ANALYSIS OF EFFECTS OF GROUND-WATER DEVELOPMENT TO MEET PROJECTED DEMANDS IN REGIONAL PLANNING DISTRICT 4

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INTRODUCTION

The Colorado River Basin Project Act of 1968, which authorized the Central Arizona Project (CAP), allows for the consumptive use of an annual average of 18,000 acre-feet of Gila River water in any period of ten consecutive years by New Mexico users, beyond the consumptive uses provided for in Article IV of the 1964 Supreme Court decree in *Arizona v. California*. Development of this supply for New Mexico would be accomplished through contract with the Secretary of Interior. Use of this water in New Mexico would be junior to any pre-existing downstream water rights and could not negatively impact those rights.

Potential uses for New Mexico’s portion of the Gila River supply include agricultural, municipal and industrial uses in Grant, Hidalgo and Luna Counties (plate 1). Presently, all existing uses in these areas, except some mining and irrigated agriculture, are supplied by ground water. Gila River surface water supplies could replace a portion of future ground-water demands. One alternative to using the Gila River water would be to attempt to meet these demands through continued pumping of ground water.

The Interstate Stream Commission (ISC) requested that Hydrology Bureau assess this alternative by evaluating existing ground-water supplies and estimating the hydrologic effects of attempting to meet selected future demands through continued ground-water pumping. The following five selected task areas were identified by ISC:

1) Evaluate the ability of existing ground water supplies to meet municipal demands for 40 years for the central Grant County area, including demands for the Town of Silver City and the communities of Tyrone, Piños Altos, Arenas Valley, Central, and Bayard.

2) Evaluate the ability of ground water supplies to meet agricultural demands for 40 years in Luna County, and municipal demands at Deming and Columbus.

3) Evaluate the ability of existing ground water supplies to meet demands for 40 years for the proposed Duke Energy power plant near Deming.

4) Evaluate the ability of existing ground water supplies to meet municipal and agricultural demands for 40 years in the Lordsburg area, and at two proposed power plants in the area.

5) Evaluate the ability of existing ground water supplies to meet agricultural demands for 40 years in the Animas Basin.

In order to evaluate existing ground water supplies in the five task areas, the hydrologic effects of ground-water pumping at existing well locations to meet projected demands were estimated. For each task area similar estimation methods were used. Calibrated numerical ground-water flow models were used in order to represent the natural hydrologic systems as accurately as possible, and to include all known regional stresses. Historical pumping was estimated and included in each model, so that effects of this pumping were incorporated in the evaluation.

Water-level declines (drawdowns) from pre-development conditions calculated by the models at 2020, 2040, and 2060 were used. For selected municipal and industrial wells, the model calculated drawdowns were adjusted to better estimate actual drawdowns that may occur in individual pumping wells. For convenience, water columns (the length of water in a well under non-pumping conditions) in existing wells were used as benchmarks against which drawdowns could be compared.

Wells in unconfined aquifers may become uneconomical to operate with about 30 percent or less remaining water column (Driscoll, 1986; p. 217). Comparison of irrigation and non-irrigation season water levels in irrigation wells in the Mimbres Basin indicates that these wells require at least 100 feet of water column to function. For this investigation, a minimum water column of 100 feet, or 30 percent of the well's initial water column, whichever was greater, was assumed necessary for the well to remain functional. Because these thresholds may not be appropriate for all the wells evaluated, results are presented so that they may be compared to other threshold values.

Estimating drawdown in a pumping well is complicated by many factors, several of which are specific to an individual well's construction and history, and cannot be rigorously evaluated in a regional assessment such as this using existing information. It is not the purpose of this report to precisely determine the life expectancy of specific wells, and conclusions presented here should be used for regional planning purposes only, and not for detailed decisions about well-specific operations.

This report is organized into five major sections according to the five task areas, and each of the major sections is internally organized in the same subsections. Estimated drawdowns and effects on water columns are presented in tables following the text, and maps (plates) of specific features in the task areas are provided at the end of the report.

SUMMARY AND CONCLUSIONS

Task 1: Central Grant County municipal demands

- A calibrated ground-water flow model of the central Grant County area (the Silver City model) was used to estimate drawdowns due to pumping at the existing well fields of Silver City, Santa Clara (Central), and Bayard to meet projected municipal demands. Pumping to meet other demands in the model area was also simulated. Drawdowns in the vicinity of pumping wells calculated by the model were adjusted to account for finite-difference discretization effects and well efficiency to estimate effects on water columns in the wells themselves.

- Two scenarios were simulated: 1) municipal demands of Silver City, Santa Clara and Bayard were considered separately, with pumping from existing well fields; and 2) municipal demands of Santa Clara and Bayard were added to those of Silver City, assuming a regional system served solely by Silver City's well fields.

- The existing wells and well fields of Silver City, Santa Clara and Bayard theoretically have the diversion capacity to meet projected demands until the year 2040, although this ignores declines in yield due to increased pumping lifts and deterioration of the wells with age.

- In scenario 1, with careful management and distribution of pumping it may be possible to meet Silver City's demands with the current well field locations until the year 2040. Drawdown by 2040 is predicted to leave water columns of less than 100 feet at the Santa Clara and Bayard well fields, which indicates these well fields cannot sustain the production necessary to meet projected demands for the entire period. Management of drawdown at either well field by pumping those wells with more available water column at higher rates, and/or deepening wells to attempt to regain production from the basin-fill aquifer is not practical. Additional wells may extend the productive life of Santa Clara's Lone Mountain well field, but this option is probably not feasible for the Bayard well field. It might be possible to attempt to produce from the underlying aquifers, but the extent and nature of these units in the area is not well known and is thought to be limited. Connection to a regional water system using other sources of supply within the next 20 years may be a more viable option for these communities.

- Under scenario 2, Silver City's well field locations cannot withstand the drawdowns estimated to occur if production were increased to meet the demands of Santa Clara and Bayard in addition to Silver City. Deepening wells at current locations would generally not be feasible, given the limited thickness of productive aquifer at the well fields, but additional wells in the basin-fill aquifer to the southeast in the Mimbres Basin could reduce drawdowns by spreading pumping laterally. New well fields in the Mimbres Basin are another option. Other sources such as the Tertiary volcanic aquifer currently tapped by the Hayes well could also possibly be exploited, although data suggest this aquifer and the basin fill are hydrologically connected.

SUMMARY AND CONCLUSIONS

Task 2: Luna County agricultural demands, and Deming and Columbus municipal demands

- A calibrated ground-water flow model of the Mimbres Basin was used to estimate drawdowns due to pumping at the existing well fields of Deming and Columbus to meet projected municipal demands for the period 2000-2060. Pumping to meet irrigation, power, commercial and industrial demands in the model area was also simulated. Drawdowns calculated by the model in the vicinity of pumping wells were adjusted to account for finite-difference discretization effects and well efficiency to estimate effects on water columns in the wells themselves. Drawdowns calculated by the model in agricultural areas were also compared to the average water column in irrigation wells in the basin to estimate the life expectancy of these wells.

- Estimated demand is projected to exceed existing capacity of the Deming Columbus well fields by the year 2015. For this investigation it was assumed that additional physical capacity would be added through time to these well fields in the same locations as existing wells to allow for sufficient diversion to meet the projected demand.

- Mimbres model simulations to 2020, 2040, and 2060 indicate that of Deming's 12 active wells, M-299-S has less than 100 feet of water column in the year 2040 and the regional water level is below that well's depth by 2060. Of Deming's 11 remaining active wells, one has less than 100 feet of remaining water column in 2060. In all, there are 10 wells with remaining water columns greater than 100 feet in 2060.

- At the end of 2020, the water level in Columbus municipal well M-584 will apparently be below the depth of the well. In the year 2040, of the two remaining wells, one may have a water column below 100 feet. By 2060, the regional water table will be below the depths of all three wells.

- Model cells with simulated irrigation wells were evaluated using the difference between the average irrigation well water column, model cell drawdown, and irrigation well pumping levels. From the resultant difference in 2020, an estimated 5 model cells near Columbus have less than the average required water columns. In 2040, an estimated 10 model cells near Columbus and 2 cells in the area of Duke Energy's supply wells have less then the required average water column for irrigation wells. By the end of 2060 about 15 model cells near Columbus, 12 in the area of Duke Energy supply wells, and 1 cell in the Deming area will have less then the required average water column for irrigation wells. This represents about 6 percent of the model cells with irrigation. Aside from local variations in saturated thickness, most irrigation wells in the Mimbres Basin should be able to be deepened to regain production.

SUMMARY AND CONCLUSIONS

Task 3: Luna Energy Facility power plant

- A calibrated ground-water flow model of the Mimbres Basin was used to estimate drawdowns due to pumping to meet projected demands at the existing wells for the proposed Luna Energy Facility in Luna County for the period 2000-2060. Simultaneous pumping to meet other demands in the model area was also simulated. Drawdowns in the vicinity of pumping wells calculated by the model were adjusted to account for finite-difference discretization effects and well efficiency to estimate effects on water columns in the wells themselves.

- By 2020, of the 20 Duke Energy wells evaluated (Red Mountain Area), 10 appear to be functional, 3 have less than 100 feet of remaining water column, and 7 are completed above the regional water level. By 2040, 8 wells appear to be functional, 4 have less than 100 feet of remaining water column, and 8 are completed above the regional water level. By 2060, 5 wells appear to be functional, 5 have less than 100 feet of remaining water column, and 10 are completed above the regional water level.

