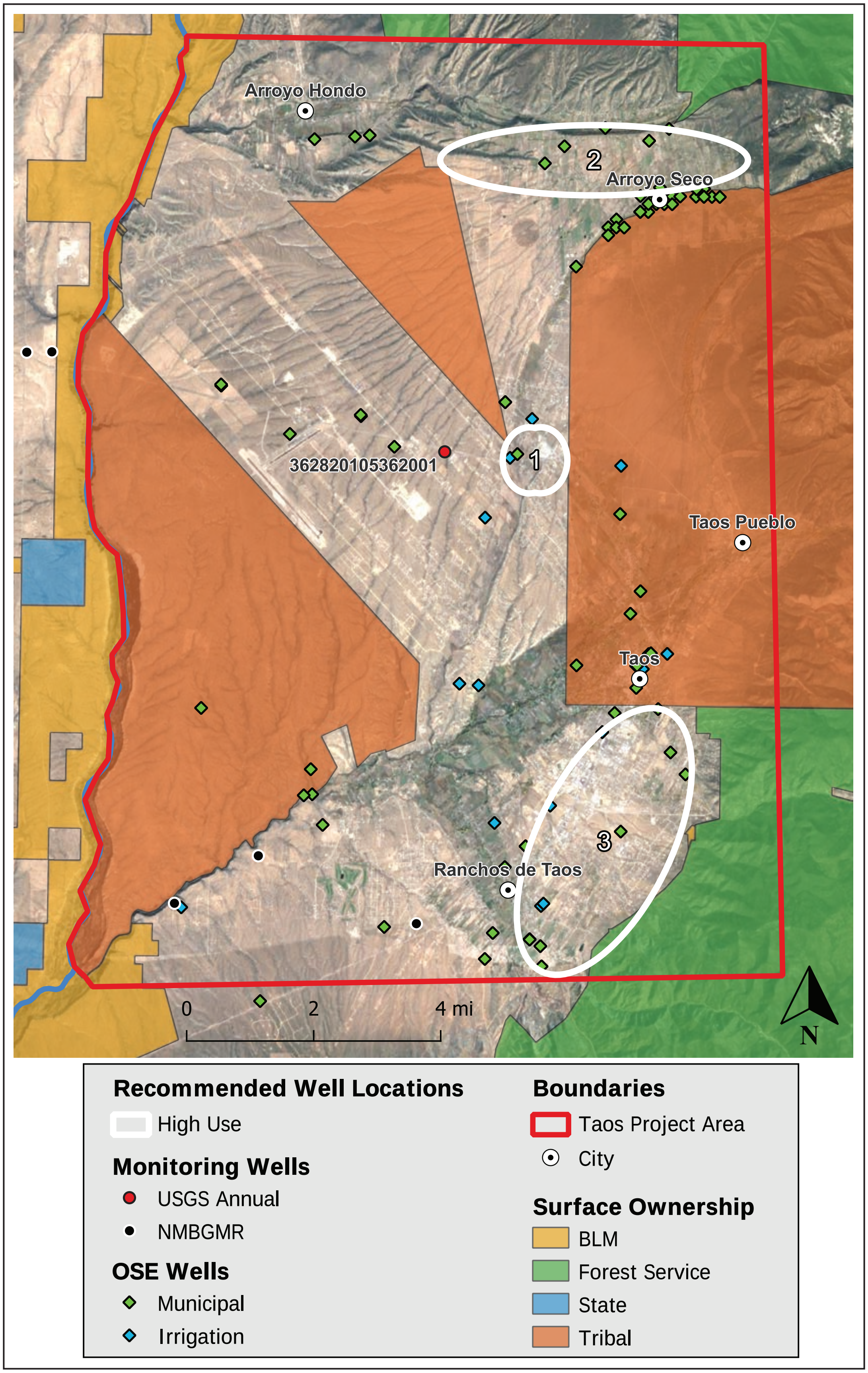


Figure 11-5. Recommended monitoring well locations and land surface ownership for the Taos project area.

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Monitoring groundwater levels in wells is a collaborative effort, requiring regular communication and frequent site visits.

