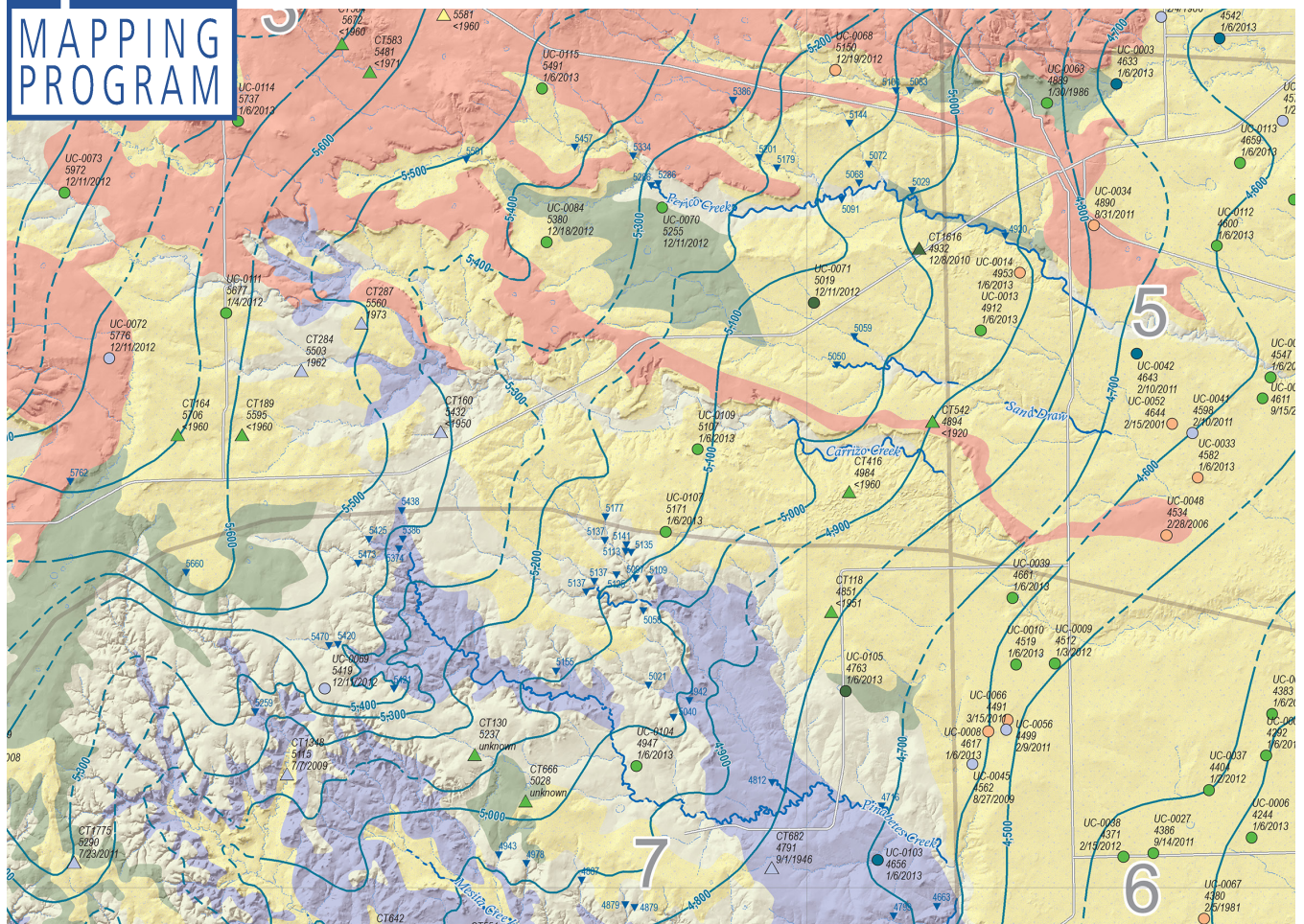


Groundwater Surface Map of Union County and the Clayton Underground Water Basin, northeast New Mexico

Geoffrey C. Rawling

AQUIFER
MAPPING
PROGRAM

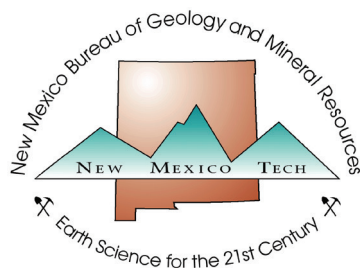
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The views and conclusions are those of the authors,
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1. Generalized geology and groundwater surface of Union County and the Clayton underground water basin, northeast New Mexico
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I. INTRODUCTION