- Of the 20 Duke Energy wells evaluated, 18 are 500 feet deep or less. At this time, Duke Energy has applied to construct new replacement wells to regain production associated with the older wells and we expect that other original irrigation wells will also be replaced with more efficient well designs. Wells in the Red Mountain area could be deepened to attempt to regain production but may be limited in their total depth by local variations in the aquifer’s productivity.

SUMMARY AND CONCLUSIONS

Task 4: Lordsburg area agricultural, municipal and power demands

- A ground-water flow model of the basin-fill aquifer in the Animas and Lordsburg Basins was developed to estimate effects of pumping to meet projected demands. The model was calibrated to regional steady-state conditions, and to transient conditions for the period 1920 to 2000. The model is considered a reasonable representation of the hydrogeologic system and can be used to estimate effects of pumping to meet projected demands in these basins. Drawdowns in the vicinity of selected municipal and industrial wells calculated by the model were adjusted to account for finite-difference discretization effects and well efficiency to estimate effects on water columns in the wells themselves.

- The existing wells and well fields of Lordsburg, the Lordsburg Power Plant and the proposed Pyramid Facility theoretically have the diversion capacity to meet projected demands until the year 2040, although this ignores declines in yields expected due to increased pumping lifts and deterioration of the wells with age.

- By 2060 all the wells in the City of Lordsburg's East well field (wells LV-269 et al.) still have more than 100 feet of water column, and retain 60-70 percent of their initial water columns. The aquifer in the East well field area should be capable of meeting Lordsburg's municipal demands until 2060.

- By 2060 all but one of the wells (LV-312) in the Lordsburg Power Plant well field still have more than 100 feet of water column, retaining about 50-70 percent of their initial water columns. With management and scheduling of pumping among its existing wells the Lordsburg Power Plant should be capable of meeting its demands with the aquifer supplying these wells during the period investigated. By 2060 all of the wells in the Pyramid Facility well field still have more than 100 feet of water column, retaining about 80 percent or more of their initial water columns. With management and scheduling of pumping among its existing wells the Pyramid Facility should be capable of meeting its demands with the aquifer supplying these wells until 2060.

- The average drawdown calculated by the model in the Lordsburg Basin irrigated area in 2020 is about 60 feet. The difference between water columns and average drawdown in the irrigated area in 2020 indicates that two wells could have less than 100 feet of water column. In 2040 average drawdown in the irrigated area is about 70 feet, resulting in two wells possibly having less than 100 feet of water column. Average drawdown in the irrigated area in 2060 is about 80 feet, resulting in 10 wells possibly having less than 100 feet of water column. The estimated average pre-development saturated thickness in the Lordsburg Basin irrigated area is 360 feet, indicating that an average of about 300 feet of saturated aquifer will remain by 2040. Aside from local variations in aquifer productivity, most irrigation wells in the Lordsburg Basin affected by projected water-level declines could be deepened to regain production.

SUMMARY AND CONCLUSIONS

Task 5: Animas Basin agricultural demands

- A ground-water flow model of the basin-fill aquifer in the Animas and Lordsburg Basins was developed to estimate effects of pumping to meet projected demands. The model was calibrated to regional steady-state conditions, and to transient conditions for the period 1920 to 2000. The model is considered a reasonable representation of the hydrogeologic system and can be used to estimate effects of pumping to meet projected demands in these basins.

- The average drawdown calculated by the model in the Animas Basin irrigated area in 2020 is about 100 feet. The difference between water columns and average drawdown in the irrigated area in 2020 indicates that 17 wells could have less than 100 feet of water column. In 2040 average drawdown in the irrigated area is about 120 feet, resulting in 18 wells possibly having less than 100 feet of water column. Average drawdown in the irrigated area in 2060 is about 140 feet, resulting in 20 wells possibly having less than 100 feet of water column. Water levels in the area may be below the depths of eight wells from 2020-2060.

- The estimated average pre-development saturated thickness in the Animas Basin irrigated area is 470 feet, indicating that an average of about 350 feet of saturated aquifer will remain by 2040. Aside from local variations in aquifer productivity, most irrigation wells in the Animas Basin affected by projected water-level declines could be deepened to regain production.

Task 1: Central Grant County municipal demands

1.1 PREVIOUS INVESTIGATIONS

Several studies predicting drawdowns and expected longevity of the well fields supplying the municipal demands of the Town of Silver City, the Village of Santa Clara (formerly Central), and the City of Bayard have been conducted. For their detailed evaluation of the Silver City, Santa Clara and Bayard well fields, Koopman and others (1969; p. 25) introduced the concept of "critical pumping level". They arbitrarily defined the critical pumping level in any well as the depth at which one-half of the saturated portion of the aquifer penetrated by a well (the initial water column) remains.

Based on demand projections and operational assumptions, and using analytical methods, Koopman and others (1969) concluded that at then-current rates of withdrawal, decline of water levels to the critical level was imminent at several of Silver City's wells. Limiting production at existing well fields and developing new wells and well fields were identified as alternatives to extend useful life. Using similar methods Trauger and others (1980) revised these earlier estimates, based on additional data and the addition of new wells, and found that Silver City's wells could continue to pump for at least 20 years before pumping levels declined to the critical level. Again, it was noted that development of new wells and well fields would extend the useful life of the existing wells.

Gordon and others (1993; table 7) estimated the remaining useful life of Silver City's wells and well fields. Water-level declines at each well field were projected to continue at the observed average annual rate of decline, and it was assumed that a well field had reached the end of its useful life when the shallowest well had less than 200 feet of available water column remaining. The estimated remaining useful life of Silver City's various wells and well fields ranged from 28 to 57 years. Alternatives including expanding and developing new well fields in the Mimbres Basin were discussed.

For this investigation, drawdowns from historical pumping, and from projected pumping to meet estimated demands, calculated using a numerical model and adjusted to estimate drawdowns in the wells, were compared to initial water columns in the wells. Results are presented as feet of water column remaining, and percentage of initial water column. A minimum water column of 100 feet, or 30 percent of the well's initial water column, whichever was greater, was assumed necessary for the well to remain functional.

1.2 HYDROGEOLOGIC SETTING

The central Grant County area is divided geologically into two major structural features by a series of northwest-southeast trending faults that include the Silver City fault (plate 2). South of these faults is an asymmetrical graben called the Mangas Trench (Hanson and others, 1994). To the southwest the Mangas Trench is bounded by the Burro Mountain uplift (Big Burro Mountains). The Silver City and Piños Altos Ranges are the physiographic expression of the Piños Altos-Silver City uplift, which bounds the Mangas Trench north of the Silver City fault.

The upper and middle units of the Gila Group (Hawley and others, 2000) comprise the principal aquifer within the Mangas Trench. These consist of slightly to partly consolidated sand, gravel, silt and clay, and where saturated yield water to wells and springs. The lower unit of the Gila Group consists of partly to well-consolidated sandstone, conglomerate, and mudstone, and generally does not yield much water. Well yields in the upper Gila range from less than 10 to 1,000 gallons per minute (gpm); yields from the lower Gila are generally in the range of a few gpm. Hydraulic conductivity of the upper Gila Group ranges up to 10 feet per day (ft/d), one to four orders of magnitude greater than the lower Gila. Ground water also occurs in younger bolson-fill and alluvial deposits of major drainages. The Gila Group and younger basin-fill deposits can be considered part of the same regional flow system, and on plate 2 all of these units are grouped together as “basin fill”. In part of the Mangas Trench this basin-fill flow system is underlain by confined flow systems of unknown extent occurring in Tertiary volcanic rocks and related sediments.

Water-level contours (Trauger, 1972; fig. 3) indicate that mountain-front recharge occurs along the Big Burro Mountains and the Piños Altos Range, and elsewhere along the Continental Divide, which under pre-development conditions was a ground-water divide. The shallow ground water flows generally north and south from these recharge areas towards the lower valleys of Bear Creek and Mangas Creek, and San Vicente Arroyo. Some ground water discharges at the surface at springs such as Allan and Dorsey Springs in Bear Creek valley, and Mangas Springs in the Mangas Valley. The remaining ground water continues downgradient, ultimately discharging to the Gila River to the northwest, or as underflow to the larger Mimbres Basin to the southeast.

1.3 DEMAND PROJECTIONS

Wilson (2001) used population projections from Alcantara (1996) to estimate municipal water demands from 2000-2060 for Silver City and communities currently served by the Silver City municipal water system (Arenas Valley, Piños Altos, Rosedale, and Tyrone), and for the communities of Santa Clara (formerly Central) and Bayard. Wilson (2001; table 12) also estimated demands for commercial, industrial, mining and power uses in Grant County for this period. For this investigation, commercial and industrial demands were combined with municipal demands to evaluate pumping effects, while mining and power demands were handled separately, as discussed below. Water rights were not considered in this analysis. It was assumed that sufficient rights would be acquired as necessary to allow existing sources to supply projected demands.

1.4 CAPACITY IN RELATION TO DEMAND

1.4.1 Town of Silver City

The Town of Silver City currently derives its water supply from wells in the Franks (GSF-1014 et al.) and Woodward (M-2735 et al.) well fields, as well as the Anderson (M-2675) and Hayes (M-2903) wells, along with several other minor wells (plate 3). For the purposes of this investigation, only the major wells and well fields (Franks, Woodward, Anderson and Hayes) are considered. Information in OSE files and other published sources (Trauger, 1972; Gordon and others, 1993) used to evaluate the physical diversion capacity of these wells is summarized in tables 1-1 and 1-2.