CHAPTER 12. SUMMARY AND NEXT STEPS

Robert Pine

The 10 regions reviewed in this report were selected due to concerns of insufficient groundwater monitoring and indications that groundwater levels have been or may soon be declining. Each of these regions differs with respect to its dependence on groundwater for municipal, irrigation, or commercial use, but all the regions have a significant dependence on groundwater. Continued decline of groundwater levels in these regions poses a significant concern for their long-term water supply because alternative sources are less productive, lower quality, distant and very costly to develop, or, in some cases, effectively non-existent. It is of the utmost importance that there be reliable, long-term monitoring of these aquifers, which can then be used to inform the management of our water resources to maintain their long-term productivity.

The approach taken here to review the groundwater monitoring needs and propose dedicated wells for specific regions is strongly recommended on a statewide basis, with the ultimate goal of a statewide groundwater monitoring network. However, it should be noted that such a network is not intended to replace current groundwater monitoring but rather to enhance any existing monitoring regime. The recommended network is purposely designed yet necessarily sparse. It is not only desirable to have continued annual measurements in additional wells, but to also periodically have a more spatially dense monitoring event that will not only give a more refined picture of groundwater levels but will also enable a more accurate estimation of groundwater movement.

Funding for installation and long-term maintenance of the proposed wells does not exist at the time this report was completed. Funding also does not yet exist to continue this work in other parts of the state. Funding options for well installation and continuation of this project include state funding (recurring or one-time), federal funding such as through the WaterSMART program (which requires matching funds), local governments concerned about their long-term water supply, or philanthropic non-governmental organizations. Funding would also be needed on an annual basis for well maintenance.

If funding to install wells becomes available, there would likely need to be a prioritization of the work. Recommended wells within each region were prioritized, but if funding is not specific to a particular region, another approach to prioritize wells would be necessary. One possible approach is to prioritize the regions themselves. Table 12-1 is a suggested point system that considers the amount of active groundwater monitoring, existence of community water systems, potential for alternative supply, amount of non-domestic use, conflict between uses, declining water levels, population, and amount of public land available. A more detailed description of this point system is found in Appendix 1.

This point system was applied to the 10 regions, and the resulting priority ranking is given in Table 12-2. Although there are many ways to select the first wells to install, it is suggested that they be selected from the highest-priority wells in the highest-priority regions. There are cost savings to be had by installing multiple wells in the same region at the same time to minimize driller mobilization costs, so this should also be considered when choosing wells for installation.

Should funding become available to extend this work into other areas of the state, a new selection process would take place similar to the one used to choose the 10 regions of this report. A review of active monitoring, production, and past water-level trends in remaining basins would take place to identify candidate regions for further analysis and monitoring recommendations.

It is also important at this step to further review local or regional groundwater monitoring networks, which may have data that are not readily accessible. These can possibly help to further refine priority regions and bring data to light that are otherwise inaccessible. It would also be useful to confer with groundwater modelers who are or have been involved with constructing, calibrating, or updating models in the project regions of interest to see if they believe groundwater-level data in particular locations would enhance modeling efforts.

Table 12-1. Region priority ranking point system.

Criteria	Point Category	Points
Active monitoring wells	Few to none	5
	Moderate amount	3
	Many	0
Community water systems utilizing groundwater	3 or more GW systems in project area	5
	1–2 GW systems in project area	3
	No GW systems in project area	0
Non-domestic use	High	5
	Moderate	3
	Low	0
Conflict between domestic and non-domestic use	Conflicts exist	5
	Potential for conflicts	2
	No conflicts or potential	0
Alternative sources	No reasonable alternative source	5
	Deeper aquifer or distant source	3
Groundwater levels	Declining levels widespread	8
	Declining levels in some areas	5
	Unknown	3
	Levels not declining	0
Population	High (>10,000)	3
	Moderate (2,000–10,000)	1
	Low (<2,000)	0
Public land availability	Large amount of public land	2
	Small amount of public land	1
	No public land	0

Table 12-2. Region priority ranking based on the point system in Table 12-1.