Union County, the northeasternmost county in New Mexico, is rural with an economy based on ranching and agriculture. Surface water resources are limited, thus development of groundwater for stock watering and irrigation is important and extensive. Groundwater studies by the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) in Union County have been conducted in concert with the Northeast Soil and Water Conservation District (NESWCD) and were driven by concerns over recent large groundwater appropriations, the reliability of the groundwater supply for the town of Clayton, and declining water levels that have been observed in many wells over the past few years.

The New Mexico Office of the State Engineer (NMOSE) declared the Clayton Underground Water Basin in 2005, ending unrestricted appropriation and development of groundwater in northeast New Mexico. Recently, the NMOSE has started development of a groundwater flow model of the Clayton Basin for administration of water rights. Important input data for a groundwater flow model include accurate delineation of the groundwater surface and an understanding of water level changes over time.

A previous study (Rawling 2013 and 2014) focused on the Seneca, Clayton, and Sedan 15-minute quadrangles in the east-central portion of the county, an area of about 650 square miles. It included revisions to the geologic map of Baldwin and Muehlberger (1959), a groundwater surface map, subsurface structure contour, isopach, and saturated thickness maps for the Ogallala and Dakota Formations, and analysis and interpretation of new and historical water chemistry data. These data facilitated characterization of the aquifer system and allowed inferences to be drawn regarding groundwater flowpaths and residence time, and locations and timing of groundwater recharge.

The goal of the present study was to create a groundwater surface elevation map (Plates 1 and 2) of the NMOSE administrative Clayton Underground Water Basin and Union County representing conditions during the winter of 2012–2013 (November 2012 - March 2013). During the winter groundwater

pumping for irrigation is at a minimum, and measured groundwater levels are more likely to represent natural flow conditions. The map is based on new and historical water levels, spring locations, and perennial stream reaches. Formations of completion for the wells were identified to determine the geologic units from which water is produced (the aquifers), and the extent of these aquifers across the county. The county was divided into regions based on geology and topography, and representative hydrographs from wells with long periods of record were identified for each region. This allows characterization of patterns of water level change across the county from the early 1960's to the present.

II. DATA SOURCES AND COMPILATION

Water Levels in Wells

New and historical water level elevations from several data sources were used in the construction of the contours in Plates 1 and 2. The NMOSE provided a list of wells recommended for measurement (Alan Cuddy, personal communication 2012). Water levels were measured in 35 of these wells in December 2012 by the NMBGMR. The measured wells were chosen for even coverage across the county. Most of the wells on the NMOSE list had been previously measured at least once by the US Geological Survey (USGS) and are recorded in the USGS National Water Information System database (NWIS, <http://water-data.usgs.gov/nwis>).

Water levels were measured in an additional 46 wells by the NESWCD in January and March 2013. The wells measured by the NESWCD comprise a network that is measured twice yearly, once in the winter when there is no groundwater pumping for irrigation, and once in the late summer when irrigation pumping has been occurring for several months. All of these wells are in the NWIS database. Water levels measured by the USGS in five additional wells in March 2013 were also plotted.

The NWIS database was searched for additional wells in areas with little data. Forty-three historical water level measurements from 1981 to August 2012 were plotted in these areas. If possible, measurements made during the winter or early spring were chosen.

Lastly, the NMOSE NMWRRS (New Mexico Water Rights Reporting System) database was searched for wells located in areas with sparse data coverage from the NMBGMR, NESWCD, and USGS NWIS datasets. Ninety-three wells with drillers logs in these areas were located and the reported static water levels plotted. Some of these reported water levels date back to at least 1906. These data are less accurate than the measurements made by the NMBGMR, NESWCD, and USGS. Water levels are reported to only 1 foot at best, and often only to ± 10 feet, and locational accuracy is often limited to a quarter-section area (160 acres or $\frac{1}{4}$ mi²). These data are considered supplemental to data from the other three well data sources.

Springs

Spring locations were digitized from USGS 1:24000 scale topographic quadrangle maps. Although many of these springs may not have been flowing during the winter of 2012–2013, it was presumed that in such cases, ground water was still within a few 10s of feet of the ground surface. Given the 100 foot contour interval used for contouring, the spring locations were considered to be reasonable constraints on the position of the groundwater surface.