Assuming 60 percent production time, Silver City's existing wells have a total capacity of about 6,319 acre-feet per year. This includes 1,961 acre-feet per year at the Franks wells, 2,517 acre-feet per year at the Woodward wells, 1,433 acre-feet per year at the Hayes well, and 407.7 acre-feet per year at the Anderson well. These represent the estimated physical capacities of the wells, unlimited by water rights considerations. Current rights associated with the Franks (1,017.42 acre-feet per year) and Woodward (1,572.8 acre-feet per year) well fields are less than the wells might be capable of producing. Based on a demand estimate of 5,061 acre-feet in 2060 (Wilson, 2001; table 3) and an assumed distribution of pumping among the wells, the capacity of these existing wells exceeds Silver City's 2060 demand.

1.4.2 Village of Santa Clara (formerly Central)

The Village of Santa Clara derives its primary water supply from the Lone Mountain well field (plate 2), which consists of four wells (M-3128 through M-3128-S-3) located in Section 15, Township 18 South (T18S), Range 13 West (R13W). Maximum diversion from the Lone Mountain well field was 295.51 acre-feet in 1996.

Some water is also drawn from the Twin Sisters infiltration gallery (M-3127 License 2167). From 1982 through 2000 (including a four-year period of no diversions from 1992-1995), diversions from the infiltration gallery have averaged about 29 acre-feet per year, or about 12 percent of total production by the Santa Clara system. For the purpose of this investigation only the Lone Mountain wells are considered. Information on these wells is summarized in table 1-3.

The Lone Mountain well field has a total capacity of about 600 gpm, or about 580 acre-feet per year assuming 60 percent production time. Demand is projected to reach 452 acre-feet per year in the year 2060 (Wilson, 2001; table 5). The existing Lone Mountain well field has sufficient physical capacity to divert the projected demand in the year 2060, ignoring effects of water-level declines and well deterioration on yields. Trauger and others (1980; p. 99) concluded that production from the Lone Mountain well field could continue at 200 acre-feet per year or even higher rates, and proposed two locations for wells that should be capable of supplying any additional capacity required.

1.4.3 City of Bayard

The City of Bayard derives its water supply from a well field in the Cameron Creek drainage southwest of town, in Section 14, T18S, R13W (plate 3). Information about the older, shallower wells (numbers 1-6) is incomplete and contradictory. Available information for all wells is summarized in table 1-4. Maximum diversion from the Bayard well field was about 395 acre-feet per year in 1995.

The seven deepest and/or highest yielding wells in the Bayard well field have a reported total capacity of over 630 gpm, or over 600 acre-feet per year assuming 60 percent production time. Demand is projected to reach 552 acre-feet per year in the year 2060 (Wilson, 2001; table 4). The existing Bayard well field appears to have sufficient physical capacity to divert the projected demand in the year 2060.

1.5 WELL FIELD CONDITIONS

1.5.1 Silver City

The Franks well field (GSF-1014 et al.) is located in the Mangas sub-basin about one to 2.5 miles west of the Continental Divide, and about 16 miles from the Gila River (plate 3). Production began in 1946, and for some 12 years the Franks field provided essentially all of Silver City's water. The upper Gila Group is present at land surface, and the log for well GSF-1014-S-6 indicates that this unit may be over 1,000 feet thick, although Gordon and others (1993; p. 12) reported that the upper Gila is at most 900 feet thick at Silver City's well fields. A transmissivity of 750 ft^2/d and a storage coefficient of 0.04 have been used for the aquifer in the Franks well field area in OSE analytical and calibrated numerical models (Hathaway, 1985; 1986; 1988; Johnson, 2000).

Diversions at the Silver City well fields are summarized in table 1-5. From 1946 to 2000 the Franks field has averaged almost 50 percent of total annual water production by Silver City. Since 1958, when the Woodward well field went into production, pumping at the Franks field has averaged less than 30 percent of total annual pumping. Maximum production was about 1,033 acre-feet in 2000. Depth to water at the Franks well field was initially less than 250 feet, but has declined to over 300 feet since 1946.

In response to declining water levels at the Franks well field, in the late 1950s the Woodward well field (M-2735 et al.) was put into production, across the Continental Divide and a few miles southeast of the Franks well field. The Woodward wells produce from the same aquifer as the Franks wells, and the properties of the Gila Group at the two locations are similar. The upper Gila Group is about 900 feet thick at the Woodward well field (Gordon and others, 1993). A transmissivity of 1,500 ft^2/d and a storage coefficient of 0.02, based on analyses of pumping tests by Koopman and others (1969), have been used for the Woodward well field area in calibrated OSE numerical models (Hathaway, 1986; 1988; Johnson, 2000).

Since 1958, the Woodward well field has averaged almost 60 percent of Silver City's total annual water production. Maximum production was 1,692 acre-feet in 1976. Depth to water at the Woodward well field was initially about 300 feet, but has declined at rates of 3 to 4 feet per year since pumping began.

Silver City also pumps from two other wells in the Mimbres Basin, the Hayes (M-2903) and Anderson (M-2675) wells. The Anderson well is completed in the Gila Group aquifer, which there has a transmissivity of 2,200 to 6,400 ft^2/d (Trauger and others, 1980; p. 70). A transmissivity of 2,300 ft^2/d and a storage coefficient of 0.04 have been used for the Anderson well area in calibrated OSE models (Johnson, 2000).

The Hayes well produces from an underlying aquifer in Tertiary volcanic rocks. The extent and properties of this aquifer, and its relationship to the overlying basin-fill aquifer are not well understood. Successful simulations of water-level changes in the basin-fill aquifer that have assumed the Hayes well affects the same flow system as pumping at Silver City’s other wells indicates there may be significant hydrologic connection between the two aquifers. The Hayes well is located in an area where aquifer properties the same as those at the Woodward well field have been used (Johnson, 2000).

From initial production in 1986 through 2000, the Hayes well has provided an average of over 30 percent of Silver City’s total annual water production. Maximum production from the Hayes well was about 1,404 acre-feet in 1987. The Anderson well has provided an average of about four percent of total annual production since 1977, although in recent years production from this well has been minor (table 1-5). Maximum production from the Anderson well was about 305 acre-feet in 1984.

1.5.2 Santa Clara and Bayard

Diversions at the Santa Clara and Bayard well fields are summarized in table 1-6. The four wells in the Lone Mountain well field are completed in the Gila Group aquifer. Depth to water at these wells when drilled ranged from about 45 feet to almost 170 feet below land surface. Trauger and others (1980) reported rates of decline of 0.7 and 1.0 feet per year from 1954 to 1979 at Lone Mountain wells no. 1 and 2, respectively. Water levels at a well located near the well field in Section 15, T18S, R13W declined about 28 feet from 1956 to 1983, or about 1.0 foot per year. The shallow wells in the Bayard well field are completed in the alluvium of Cameron Creek and the underlying Gila Group; the deeper wells may produce from underlying aquifers in Tertiary volcanic rocks or Paleozoic limestones. For this investigation all pumping by Santa Clara and Bayard was simulated as occurring in the Gila Group aquifer.

1.6 METHODS

The most effective means of simultaneously evaluating regional and local effects of ground-water pumping is through the use of a calibrated ground-water flow model. Several models of the area have been developed. Hanson and others (1994) developed a calibrated model of the entire Mimbres Basin, which includes the Santa Clara and Bayard well fields, along with Silver City's Woodward well field and the Anderson and Hayes wells, but the Franks well field is outside of the model area. Hargis & Montgomery (1983) modeled the San Vicente sub-basin, and Hathaway (1986) modeled the Tyrone Mine area. A model developed by the OSE Hydrology Bureau to evaluate effects of pumping at Silver City's well fields (the Silver City model; Johnson, 2000) was determined to be the best available tool for this analysis, and was used to estimate effects of future pumping to meet projected demands in the area.

1.6.1 Silver City model

The Silver City model is a finite-difference model with one layer that represents the flow system primarily in the basin-fill aquifer, with a grid of 48 rows by 50 columns and 1,413 active cells (plate 4). Model cells range in size from 0.25 square miles at Silver City's well fields to one square mile. Boundary conditions simulated include mountain-front recharge, and regional discharge to the Gila River and as underflow to the larger Mimbres Basin.

The original Silver City model was calibrated to regional steady-state conditions, and to transient conditions for the period 1946 to 1999 at Silver City's Franks, Woodward and Anderson well fields. For this investigation the transient calibration was extended by including Silver City's pumping in 2000, and adding historical withdrawals at the Santa Clara and Bayard well fields, at the Cron Ranch wells, by Phelps Dodge at the Tyrone Mine and at four wells in the Mimbres Basin, and by Chino Mines Company (CMC) at several well fields south of Hurley. The model is considered a reasonable representation of the geohydrologic system that can be used to estimate hydrologic effects of activities at the municipal well fields of Silver City, Santa Clara and Bayard. For more detail on the Silver City model refer to Johnson (2000; 2002).