Region	Active monitoring	Community water systems utilizing groundwater	Non-domestic use	**Conflict**	Alternative sources	Groundwater levels	Population	Public land	Point total	Rank
Estancia Basin	3	5	5	5	5	8	1	1	33	1
Roswell Area	3	5	5	5	5	5	2	1	31	2
Southern Lea County	5	3	5	5	3	5	1	3	30	3
LRG (southern Jornada)	5	5	3	0	3	8	2	3	29	4
Nutt-Hockett Basin	5	3	5	2	5	5	0	3	28	5
East-Central Clayton Basin	3	3	5	3	3	5	1	3	26	6
Bluewater Basin	3	5	3	2	3	5	1	3	25	7
Mimbres Basin	5	3	3	2	3	5	2	1	24	8
Animas Basin	5	0	5	0	5	5	0	3	23	9
Taos Area	5	5	0	0	3	5	2	0	20	10

APPENDIX I.
REGION PRIORITY RANKING POINT SYSTEM

The region priority ranking point system listed in Table 12-1 is a suggested approach to prioritizing the project regions detailed in this report in order to facilitate the allocation of limited funding for monitoring well installation. Other approaches to prioritization are possible and should be explored in the event that funding is obtained. The following is a more detailed explanation of the suggested ranking system. In general, more points assigned to a category reflects the relative importance of that category.

Active monitoring wells: The fewer the number of active monitoring wells in a region, the greater the number of points. This category should also consider well placement relative to the monitoring goals for the region. The points assigned in this category cannot be based on the absolute number of wells since that is relative to the size of the region. Therefore, the number of points assigned is somewhat subjective. A possible alternative metric is monitoring well density (number of active monitoring wells/size of region), but this would not take into account well placement.

Community water systems utilizing groundwater: Although current water law in New Mexico does not prioritize beneficial uses, there should be heightened concern when an aquifer that serves the domestic needs of a non-transient population is at risk. One measure of this is the existence of community water systems as defined by the Safe Drinking Water Act (i.e., a public water system that supplies water to the same population year-round). The division of points based on the number of systems is somewhat arbitrary and can be modified.

Non-domestic use: This category covers irrigation, commercial, and industrial beneficial uses. As with the active monitoring well category, this is relative to the size of the region and so cannot be based solely on the total amount of permitted and declared water rights.

Conflict between domestic and non-domestic use: This category is meant to capture whether groundwater use for community water systems and by domestic wells is possibly threatened by non-domestic groundwater production, either based on the amount of non-domestic production or proximity of non-domestic wells to wells for domestic purposes. A good example of this is in southern Lea County where commercial wells have recently been permitted close to the water supply wells of Jal as described in Chapter 10.

Alternative sources: This category reflects the possibility of locating and developing alternative water sources should the dominant groundwater source(s) become unproductive due to overuse. This report does not include an evaluation of potential alternative sources, but the assignment of points in this category is based on the current knowledge of aquifers and surface water sources in and around the project regions. For example, the Estancia Basin was given 5 points, i.e., no reasonable alternative source, because there is no perennial surface water in the basin and no possibility of appropriating and transporting surface water from the Rio Grande, and the deeper aquifers in the basin are already tapped into and appear to be declining in many areas. On the other hand, the Bluewater Basin received 3 points (deeper aquifer or distant source) because there are deeper aquifers in many areas that are not currently producing significant amounts of water (though in any particular area, the amount of potential production and water quality may not be well understood).

Groundwater levels: This category reflects the extent of groundwater-level declines occurring in the project region. The most potential points are assigned to this category because declining water levels reflect the greatest need for water-level monitoring of all the categories. The ability to assign points depends on having a sufficient amount of time-series data available. Average rate of decline is not specified, though the rate should be considered relative to saturated thickness or height of the water column above a confining layer (if known).

Population: This category is an estimate of the number of people living in the project region and thus the number of people who would be impacted by the loss of a critical groundwater source. It may appear somewhat redundant to the number of community water systems, but many of these systems are small and so the number of systems does not reflect the population served.

Public land availability: As described in Chapter 1, public land is desirable for siting monitoring wells because there is less likelihood of having conflicts with landowners that may shorten the usable life of a monitoring well. The points given are somewhat subjective because the amount of public land is relative to the size of the project region and to distribution of the public land in relation to desired well locations.

Disclaimer:
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