Perennial Stream Reaches

Perennial stream reaches, those in which baseflow is maintained by groundwater discharge to the stream bed, were identified within the study area using the USGS National Hydrography Dataset (NHD) for New Mexico (<http://nhd.usgs.gov/>). Similar to the spring locations, most of these stream reaches were not flowing during the time period represented by the map (winter of 2012-2013). However, it is likely that the groundwater surface was still within a few 10s of feet of the streambed, thus providing a useful constraint on the groundwater surface position. Add text describing NHD data if I get email reply

III. METHODS

Water Level Measurements

The NMBGMR, NESWCD, and USGS collected well water level measurements using a steel tape. From a specific measuring point on each well, depth to water measurements were made and repeated until a precision of 0.02 feet was obtained. Well locations were recorded with a handheld GPS unit and are considered accurate to within a few meters (less than 10 feet). Wellhead elevations were extracted from a 10m digital elevation model (DEM) of the study area using the well location determined with the GPS unit. Elevations are accurate to the resolution of the topographic maps used to produce the DEM, which vary across the study area. Wellhead elevations and thus water level elevations are considered accurate to ± 10 feet. For static water levels reported on drillers logs from the NMOSE, the measurement method is unknown.

Water Level Contours

Initial water level contours with 100-foot intervals were drawn based on water level data collected in the winter of 2012 - 2013, spring locations, and perennial stream reaches. Intersections of the perennial stream reaches with topography at 100-foot contour intervals were calculated and plotted as points to guide contouring. No attempt was made to discriminate regional aquifers from localized or perched systems. Areas where perched aquifers may be present or groundwater levels vary greatly with well depth are discussed below. The contours were progressively refined with the older, historical well water level datasets.

Additional refinement of the water level contours was accomplished by subtracting a interpolated raster surface defined by the preliminary groundwater contours from the land surface defined by a 10-m resolution digital elevation model (DEM). Areas where the contoured groundwater surface projected above the land surface were highlighted. In areas with mapped springs or perennial streams it is reasonable for the regional groundwater surface to project above ground level – the discharging groundwater is manifested as

these features. In these areas the groundwater surface was modified slightly or not at all. Elsewhere, the groundwater contours were revised in an iterative fashion such that the ground water surface did not project above the ground level.

Trauger and Kelley (1987) examined water resources of the Capulin topographic basin, in the northwestern part of the present study area, and presented a water table map based on water level measurements in 126 wells. It is not certain that any of the wells used for the present study are identical to those measured by Trauger and Kelley (1987). Comparison of water levels from wells in the present study that are near to wells measured by Trauger and Kelley (1987) in 1975 suggests that water levels west and southwest of Capulin have changed little from 1975 to the winter of 2012–2013. The contours of Trauger and Kelley (1987) around Capulin are based on many more measurement locations than were available during the present study (126 vs 12) and were thus used as a guideline in contouring the present data in the Capulin region.

The confidence of the water level contours was characterized as “certain” or “approximate” based on proximity to well-constrained data points (wells and springs) and lines (perennial stream segments). Distance fields to all data sources across the study area were calculated independently and split into four classes each. The lowest distance class for each data type (i.e., the regions closest to a data point or line) were combined and water level contours within these regions were identified as “accurate,” and those in other regions as “approximate.”

Identification of Formation of Completion

Identification of the rock unit supplying water to a given well - the formation of completion - was accomplished by: 1) comparison of well depth with mapped structure contours; 2) interpretation of lithologic descriptions from well logs; 3) unit identification from the NWIS database; and 4) comparison with surficial geology. Wherever possible, the identification was cross-checked using multiple methods.

Structure contours on the base of the Dakota Formation across Union County were digitized from Baldwin and Muehlberger (1959; figure 14). Contours from Rawling (2013) were used within the area of that study. Some of the contours from Rawling (2013) were modified based on more recently available well data. Within Colfax County, structure contours on the top of the Dakota Formation from Griggs (1948) were converted to contours on the base of the Dakota by assuming a constant 200 foot thickness for the formation in the area. The Dakota top contours in this area are poorly constrained by data, and the assumption of constant thickness also introduces error; the derived base contours are likely only accurate to ± 100 feet. An interpolated raster surface of the top of the Dakota Formation was created from the structure contours across the study area.