1.6.2 Estimating drawdown in the well

Drawdowns are calculated at model cell nodes, based on heads that are averages for the area within the cell. Drawdowns at pumping wells located within a model cell would differ from these values. To estimate drawdowns at the wells, model drawdowns were adjusted using the following equation (Anderson and Woessner, 1992; p. 148):

$$\mathbf{s = h_{i,j} - h_w = (Q/2\pi T)\ln(r_e/r_w)}$$

where: s is the additional drawdown (feet) to be added to model calculated drawdown to estimate drawdown in the pumped well; h_w is head (feet) in the well; $h_{i,j}$ is head (feet) calculated by the model at the cell node; Q is the pumping rate of the well (cubic feet per day); T is the aquifer transmissivity in the vicinity of the well (feet squared per day); r_e is the radial distance from the cell node at which head is equal to $h_{i,j}$ (feet), or the "effective well block radius"; and r_w is the effective radius of the well (feet).

For each individual well the average pumping rates from beginning of service to 2020, 2040, and 2060 were used for Q. An effective transmissivity (T) was calculated for each well (cell) by multiplying the hydraulic conductivity assigned to the model cell by an average saturated thickness, determined by subtracting one-half the model calculated drawdown at 2020, 2040, and 2060 from the initial saturated thickness (1,000 feet at all cells). Transmissivity was not adjusted to account for partial penetration (Anderson and Woessner, 1992; p. 149).

The effective well radius (r_w) was assumed to be the radius of the borehole. If borehole radius was not available for a well, it was assumed to be 50 percent larger than the casing size. For the Santa Clara and Bayard well fields, an average casing diameter was calculated and used to estimate an average r_w for these well fields. For a grid with regular spacing $\Delta x = \Delta y = a$ in the vicinity of the pumping node, the effective well block radius (r_e) is equal to 0.208a. For irregular grid spacing $\Delta X \neq \Delta Y \neq a$ (as in the Santa Clara and Bayard areas), the effective radius (r_e) is calculated as $r_e = \sqrt{\frac{\Delta X \Delta Y}{\pi}}E$ (value of E is from table 5.1 in Anderson and Woessner, 1992; p. 150) then solved using the general equation shown above. Drawdowns were further adjusted by dividing by 0.7, assuming a well efficiency of 70 percent for all wells.

1.6.3 Model scenarios

Two model scenarios were developed for evaluating potential effects of meeting future demands in the central Grant County area. In scenario 1 the municipal demands of Silver City, Santa Clara and Bayard were considered separately, and pumping to meet these demands was simulated as occurring from the existing well fields for these communities. For model scenario 2 it was assumed that the communities of Santa Clara and Bayard would be served by a regional water system whose source would be the Silver City wells. For this scenario demands for Santa Clara and Bayard estimated by Wilson (2001; tables 4 and 5) were added to Silver City's projected demands, and pumping to meet these demands was simulated as coming entirely from existing sources (the Franks and Woodward well fields, and the Hayes and Anderson wells) for the period 2000-2060. For both scenarios the same procedure was used to distribute total pumping among the various Silver City sources, as described in the following section.

1.6.4 Simulation of projected demands

1.6.4.1 Silver City

The projected municipal demands of Silver City estimated by Wilson (2001; tables 3 and 6) were assumed for this investigation to be met entirely by pumping at the existing Franks and Woodward well fields, and at the Anderson and Hayes wells. In addition, it was assumed that commercial and industrial demands in Grant County (Wilson, 2000; table 12) would be met entirely by the Silver City municipal system, and so were added to the municipal demands for the purpose of simulating pumping.

For both scenarios, pumping was distributed among Silver City's wells and well fields based on recent pumping history. Average pumping from 1986-2000 was 21 percent from the Franks well field, 42 percent from the Woodward well field, 33 percent from the Hayes well, and four percent from the Anderson well (table 1-5). These percentages were used to distribute the total projected demand among Silver City's sources. Many different distributions of the demand among Silver City's various sources are possible, which would result in different drawdown estimates at individual wells. The distribution used concentrates pumping near the center of these sources, resulting in a reasonable "worst case" scenario with higher drawdowns at the sources.

Since 1989 in the Franks well field only wells GSF-1014-S, GSF-1014-S-4, GSF-1014-S-5, and GSF-1014-S-6 have been in service; it was assumed that these wells would continue as the diversion points for future pumping from this source. During part of the period in which only these wells have been producing (1994-2000), well GSF-1014-S produced on average about five percent, well GSF-1014-S-4 produced 15 percent, well GSF-1014-S-5 produced 10 percent, and well GSF-1014-S-6 produced 70 percent of total production. These percentages were used to distribute total Franks well field pumping.

Pumping records from 1995-2000 were used to distribute projected pumping among the Woodward wells. During that period well M-2735 produced on average 6.6 percent, well M-2735-S produced 15.9 percent, well M-2735-S-2 produced 26.1 percent, well M-2735-S-3 produced 14 percent, well M-2735-S-4 produced 19.7 percent, and well M-2735-S-5 produced 17.7 percent of total annual production from the Woodward well field. These percentages were used to distribute the total projected Woodward well field pumping among these wells.

For some time Silver City has discharged its wastewater effluent into upper San Vicente Arroyo in the Mimbres Basin southeast of town. Trauger (1972; p. 61) postulated that these discharges are providing some recharge to the basin-fill aquifer. Some of the discharged wastewater probably percolates to the water table, recharging the aquifer and affecting water levels locally. However, transient simulations of the historical period (1946-2000) using the Silver City model have shown that these discharges have not had significant hydrologic effects on water levels in the vicinity of the Silver City, Santa Clara and Bayard well fields. In order to provide a conservative analysis of effects on water levels at these well fields, these discharges were not simulated in the model.

There have also been returns from pumping at the Tyrone Mine and at the CMC tailings ponds south of Hurley. However, transient simulations using the Silver City model have shown that these discharges also have not had significant hydrologic effects on water levels at the Silver City, Santa Clara and Bayard well fields. For consistency no returns to the flow system from any pumping in the model area were simulated.

1.6.4.2 Santa Clara and Bayard

Under scenario 1 the projected municipal demands of Santa Clara and Bayard estimated by Wilson (2001; tables 4 and 5) were assumed for this investigation to be met entirely by pumping at the existing Lone Mountain and Bayard well fields, respectively. Under scenario 2 these demands were added to the Silver City demands beginning in 2001, and no pumping was simulated at the Lone Mountain and Bayard well fields from 2001-2060. All four wells in the Lone Mountain well field are located in a single model cell (row 23, column 44, or 23,44), and all pumping was simulated as coming from that cell. All of the pumping from the Bayard wells was also simulated from one model cell (21,45).

1.6.4.3 Other demands

Pumping to meet other projected demands in the area was distributed using historical trends and projected demands estimated by Wilson (2001). Only pumping for mining uses was simulated separately; projected demands for all of Grant County (Wilson, 2001; table 12) for commercial and industrial uses were assumed to be supplied by the Silver City municipal system, and were added to the total municipal demand. Demand projections for power uses in Wilson (2001) for the Chino Mines power plant (280 acre-feet per year) were not simulated, because the location of these demands is outside the model area (B. Wilson, written communication). Demands for self-supplied domestic, livestock, and reservoir evaporation were not estimated by Wilson (2001), and were not included in this analysis.

Wilson (2001; table 12) provides projected total demands for mining in Grant County from 2000 to 2060. Under this schedule total demands decrease to zero by 2035. All withdrawals in Grant County for mining uses in 1990 (Wilson, 1992) and 1995 (Wilson and Lucero, 1997) were from ground-water pumping. Ground-water withdrawals in the model area from 1990 to 2000 for mining uses have averaged about 33 percent of total ground-water withdrawals for mining in all of Grant County (table 1-7). Based on this, future pumping from all well fields in the model area for mining uses was assumed to be 35 percent of the total Grant County mining demand in Wilson (2001; table 12).

This pumping was distributed among the various well fields according to the historical distribution during the 1990 to 2000 period (table 1-8). During that period pumping at the Chino Mines well fields in the model area south of Hurley has averaged about 21 percent of total Grant County mining withdrawals, pumping at Phelps Dodge wells in the Mimbres Basin has averaged about seven percent, and pumping at the Phelps Dodge Tyrone Mine has averaged about four percent. To reach the assumed 35 percent total, percentages of Tyrone Mine and Cron Ranch pumping were increased to six percent and one percent, respectively. Pumping at the Cron Ranch wells M-2575 and M-2576 has been much less than one percent of total Grant County mining withdrawals during this period, but was about one percent of ground-water withdrawals in 1980. Because the Cron Ranch wells are close to the Santa Clara and Bayard well fields, which are the subject of this part of the investigation, use of this higher percentage was considered conservative in that it would produce greater effects on these well fields.

1.7 Results

1.7.1 Scenario 1: Separate Silver City, Santa Clara and Bayard demands

Model calculated drawdowns in the year 2040 under scenario 1 are greatest near the Woodward well field (about 220 to 245 feet); drawdowns in the Franks well field range from about 140 feet to over 220 feet in the vicinity of well GSF-1014-S-6 (plate 4). Drawdowns in 2040 near the Anderson and Hayes wells are calculated to be about 165 feet and 220 feet, respectively. Drawdown calculated by the Silver City model in 2040 at the Santa Clara and Bayard well fields is about 112 feet and 125 feet, respectively.

Estimated drawdowns in the wells based on adjusted model drawdowns are reported in tables 1-9 and 1-10 for the years 2020, 2040, and 2060 at the Franks and Woodward well fields, the Anderson and Hayes wells, and the Lone Mountain and Bayard well fields. By 2020 all the Franks wells retain more than 100 feet of water column, while by 2040 one well (GSF-1014-S) has less than 100 feet remaining, which is less than 30 percent of the initial water column in this well. The remaining producing wells in the Franks well field (wells S-4, S-5, and S-6) retain more than 200 feet of water column by 2040. By 2040 wells GSF-1014, GSF-1014-S and GSF-1014-S-3 have less than the 200 feet of available water column threshold of Gordon and others (1993).

By 2020 all of the wells in the Woodward well field retain more than 100 feet of water column. Two wells (M-2735-S and M-2735-S-2) are predicted to have less than 100 feet of water column, or less than 30 percent of their estimated initial water column, remaining by 2040. The Anderson well (M-2675) is estimated to have about 44 percent of its initial water column remaining in 2040, while the remaining water column in the Hayes well (M-2903), which under both scenarios is pumped harder than any other single well, is estimated to be less than 100 feet before 2020. It is possible that a different pumping distribution could result in scenario 1 demands to 2040 being met at the existing Silver City well locations, while maintaining greater than 100 feet of water column in these wells.

For the Lone Mountain wells, the estimated drawdown is compared to an average initial water column for all four wells of about 325 feet. The estimated drawdown at the Lone Mountain well field under scenario 1 of about 244 feet represents 75 percent of this average water column, and would reduce the available average water column in the well field to about 81 feet. It is unlikely that production sufficient to meet projected demands for the entire period could be sustained under such conditions.

Drawdown in the Bayard well field is compared to an average initial water column for all wells of about 360 feet. The estimated average drawdown at 2040 at the Bayard wells under scenario 1 of about 299 feet represents 83 percent of this average water column, and would reduce the available average water column in the well field to about 61 feet. It is unlikely that production sufficient to meet projected demands for the entire period could be sustained under such conditions.

Since the deepest Lone Mountain wells are only a little over 500 feet deep, and most of the Bayard wells are 500 feet deep or less, there is not much opportunity to manage drawdown at either well field by pumping those wells with more available water column at higher rates than the others. Because the average thickness of the productive upper Gila Group is probably not more than 600 feet in the area, deepening the wells to attempt to regain production from this aquifer would not be practical. It might be possible to attempt to produce from the underlying Tertiary volcanic or Paleozoic carbonate aquifers, but the extent and nature of these units in the area is not well known, and is thought to be limited (Trauger, 1972; Trauger and others, 1980).

1.7.2 Scenario 2: Combined Silver City, Santa Clara and Bayard demands

Model calculated drawdowns in the year 2040 under scenario 2 are greatest in the Woodward well field (about 270 to 290 feet); drawdowns in the Franks well field range from about 150 feet to over 260 feet in the vicinity of well GSF-1014-S-6 (plate 4). Drawdowns in 2040 near the Anderson and Hayes wells are calculated to be about 190 feet and 260 feet, respectively. By 2040 the additional pumping to meet Santa Clara and Bayard demands would add up to 40 feet of drawdown in the vicinity of Silver City's wells (plate 4).

As would be expected, under this scenario water levels in the vicinity of the Lone Mountain and Bayard well fields recover somewhat due to the cessation of pumping from those well fields (plate 4). Residual drawdown calculated by the Silver City model in 2040 at the Lone Mountain and Bayard well fields is a little over 40 feet, meaning that by 2040 the average water column in both well fields recovers to about 70 percent of the initial average water column.

Adjusted drawdowns at 2040 in the Franks wells under scenario 2 (tables 1-11 and 1-12) are generally less than 70 percent of the wells' initial water columns, with the exception of well GSF-1014-S. Another well (GSF-1014-S-3) is estimated to have only 31 percent of its initial water column remaining. By 2040 these wells and well GSF-1014 all have less than 200 feet of available water column (Gordon and others, 1993).

In the Woodward well field three wells (M-2735, M-2735-S and M-2735-S-2) have less than 30 percent of their estimated initial water column remaining by 2040. These three wells all have less than the minimum 200 feet of available water column proposed by Gordon and others (1993). Drawdown in one of these wells (M-2735-S) is estimated to exceed the initial water column in the well before 2040.

Under scenario 2 the Anderson well (M-2675) is estimated to have about 36 percent of its initial water column remaining in 2040, while drawdown in the Hayes well (M-2903) is estimated to exceed the initial water column in that well before 2040 (as in scenario 1). Even with a different pumping distribution, scenario 2 demands could probably not be met at the existing Silver City well field locations.

1.8 Discussion

Drawdowns estimated at the Lone Mountain (Santa Clara) and Bayard well fields indicate that the existing well field locations will not be capable of meeting the projected demands of these communities through the year 2040. Options such as deepening wells or drilling additional wells at these locations may extend the lives of these well fields, but are short term given the limited thickness and extent of the basin-fill aquifer. Deeper aquifers may be exploited but are unproven. Connection to a regional water system using other sources of supply may be a more viable option for these communities.

Presumably the Silver City system could be extended into such a regional system serving the communities of Santa Clara and Bayard. With careful management and distribution of pumping it may be possible to meet Silver City's demands alone with its existing well field locations until the year 2040. However, these areas cannot withstand the drawdowns estimated to occur if production were increased to meet the demands of Santa Clara and Bayard in addition to Silver City.

Deepening wells at current locations would not be feasible, given the limited thickness of productive aquifer remaining at Silver City's well fields. Additional wells in other locations could reduce drawdowns by spreading pumping laterally, replacing existing sources or extending their productive lives. This option is available primarily in the Mimbres Basin to the southeast of the Anderson and Hayes wells, and perhaps also northwest of the Franks well field (plates 3 and 4). New well fields in the Mimbres Basin are another option, and 53 specific potential well sites have been identified (Gordon and others, 1993; p. 37-38; table 13). Any of these options would require acquisition and transfer of water rights, a potentially time-consuming, costly and uncertain process.

The existing source areas of Santa Clara and Bayard are inadequate to meet the projected demands of these communities, and the existing source areas of Silver City will be inadequate to meet the increased demands of a regional system, requiring development of new sources. However, hydrologically feasible options for new sources exist. From a hydrologic standpoint ground-water use remains a viable option for meeting municipal demands in central Grant County through the year 2040.

TASK 2: Luna County agricultural demand, and Deming and Columbus municipal demands

2.1 PREVIOUS INVESTIGATIONS

Leedshill-Herkenhoff (1997) compiled information related to the City of Deming’s well field and water system. They estimated demands to 2040, and evaluated alternatives to meet the projected demands. They recommended the phased acquisition of 5,288 acre-feet of water rights in the Mimbres Underground Water Basin and expansion of Deming’s production capacity to make full use of acquired rights.

2.2 HYDROGEOLOGIC SETTING

Luna County lies almost entirely within the Mimbres Basin (plates 1 and 2). Detailed discussions of the hydrogeology of the Mimbres Basin can be found in Hanson and others (1994) and Hawley and others (2000). Basin-fill deposits form the principal aquifer in the basin, ranging in thickness from 0 to over 4,200 feet. Permeabilities of the basin-fill sequence overall tend to decrease with depth, and in most of the basin only the upper 1,000 feet are productive. This interval generally consists of hydrostratigraphic units of the upper and middle Gila Group, and overlying younger basin-fill deposits (Hawley and others, 2000). Most wells in the basin are completed within these units.

Recharge to the aquifer occurs by infiltration of streamflow, ground-water underflow from adjacent basins, and infiltration of springflow from bedrock units. Discharge occurs through pumping, evapotranspiration, discharge to the Mimbres River, and underflow to adjacent basins (plate 2).

2.3 DEMAND PROJECTIONS

Wilson (2001) used population projections from Alcantara (1996) to estimate municipal water demands from 2000-2060 for Deming and Columbus in Luna County. Wilson (2001; table 12) also estimated demands for commercial, industrial, mining and power uses in Luna County as a whole for this period. For this investigation, commercial and industrial demands were combined with Deming municipal demands to evaluate pumping effects, while other demands were handled separately, as discussed below. Agricultural demands were assumed to remain at 1995 levels (Wilson, 2001).

2.4 CAPACITY IN RELATION TO DEMAND

2.4.1 City of Deming

The sole source of water supply for the City of Deming is a well field with 12 active wells (M-299 et al.). Information about these wells from OSE files and databases, and from Leedshill-Herkenhoff (1997), is summarized in table 2-1. Maximum reported production from these wells was 4,347.1 acre-feet in 1996 (Leedshill-Herkenhoff, 1997; p. 30). Total capacity of these wells is about 5,900 gallons per minute, or over 5,700 acre-feet per year assuming 60 percent production time. The estimated demand is projected to exceed existing capacity of the Deming well field between 2010 and 2015, reaching 16,442 acre-feet in the year 2060 (Wilson, 2001; table 10). For this investigation it was assumed that additional physical capacity would be added through time to the Deming well field in the same locations as its existing wells to allow for sufficient diversion to meet the projected demand.