Structure contours of the “buried bedrock surface” of Baldwin and Muehlberger (1959; figure 12) were digitized. This surface represents the base of the Ogallala Formation, Tertiary and Quaternary volcanic rocks, and post-Ogallala age alluvial and aeolian deposits, the latter being generally unconsolidated. Most of the volcanic rocks probably overlie some thickness of Ogallala Formation. An interpolated raster surface of the base of the Ogallala Formation and younger volcanic rocks and upland deposits was created from the structure contours.

There is little data available on the screened interval in wells, so total depth was used to identify the formation of completion. For each well, the elevation at total depth was calculated from the reported depth and the DEM elevation at the wellhead location. The total depth elevation was compared to the elevation of the base of the Dakota Formation and the elevation of the “buried bedrock surface” at the well site to determine formation of completion. Formation identifications were then cross checked with log data where available, formations listed in the NWIS database, and surficial geology. Identifications below the Dakota Formation are necessarily more uncertain, although in the rugged terrain in the northern half of the study area reasonable assumptions can be made based on the nearest outcrop occurrence of rocks at the same elevation as the total depth of the well.

identified. A long-period hydrograph was defined as consisting of water-level measurements from the winter of 2012–2013, or within two to three years of that time, to the early 1980s or earlier. Sixty-three wells had enough water-level measurements to constitute a long-period hydrograph.

The study area was divided into regions based on geology and topography (described below), and long-period hydrographs in each region were examined for water-level trends. Representative hydrographs were chosen as those with the most data points and which best exemplified general water-level trends, if any, seen in all hydrographs in the region.

Representative Hydrographs

Representative hydrographs from wells across the study area with long periods of record were

IV. GEOLOGY OF THE STUDY AREA

The study area consists of flat-lying or shallowly east-dipping Triassic, Jurassic, and Cretaceous sedimentary rocks. These are overlain over much of the region by the Tertiary Ogallala Formation and Tertiary and Quaternary volcanic rocks (largely basalt flows) and volcanoes composed of basalt flows and cinders. The geology shown on Plate 2 has been simplified from the Geologic Map of New Mexico (New Mexico Bureau of Geology and Mineral Resources, 2003) and the stratigraphy was reclassified to emphasize features of hydrologic significance where possible. For detailed descriptions of the regional stratigraphy, see Lucas et al. (1987), Mankin (1972), Kues and Lucas (1987) and Pazzaglia and Hawley (2004). The reclassified geology is described below.

Quaternary landslide deposits: These are only present in abundance along the flanks of Johnson Mesa and along mesas in the upper reaches of the Dry Cimarron River Canyon. The deposits are composed of a poorly sorted mix of sand, silt and clay, with abundant cobbles and boulders of sandstone and basalt.

Quaternary alluvium and aeolian deposits, and Tertiary Ogallala Formation: These units are the most widespread rocks south of the Dry Cimarron valley. The Ogallala Formation is a vertically and laterally complex rock unit composed of conglomerate, sandstone, and siltstone. Coarser grained materials are generally present in paleo-channels scoured into the underlying bedrock, while finer-grained sediments are present on paleo-upland surfaces (Gustavson and Winkler, 1988). A thick, indurated calcic soil horizon (the “caprock” or “caliche”) is present at the top of the formation. The Ogallala is usually covered with a mantle of unlithified aeolian sand occurring in sheets and small dunes. Drainages are floored with unlithified sandy alluvium.

Quaternary and Tertiary volcanic rocks: Coeval and younger than the Ogallala Formation are the basalt flows and volcanoes that form much of the dramatic skyline of northeast New Mexico. The widespread flows are abundantly fractured and often

covered with a mantle of windblown silt. The shield volcanos (e.g., Sierra Grande) and cones (e.g., Rabbit Ears Mountain) are composed of mixed basalt flows and loosely consolidated volcanic tephra.

Cretaceous shale and minor limestone: This unit includes all shale-dominated Cretaceous rocks above the Dakota Formation, and subordinate limestone beds. Included are the Graneros Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, and Pierre Shale. Exposures of these rocks are scattered across the northern two-thirds of the study area.