2.4.2 Village of Columbus

The Village of Columbus currently derives its water supply from three wells: the North well (M-584) and the South wells (M-1420 and M-1420-S). Information about these wells from OSE files and databases is summarized in table 2-1. The capacity reported for well M-1420-S is 350 gallons per minute; capacity of the two older wells was estimated as the maximum diversion reported in the 1990s (about 85 gpm at well M-584; and about 103 gpm at well M-1420), for a total capacity of about 538 gpm or about 520 acre-feet per year. The estimated demand is projected to exceed existing capacity of the Columbus well field after 2015, reaching 1,505 acre-feet in the year 2060 (Wilson, 2001; table 11). For this investigation it was assumed that additional physical capacity would be added through time to the Columbus well field in the same locations as its existing wells to allow for sufficient diversion to meet the projected demand.

2.4.3 Luna County irrigation

Existing well capacity in the Mimbres Basin was assumed to be sufficient to have met agricultural demands in 1995. Because projected demands are assumed to remain at 1995 levels, existing well capacity should be sufficient to meet projected demands.

2.5 WELL FIELD CONDITIONS

2.5.1 Deming

The Deming well field is located in the Deming sub-basin of the larger Mimbres Basin (plate 5). The Deming sub-basin is the location of some of the greatest drilled and estimated total thicknesses of basin fill in the Mimbres Basin (over 4,200 feet). Records of eight aquifer tests near Deming (Hanson and others, 1994; table 4) indicate a range of transmissivity of 1,500 to 16,000 ft^2/d in the area.

2.5.2 Columbus

The Columbus well field is located in the Columbus sub-basin of the larger Mimbres Basin (plate 5). Estimates of average total basin-fill thickness in the Columbus sub-basin range from 550 to 1,000 feet (Hanson and others, 1994; figure 8). Records of five aquifer tests in T28S, R8W (Hanson and others, 1994; table 4) indicate a range of transmissivity of 4,500 to 50,000 ft^2/d in the area.

2.5.3 Irrigation wells

The USGS GWSI database lists 966 irrigation wells located in the Mimbres Underground Water Basin with information for calculating water columns. The average irrigation well depth in the basin is 374 feet, and the average water column is about 258 feet. Maximum water-level declines of over 80 feet and 200 feet from 1930-1985 were calculated by model simulation of historical pumping in irrigated areas south of Deming and in the Columbus sub-basin, respectively (Hanson and others, 1994; fig. 28).

2.6 METHODS

2.6.1 Mimbres Basin model

The Mimbres Basin ground-water flow model was developed by the U. S. Geological Survey (USGS), in cooperation with the Office of the State Engineer, to simulate all active wells, basin recharge and evaporative losses to the aquifer. Hanson and others (1994) describe the geologic and hydrologic system in the basin and discuss how they were characterized in the model. The model is a one-layer model that represents the bolson-fill aquifer in the Mimbres Basin, and is gridded into 56 rows and

46 columns with 1,513 active cells (plate 6). Cell size varies from 1.3 to 15.2 square miles with the smallest size cells in the greater Deming area. The model was calibrated to steady-state conditions, and to transient conditions for the period 1930-1985. Hydraulic conductivity values assigned to zones defined by structural elements range from 0.003 to 62 feet per day. Storage coefficient values assigned to zones based on lithology range from 0.001 to 0.17.

2.6.2 Estimating drawdown in the well

Procedures similar to those described in section 1.6.2 (Estimating drawdown in the well) were used to adjust model cell nodal drawdown to estimate drawdown in pumping wells. Diversion (Q) and transmissivity (T) values for these calculations came from projected diversions per well and the pertinent model cell. Calculated diversions (Q) were selected at 2020, 2040, and 2060 time periods. Transmissivity (T) was calculated by multiplying the hydraulic conductivity assigned to the pertinent model cell by an average saturated thickness. An average saturated thickness was determined by subtracting one-half the model-calculated drawdown at 2020, 2040 and 2060 from the initial saturated thickness (1,000 feet Deming wells and 700 feet for Duke Energy and Columbus well cells). Transmissivity was not adjusted to account for partial penetration of the wells (Anderson and Woessner, 1992; p. 149). Neither borehole nor casing size was available for the Deming, Columbus, or Duke Energy wells so the average borehole radius (r_w) was assumed to be 12 inches. For a grid with regular spacing $\Delta x = \Delta y = a$ in the vicinity of the pumping node, the effective well block radius (r_e) is equal to 0.208a. For irregular grid spacing $\Delta X \neq \Delta Y \neq a$ (as in the Columbus area), the effective radius (r_e) is calculated as $r_e = \sqrt{\frac{\Delta X \Delta Y}{\pi}} E$ (value of E is from table 5.1 Anderson and Woessner, 1992; p. 150) then solved using the general equation shown in section 1.6.2. Drawdowns were adjusted by dividing by 0.7, assuming 70 percent well efficiency.

2.6.3 Simulation of historical pumping

The USGS Mimbres Basin model documented in Hanson and others (1994) used a well file with 5-year time increments (stress periods) from 1930 to 1985 to simulate active municipal, irrigation, industrial, and commercial wells, that are all represented as a single diversion rate in a cell. Water uses in the basin are represented in the USGS well file as depletion rates rather than withdrawal rates for all wells. Water uses in the extended file from 1985 to 2060 represent withdrawal rates, under the assumption that depletion rates are poorly known in this area and may be over estimated in the USGS file.

In order to extend the existing well file to 2060, the last stress period in the USGS file (1980 to 1985) was separated first into two classes (municipal and other uses), then the other uses were further separated into irrigation and commercial-industrial uses. Known average municipal uses for 1985, 1990, and 1995 (reported data from OSE Deming; Wilson, 1986; 1992; Wilson and Lucero, 1997) for Bayard, Central, Silver City, Deming, and Columbus were used to separate the municipal from the other uses and to separate the municipal into individual wells. For the remaining pumpage assigned to "other uses" the model cells were separated into Grant and Luna counties to conform to Wilson's water use categories. Each category increases with time at different rates requiring that the model cell withdrawal rates classified as "other uses" be further separated into irrigation, commercial, and industrial uses by means of known data for the 1985 to 2000 time period (Wilson, 1986; 1992; and 2001; Wilson and Lucero, 1997). Commercial and industrial data are treated as one category and will be called industrial for the remaining discussion and are assumed to occur in municipal model cells. Wilson's data were used to determine the percentage of increase in each class for 1985, 1990, and 1995. This percentage of use per category was used to increase projected withdrawals for irrigation and industrial uses through the year 1995.

2.6.4 Simulation of projected municipal, industrial and irrigation demands

After the year 1995, pumping for all irrigation and industrial uses was held constant, only projected municipal uses continued to increase production through 2060 (Wilson, 2001). Luna County power use started in 2005 and production was held constant at 3,000 acre-feet per year until 2060. Municipal production was distributed into individual cells using the percentage of an individual wells average 5-year use for the year 1995 to their percentage of the total well field production (Wilson, 2001). Projected increases in municipal withdrawals (Wilson, 2001) continue to the year 2060. Existing wells in the year 2000 were assumed to continue producing until the year 2060.

2.7 RESULTS AND DISCUSSION

To determine the drawdown effect of multiple wells in the basin on municipal and industrial wells, the model is run and the average drawdown for a selected time period is used to calculate the total drawdown in an individual well. Solution of this equation allows the determination of a well's ability to function at the end of a selected time period assuming the only factor affecting a well's production is the remaining water column. Calculation of the total drawdown in a well is solved with the analytical equation described in this report in section 1.6.2 (Estimating drawdown in the well). Solution of this equation allows the determination of a well's ability to function at the end of a selected time period. Mimbres model results for the time periods 2020, 2040, and 2060 were selected for these calculations for individual well drawdown in the communities of Deming and Columbus, and wells producing water for the Luna Energy Facility (Duke Energy) near Deming. Model calculated drawdowns at 2040 are shown in plate 6.

For the time periods ending in 2020, 2040, and 2060, the adjusted drawdown in a well is subtracted from the estimated water column (the difference between the well depth and the most recent water level, or the model average drawdown, which ever is greatest). If the remaining water column at the end of a time period is negative then it is assumed that the well is no longer functional (dry). Results are listed in table 2-2 for the years 2020, 2040, and 2060 to illustrate the possibility of wells losing production prior to the end of the utilities planning period. Wells with less than 100 feet of remaining water column may not be able to continue operating at the rate of diversion used in this simulation based on a comparison of summer and winter water-level data.

2.7.1 Deming and Columbus municipal wells

Table 2-2 summarizes estimated drawdowns and remaining water columns in the municipal wells of Deming and Columbus. Mimbres model simulations to 2020, 2040, and 2060 indicate that of Deming's 12 active wells, M-299-S has less than 100 feet of water column in the year 2040 and the regional water level is below that well's depth by 2060 (table 2-2). Of Deming's 11 remaining active wells in 2060, one has less than 100 feet of remaining water column. In all, there are 10 wells with remaining water columns greater than 100 feet in 2060 (table 2-2).

Columbus is in the southern segment of the Mimbres Basin and has three active municipal wells. At the end of 2020, the water level in well M-584 will apparently be below the depth of the well. In the year 2040, of the two remaining wells, one may have a water column below 100 feet. By 2060, the projected regional water table will be below the depths of all the wells (table 2-2).

2.7.2 Irrigation wells

Water levels in irrigation wells are assumed to be approximately equal to the model-simulated drawdowns for 365.25 days per year due to the variable nature of actual irrigation well usage. Irrigation wells are pumped for variable lengths of time during the growing season and may be idle for several years at a time if irrigated lands are allowed to go fallow causing drawdowns to be somewhat less than simulated. There are 494 model cells simulating irrigation wells and 966 wells in these cells with data to calculate water columns. From this data, the average well depth for irrigation wells in the Mimbres Basin is about 374 feet with an average water column of 258 feet.

Over the last 20 years, most irrigation wells of record in the Mimbres Basin require an average of 100 feet of production water column (USGS, GWSI database). In model cells with irrigations wells, the difference between the average water column, cell drawdown, and production water levels in 2020 is less than required in 6 cells near Columbus. By 2040, there are 10 model cells near Columbus and 2 cells in the Duke Energy supply well area near Deming with less than the required water columns. At the end of 2060, as many as 15 model cells in Columbus, 12 model cells in the Duke Energy supply area, and 1 in Deming have less than the required remaining water columns. There are about 51 wells in these model cells or about 5 percent of the wells evaluated. Aside from local variations in saturated thickness, most irrigation wells in the Mimbres Basin should be able to be deepened to regain production.

Task 3: Luna Energy Facility power plant

3.1 PREVIOUS INVESTIGATIONS

Hanson and others (1994) developed a calibrated ground-water flow model of the Mimbres Basin, but did not predict pumping effects. Power generation is currently non-existent in Luna County, and there are no previous investigations of this demand.

3.2 HYDROGEOLOGIC SETTING

Wells used to supply water to the proposed Luna Energy Facility would be located in the Red Mountain area, west of Deming within the Mimbres Basin (plate 2). There are no wells located at the power-generating site. The regional hydrogeologic setting of the Mimbres Basin is discussed briefly in section 2.4 (Hydrogeologic setting).

3.3 DEMAND PROJECTIONS

Wilson (2001; table 12) reported water demands for power production in Luna County of 3,000 acre-feet per year from 2005-2040. These are based on projected demands for the Luna Energy Facility proposed by Duke Energy northwest of Deming.

3.4 CAPACITY IN RELATION TO DEMAND

Capacity of the wells proposed for use at the Luna Energy Facility was assumed sufficient to meet the projected demand of 3,000 acre-feet per year.

3.5 WELL FIELD CONDITIONS

Duke Energy's proposed water supply for the Luna Energy Facility is from existing irrigation wells primarily located in T24S, R11W (plate 5). At this time, 20 applications to change purpose and place of use of ground water from 46 wells have been filed with the OSE Deming Office; more applications are anticipated. For this evaluation, the primary well or deepest well was selected using the known well depth and latest water level. The Luna Energy Facility well field is located near the western margin of the Deming sub-basin. Estimates of average total basin-fill thickness in this area range from 50 to 400 feet (Hanson and others, 1994; figure 8). Records of five aquifer tests in T24S, R11W (Hanson and others, 1994; table 4) indicate a range of transmissivity of 670 to 16,000 ft^2/d in the area.

3.6 METHODS

3.6.1 Estimating drawdowns

The Mimbres Basin ground-water flow model briefly described in section 2.6.1 (Mimbres Basin model) was used to estimate effects of basin pumping on irrigation wells used to meet projected industrial demands at the proposed facility. Drawdowns calculated by the model were adjusted to estimate drawdown in the pumping wells according to the procedures described in section 2.6.2 (Estimating drawdown in the well).

3.6.2 Simulation of projected demands

Power uses are separated into Luna and Grant counties in Wilson's reports. Grant County power usage is assumed constant after year 1980 in the Mimbres model. In Luna County, water use for power generating is expected to begin in 2005 with the completion of Duke Energy's Luna Energy Facility in Deming (Wilson, 2001). Duke Energy acquired their water through individual water right owners who filed applications to change place and purpose of use from irrigation water to commercial and industrial use by the Luna Energy Facility. Water production will remain at or near its historical point of diversion and is limited to the historical irrigation consumptive use.

Duke Energy's ground-water conservation plan proposed using 3,000 acre-feet per year for normal plant operations. This amount was distributed to model cells at the location of the original irrigation wells. Water usage in a particular model cell was based on the percentage of the irrigation well's consumptive use to the 3,000 acre-feet total usage.

3.7 RESULTS AND DISCUSSION

Table 3-1 summarizes estimated drawdowns and remaining water columns in the 20 wells evaluated. By 2020, of the 20 wells evaluated, 10 appear to be functional, 3 have less than 100 feet of remaining water column, and 7 are completed above the projected regional water level. By 2040, 8 wells appear to be functional, 4 have less than 100 feet of remaining water column, and 8 are completed above the projected regional water level. By 2060, 5 wells appear to be functional, 5 have less than 100 feet of remaining water column, and 10 are completed above the projected regional water level.

Of the 20 Duke Energy wells evaluated, 18 are 500 feet deep or less. At this time, Duke Energy has applied to construct replacement wells in the Red Mountain area to regain production associated with the older wells and we expect that many of these older irrigation wells will be replaced with more efficient well designs. Hanson (1994) indicates that the bolson-fill in the Red Mountain area is about 400 feet thick and lies just north of an area with a 700-foot average thickness. Wells in the Red Mountain area could be deepened to attempt to regain production but may be limited in their total depth by local variations in the aquifer's productivity.

Task 4: Lordsburg area agricultural, municipal and power demands

4.1 PREVIOUS INVESTIGATIONS

Previous investigations projecting drawdown in the area and effects on the City of Lordsburg's wells include RTI (1991) and Gordon (1994). Projected drawdowns of 40 feet in 40 years (one foot per year) in the Lordsburg area were estimated by RTI (1991). Gordon (1994; table 6) presented water-level data from wells in Lordsburg's East well field that indicated average declines of about one foot per year from 1973-1994, and concluded that the aquifer supplying the wells could produce sufficient supplies to meet projected demands for the 40-year planning period (1994-2034).

4.2 HYDROGEOLOGIC SETTING

The Lordsburg sub-basin is part of the larger Animas Basin (Hawley and others, 2000), a topographically closed, internally drained surface water basin in the Basin and Range physiographic province. The Continental Divide forms the southern, eastern and northeastern boundaries of the Lordsburg sub-basin; the northern and western boundaries are formed by the divide between the Lordsburg and Lower Animas sub-basins. Lordsburg Draw and its tributaries are ephemeral streams that occasionally drain to playas in the northern Lower Animas sub-basin.

Hydrostratigraphic units of the upper and middle Gila Group comprise the principal aquifer within the Lordsburg sub-basin (Hawley and others, 2000). These intermontane basin-fill deposits consist of unconsolidated to partly consolidated sand, gravel, silt and clay. The lower unit of the Gila Group consists of partly to well-consolidated sandstone, conglomerate, and mudstone, and generally does not yield much water. Younger basin-fill units that include piedmont and axial alluvial deposits overlie the Gila Group and are mostly above the water table (Hawley and others, 2000).

Mountain-front recharge in the Lordsburg sub-basin occurs along the South Burro Mountains and the Pyramid Mountains, and possibly elsewhere along the Continental Divide such as the Cedar Mountains. Ground water flows towards the central Lordsburg Valley and then northwest, discharging to the Lower Animas sub-basin. Ground water in the Lower Animas sub-basin discharges north beneath the topographic divide with the Gila Basin as underflow, ultimately reaching the Gila River (plate 2).

4.3 DEMAND PROJECTIONS

Wilson (2001; tables 8 and 12) estimated municipal water demands for the City of Lordsburg, and for commercial, industrial, and mining uses in Hidalgo County for the period 2000-2060. The mining demands occur outside of the area in the Playas Basin, industrial demands are for a chili processing plant in the Animas Basin, and commercial demands are varied but are predominantly associated with a greenhouse operation in the Animas Basin (B. Wilson, written communication). Power demands at two facilities were assumed to equal the water rights associated with the wells, as discussed below. Agricultural demands were assumed to remain at a level estimated from 1999 demands.

4.4 CAPACITY IN RELATION TO DEMAND

4.4.1 City of Lordsburg

At various times the City of Lordsburg has derived its water supply from wells in the North (wells LV-37 et al.) and East (wells LV-269 et al.) well fields, and from the Cemetary well (LV-268). The City has also leased water from the Well's well (LV-380). Since the North well field and Cemetary well were abandoned in 1973 (Gordon, 1994), and diversions for municipal use from LV-380 ceased, the East well field has provided all production. For the purposes of this investigation, only those wells in the East well field that are currently utilized (wells LV-269-S, LV-269-S-2, LV-269-S-3, and LV-269-S-4) are considered. Information in OSE files and other published sources (Gordon, 1994) used to evaluate the physical diversion capacity of these wells is summarized in table 4-1.

Assuming 60 percent production time, Lordsburg's existing wells have a total capacity of about 2,420 acre-feet per year. This represents the estimated physical capacities of the wells, unlimited by water rights considerations. The water right associated with the East well field (1,400 acre-feet per year) is less than the wells are capable of producing. Based on a demand estimate of 1,001 acre-feet in 2060 (Wilson, 2001; table 8), the capacity of these existing wells exceeds Lordsburg's 2060 demand.

4.4.2 Lordsburg area power plants

Public Service Company of New Mexico (PNM) is planning to reopen the currently inactive Lordsburg Power Plant in Sec. 33, T22S, R18W previously owned by

Community Public Service and the Texas-New Mexico Power Company. This plant has utilized four wells (LV-310, 311, 312, and 313) for its water supply in the past, and it is expected that some combination of these wells will supply the plant when reopened by PNM. A new power plant, the Pyramid Facility, has been proposed by the Tri-State Generation and Transmission Association (TSGTA) at a location about 12 miles southeast of Lordsburg in Sec. 12, T24S, R17W. The proposed water supply for the Pyramid Facility is from six existing irrigation wells located in Sections 11, 12 and 13. Information on all of the wells to be used at the two plants is summarized in table 4-2.