Cretaceous sandstone: Almost as widespread as the volcanic rocks are exposures of Cretaceous sandstones, mostly the Dakota Formation with minor exposures of the Vermejo and Trinidad Sandstones around Johnson Mesa. The latter two units are stratigraphically above the shales described previously. Included in this map unit are small exposures of undivided Cretaceous rocks, which are assumed to be largely the Dakota Formation. The Dakota Formation contains minor shaley beds and coal but is dominated by sandstone beds. Cretaceous rocks below the Dakota Formation are mixed sandstone and shale of the Glencairn Formation and Lytle Sandstone (together equivalent to the Puragatoire formation, Kues and Lucas, 1987) and are included in this map unit.

Jurassic sandstone, shale, and mudstone: This unit consists of the Morrison and Entrada Formations. The Morrison is composed of mudstone and shale with locally abundant sandstone beds, whereas the underlying Entrada is a widespread clean aeolian sandstone that forms a prominent cliff in the Dry Cimarron Valley. Both units appear to be present throughout the study area, with exposures abundant in the Dry Cimarron valley and the upper reaches of Tramperos Creek.

Triassic shale and sandstone: Exposures of sandstone and shale of the Chinle group are abundant along the floor of the Dry Cimarron valley. There is an isolated exposure of Chinle in the southeast panhandle of the county.

V. REGIONS

To facilitate the discussion, the study area was divided into regions based on geology and topography as follows (Plates 1 and 2):

Region 1. Capulin Basin and Northwest

This comprises the high elevations of Johnson Mesa in the northwest corner of the study area and the volcanic edifices around Capulin. The geology is dominated by basalt flows and tephra overlying upper Cretaceous shales and sandstones which rest on the Dakota Formation. The volcanic terrain in the south and southwest of this region has poor drainage development compared to the steep drainages on the north side of Johnson Mesa and the headwaters of the Dry Cimarron River. Inventoried wells are completed in the Ogallala formation and/or upland deposits and basalt, Cretaceous shales above the Dakota Formation, the Dakota Formation, and Jurassic rocks below the Dakota (probably the Morrison Formation) and range from 37 to 680 feet deep with an average of 198 feet.

Region 2. Dry Cimarron River Drainage.

The Dry Cimarron valley and its steep-walled tributary canyons form the rugged topography along the northern border of Union County. The valley is floored with Triassic rocks, while the adjacent canyon walls and uplands are composed of Cretaceous Dakota Formation overlying the Jurassic Morrison Formation and Entrada Sandstone. Wells along the valley floor are completed in Triassic rocks, while those in tributary drainages and adjacent uplands are completed in Jurassic rocks and the Dakota Formation. Inventoried wells range in depth from 40 to 250 feet with an average of 119 feet.

Region 3. Central Uplands

The central uplands comprise the largest portion of the study area. The area is largely undissected by drainages other than the upper reaches of Corrupa Creek in the northeast. Small playa lake basins, usually dry, are common features on the landscape. Basalt flows, Ogallala Formation, and Dakota Formation comprise the exposed geology, with an area of Jurassic rocks exposed in the headwaters

of Corrupa Creek. Most wells are completed in the Dakota Formation, and probably underlying Cretaceous rocks (the Purgatorie Formation), with a few wells each in the Jurassic Morrison Formation and Ogallala Formation. Inventoried wells range from 32 to 595 feet deep with an average of 173 feet.

Regions 4, 5, and 6. East-Central Irrigated Regions

These regions comprise the east-central portion of the county that was addressed in detail by Rawling (2013) and includes most of the irrigated acreage in the county and the highest density of wells. Almost the entire area is covered by Ogallala Formation, which locally is quite thick and forms the westernmost extent of the High Plains aquifer system, which is largely within the Ogallala Formation (Gutentag et al., 1984). Several east-west trending drainages cross the area and locally have eroded through the Ogallala Formation to expose the Mesozoic rocks beneath. Basalt flows are present north and south of Clayton, and the Dakota Formation and Jurassic rocks are exposed along Tramperos Creek in the southwest. Inventoried wells are completed in the Ogallala Formation, the Dakota Formation, the Morrison Formation and the Entrada Sandstone and range from 40 to 510 feet deep with an average of 263 feet.

Region 7. South Central – Tramperos Creek Drainage

This is an area of small canyons and arroyos with extensive exposures of Jurassic rocks of the Morrison and Entrada Formations. Wells are completed in the Dakota Formation and underlying Jurassic rocks and range from 23 to 497 feet deep, with an average of 191 feet.

Region 8. Southeast Panhandle

This is the southeast panhandle of Union County. Much of the area is an undissected upland, whereas the exposed geology is almost entirely Ogallala Formation and upland deposits. Wells are completed in the Ogallala Formation and Jurassic rocks; the Dakota Formation appears to be absent here. Inventoried wells range from 32 to 300 feet deep with an average of 168 feet.

VI. HYDROGEOLOGY

The contoured water level surface representing conditions in winter 2012-2013 is shown in Plates 1 and 2. No attempt was made to differentiate perched from regional aquifers during contouring.

Hydraulic head variations and anomalous water levels

Smooth groundwater elevation contours could be drawn across the study area using data from wells (without regard to depth), springs, and topography, consistent with the hydrologic data being derived from a continuous, interconnected aquifer system. However, in some areas there are indications of head variations and/or discontinuities of water levels in wells of varied depths. These may be due to the presence of confining beds and/or vertical head gradients, or merely poor quality data.

Rawling (2013, 2014) described variations of water level with well depth, perched zones, and evidence for deep, confined zones in the East-Central Irrigated Regions (regions 4, 5, and 6). An abundance of deep irrigation wells in addition to shallow stock and household wells, and an overall greater density of wells, in the East-Central Irrigated Regions makes delineation of such complexities in the aquifer system possible there. Variations of hydraulic head with depth and zones of possible perched water outside East-Central Irrigated Regions are described here. The general lack of data on screened intervals, differences in dates of measurement, and variable quality of data from drillers logs must be considered in the following discussion. The wells discussed below are indicated on Plate 1.

Well CT574 at Capulin National Monument is 680 feet deep and had a static water level of 643 feet below ground surface (bgs) when drilled in 1962. Nearby wells range from 283 to less than 100 feet deep and have water levels that are hundreds of feet shallower. The 1962 water level in well CT574 is 250 feet below the local mapped groundwater surface.

Well CT1682 with a total depth of 420 feet is south of Sierra Grande in an area of sparse data. The reported water level in 2011 was 342 feet bgs

or 6,240 feet in elevation. Strong deflections in the regional groundwater contours would be required to accommodate this water level. It seems likely that this well taps a different water-bearing zone in Jurassic rocks. Wells to the north and south tap water-bearing zones in overlying formations.

Well CT355 is northeast of Folsom with a reported water level in 1987 of 190 feet bgs, or a water level elevation of ~6,130 feet. This is more than 100 feet below the water level surface defined by nearby wells, springs and perennial streams, suggesting it is in a water-bearing zone distinct from that tapped by nearby wells, which are shallower in depth (20 – 130 feet).

Well CT168 is in the east-central portion of the Central Uplands directly east of Mount Dora. It is 365 feet deep with a reported water level of 42 feet bgs, for a water level elevation of 5646 feet. This is several hundred feet higher than the water table surface drawn through nearby data points. The well is more than 100 feet deeper than other wells in the region, suggesting that it taps a deeper, confined water-bearing zone with relatively higher head.

Well CT583 is about 8.5 miles southwest of well CT168. It is 380 feet deep with a reported water level of 340 feet bgs at an elevation of 5,481 feet. This is about 150 feet below the groundwater surface defined in the area by several other nearby wells. It appears to be completed in a lower portion of the Dakota Formation than the nearby wells.

Groundwater surface gradients

The lowest groundwater surface gradients are found across the Central Uplands and into the East-Central Irrigated Regions, the South Central - Tramperos Creek Drainage region, and the Southeast Panhandle. Gradients range from 0.0055–0.0096 (29 to 51 feet per mile). In these areas the topography is very gently sloping and the landscape is not strongly dissected other than by shallow ephemeral drainages and arroyos. The surficial geology in low-gradient areas is varied, from basalt flows overlying the Dakota and Ogallala formations in the central part of the Central

Uplands, to exposed bedrock of Mesozoic sandstones in the east part of the South Central – Tramperos Creek drainage region, to thick occurrences of the Ogallala Formation in the southwest part of the county. Wells in these areas are completed in all of the rock units exposed at the surface, to depths ranging from a few tens to several hundred feet.

The low groundwater surface gradients cannot be attributed to one factor alone, rather a combination of low topographic gradients and laterally extensive, transmissive sandstones in the Ogallala, Dakota, and Morrison Formations. There is good lateral hydraulic connectivity where these units are juxtaposed, for example, where paleochannels filled with sand and gravel of the Ogallala Formation are eroded into Mesozoic rocks (Rawling, 2013).

The highest groundwater surface gradients range from 0.05 to 0.14 (264 to 740 feet per mile). The high gradient areas are in the steep-walled canyons along the sides of the Dry Cimarron River valley and the flanks of Johnson Mesa in the Capulin Basin and Northwest region. The rugged canyon topography is eroded in nearly flat-lying Mesozoic sedimentary rocks consisting of interbedded sandstone and shale layers, and overlying basalt flows on Johnson Mesa and Emery Peak. The close correspondence of the groundwater surface to topography in these areas, numerous springs, and the steep gradients may be due to multiple zones of perched water overlying shale and mudstone beds or paleosols between lava flows. If the geology consisted of vertically continuous high permeability rocks, such as clean sandstones or fractured basalt flows it is unlikely that such an irregular groundwater surface with steep gradients could be maintained.

Water level trends

Plate 1 shows representative hydrographs from each of the regions defined above. The earliest data in the hydrographs range from the mid-1950s to the early 1980s. The two predominant water-level trends are stable levels and declining levels. Notable, no region shows a predominant trend of rising water levels.

Water level declines are prominent in the East-Central Irrigated Regions (discussed in detail by Rawling, 2013 and 2014) and in the Southeast Panhandle. Declines range from several 10s to several hundred feet since the late 1960s. These areas have the most widespread and thickest occurrences of the Ogallala Formation and have experienced the most extensive groundwater pumping for agriculture.

Long-term water-level declines have occurred in wells completed in the Ogallala Formation, the Dakota Formation, and in Jurassic rocks.

In contrast, the Central Uplands and South Central – Tramperos Creek Drainage regions, to the west of the heavily irrigated eastern part of the county, do not show significant water level declines over the past 30 years. Irrigation for agriculture is only prevalent in the eastern portion of these regions. The majority of the land is open ranch country used for grazing and most wells are stock wells. Groundwater pumping is much less extensive than to the east and this is reflected in the water level trends.

Some wells in the central (UC-110, UC-116) and eastern (UC-40, UC-38, UC-6, UC-105) regions show biannual irrigation cycles, in which water levels drop from late spring to early fall due to groundwater pumping for irrigation (Plates 1 and 2). Winter measurements show recovery in water levels when pumping is at a minimum. However, in the eastern regions, the recovery is most cases superimposed on a long-term water level decline that is indicative of progressive dewatering of the aquifer (Rawling 2103, 2014).

In the Dry Cimarron River Drainage water level changes are a few tens of feet or less and there is no consistent indication of long-term water level declines. Many of these wells are completed in Triassic or lower Jurassic rocks, likely in water-bearing zones beneath those tapped by wells in the higher terrain to the south. There is much less agricultural development and very few households in this region; most of the wells are stock wells.

There is only one long period hydrograph available for the Capulin Basin and Northwest region. It is from a relatively shallow well (UC-119, total depth 37 ft) west of Capulin. Water levels have dropped about 12 feet since the 1950s, with the decline increasing since 2000. Well UC-119 near Capulin shows an ambiguous trend.

VII. SUMMARY

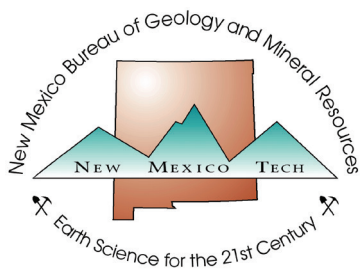
New and historical water level measurements were used to define the ground water surface in Union County and the Clayton Underground Water Basin during the winter of 2012 – 2013. Inventoried wells have water levels ranging in depth from a few tens to many hundreds of feet and are completed in rock units ranging from Triassic to Quaternary in age. Groundwater surface topography and gradients are controlled by land surface topography and geology. Very low gradients are present in areas of smooth, gently sloping topography and laterally extensive, transmissive rock units. Water level trends since the 1960s are most reflective of extensive groundwater pumping for irrigation in the eastern part of the study area. Water level declines of up to more than 100 feet have occurred there, while water levels elsewhere in the county have declined slightly or not at all. No wells with long-period hydrographs showed a consistent trend of increasing water levels.

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