Assuming 60 percent production time, the existing Lordsburg Power Plant and Pyramid Facility wells have total capacities of about 1,875 and 2,000 acre-feet per year, respectively. This represents the estimated physical capacities of the wells, unlimited by water rights considerations. The water rights associated with these wells (1,395 acre-feet per year at the Lordsburg plant and 1,054.6 acre-feet per year at the Pyramid Facility) are less than the wells are capable of producing. The demand estimates for these facilities was assumed to equal the water rights associated with the wells, so the existing wells have sufficient capacity to meet demands to 2060.

4.4.3 Lordsburg Basin agriculture

Existing well capacity in the basin was assumed to be sufficient to have met irrigation demands in 1999. Because projected demands are assumed to remain at a level estimated from 1999, existing well capacity should be sufficient to meet these demands.

4.5 WELL FIELD CONDITIONS

4.5.1 Lordsburg

The City of Lordsburg owns 10 wells and in the past has leased water from another well. Most of the wells are located in two well fields: the North well field (wells LV-37 et al.) and the East well field (wells LV-269 et al.) The North well field consists of four wells located in Sec. 28, T22S, R18W. Production began in 1912 when the first two wells were drilled, and continued until around 1973 (Gordon, 1994). Maximum production from the North well field probably occurred around 1970, the year of Lordsburg's highest recorded pumping (1,256 acre-feet). Water quality problems, including high nitrate concentrations, and operational considerations led to abandonment of the North well field in the mid-1970s (Gordon, 1994, p. 2). All of the North well field wells have been plugged except for the "D" well (LV-37-S-3), which has been capped (Gordon, 1994, p. 5).

No water-level data were available to evaluate declines in these wells, but model simulations of historical pumping indicate maximum drawdowns in the vicinity of the North well field of over 40 feet occurring by the mid-1970s, with water levels recovering over 10 feet by 2000. Transmissivity values of 2,700 ft^2/d to over 13,000 ft^2/d, and a storage coefficient of 0.10 have been used to simulate the aquifer in the North well field area in OSE analytical (West, 1961) and numerical (this study) models.

The East well field consists of five wells located in Sec. 2, T23S, R18W. The first well (the "SP" well or LV-269) was drilled in 1897 by Southern Pacific for the railroad, but is owned by Lordsburg. An additional well was drilled in 1943, and the East well field became Lordsburg's primary source of supply after the drilling of wells LV-269-S-2 and LV-269-S-3 in 1973 (Gordon, 1994). The original SP well has been plugged. With the completion of well LV-269-S-4 in 1998, the East well field now has four active wells (table 4-1).

Based on water-level data from three wells, Gordon (1994; p. 9) estimated an average rate of decline of about 1.1 feet per year in the East well field from 1973-1994. Transmissivity values of 2,700 ft^2/d to over 14,000 ft^2/d, and a storage coefficient of 0.10 have been used to simulate the aquifer in the East well field area in OSE analytical (West, 1961) and numerical (this study) models.

The Cemetary well (LV-268) was used for irrigation of the cemetery from 1947 until 1973, and is capped (Gordon, 1994, p. 5). Well LV-380 was used primarily in the 1970s under a lease agreement, but is no longer a source for Lordsburg (Gordon, 1994).

4.5.2 Lordsburg area power plants

The well field for the Lordsburg Power Plant consists of four wells, LV-310, LV-311, LV-312 and LV-313. The wells were originally closely spaced, about 150 feet apart in an east-west line in the NW¼, NW¼ of Sec. 34, T22S, R18W. In 1966 wells LV-310 and LV-311 were moved to the NE¼, NW¼ of Sec. 34 to alleviate interference problems.

The four wells range in depth from 290 to 440 feet, and have initial water columns estimated to range from 200 to 325 feet (table 4-2). The maximum annual diversion from these three wells was 1,376.94 acre-feet in 1993, with reported diversions decreasing to zero by 1995.

No water-level data were available to evaluate declines in these wells, but model simulations of historical pumping indicate drawdowns in the vicinity of the wells of about 35 feet by the year 2000. Transmissivity values of 2,700 ft^2/d to almost 14,000 ft^2/d, and a storage coefficient of 0.10 have been used to simulate the aquifer in the Lordsburg Power Plant well field area in OSE analytical (West, 1961) and numerical (this study) models.

Water for the proposed Pyramid Facility would be supplied by some combination of six existing irrigation wells (LV-8, LV-9, LV-40, LV-40-S, LV-282 and LV-282-S). Initially well LV-282 would be the primary well, with LV-282-S used as a backup; other wells would be utilized later as plant operations require (TSGTA, 2001). These wells were all drilled in the 1950s and 1960s to depths ranging from less than 700 to over 1,000 feet, with initial water columns of less than 600 to over 900 feet (table 4-2). Well records and cross sections (Hawley and others, 2000; plate 1) indicate these wells are completed in the upper and middle Gila Group.

No water-level data were available to evaluate declines in these wells, but model simulations of historical pumping indicate drawdowns in the vicinity of the wells of over 40 feet by the year 2000. Transmissivity values of 2,700 ft^2/d to about 10,700 ft^2/d, and a storage coefficient of 0.10 have been used to simulate the aquifer in the Pyramid Facility well field area in OSE analytical (West, 1961) and numerical (this study) models.

4.5.2 Lordsburg area irrigation wells

The OSE WATERS database lists 106 irrigation wells located in the Lordsburg Underground Water Basin. Of these, 29 have information from which a water column can be calculated. The average irrigation well depth in the basin is 505 feet, and the average water column is about 399 feet. Maximum water-level declines of over 50 feet by 2000 in irrigated areas were calculated by model simulation of historical pumping.

4.6 METHODS

4.6.1 Lower Animas-Lordsburg model

A ground-water flow model of the upper part of the basin-fill aquifer in the Lower Animas and Lordsburg sub-basins was developed to estimate effects of pumping to meet projected demands (plate 8). The Lower Animas-Lordsburg model consists of one layer representing the upper Gila Group and overlying hydrostratigraphic units, with a grid of 60 rows by 42 columns and 1,464 active cells. Model cells are uniformly one square mile in size. Mountain-front recharge and regional discharge to the Gila River are simulated as boundary conditions, with all other boundaries simulated as no-flow. The model was calibrated to regional steady-state conditions using estimated flows and synoptic water-level data from 1913 at 89 points, and to transient conditions for the period 1920 to 2000. The model is considered a reasonable representation of the hydrogeologic system and can be used to estimate effects of pumping to meet projected demands in these basins.

4.6.2 Estimating drawdown in the well

Procedures similar to those described in section 1.6.2 (Estimating drawdown in the well) were used to adjust drawdowns calculated at model cell nodes to estimate drawdowns in the pumping wells. The same procedure was used to calculate Q, and T was calculated for each well (cell) by multiplying the hydraulic conductivity assigned to the model cell by an average saturated thickness, determined by subtracting one-half the model calculated drawdown at 2020, 2040 and 2060 from the initial saturated thickness. Transmissivity was not adjusted to account for partial penetration of the wells (Anderson and Woessner, 1992; p. 149). The Lower Animas-Lordsburg model grid has a regular spacing of 5280 feet, so the effective well block radius (r_e) for all wells was equal to about 1,100 feet. Drawdowns were further adjusted by dividing by 0.7, assuming a well efficiency of 70 percent for all wells.

4.6.3 Simulation of historical pumping

Municipal diversions at Lordsburg for the period 1920-2000, industrial diversions at the Lordsburg Power Plant (1937-2000) and at a chili processing plant in the Animas Basin (1990-2000), self-supplied commercial diversions associated with a greenhouse operation in the Animas Basin (1985-2000), and irrigation diversions in the Lordsburg (1956-2000) and Animas (1947-2000) Basins were simulated in the model based on OSE reports, databases, files and other sources. Irrigation pumping was distributed based on published reports and digital coverages of irrigated acreage; municipal and industrial pumping was based on information in OSE files and databases, and in Gordon (1994).

4.6.4 Simulation of projected municipal, industrial and irrigation demands

After the year 2000, pumping for all irrigation, commercial and industrial uses was held constant, only projected municipal uses continued to increase through 2060 based on Wilson (2001). Industrial demands of 75 acre-feet per year were simulated where the chili processing plant in the Animas Basin is located (model cell 44,5). Commercial demands of 460 acre-feet per year were assumed to be associated with the greenhouse operation in the Animas Basin, and were simulated in model cells 39,7 and 39,8. No mining demands were simulated.

Lordsburg municipal pumping was distributed based on relative capacities of the four East well field wells, with 70 percent from model cell 28,20 where wells LV-269-S, LV-269-S-3, and LV-269-S-4 are located, and 30 percent from model cell 29,20 where well LV-269-S-2 is located. Production was held constant from 2000-2060 at both the Lordsburg Power Plant (1,395 acre-feet per year) and the Pyramid Facility (1,054.6 acre-feet per year). Two-thirds (67 percent) of the pumping at the Lordsburg plant was simulated from two wells in model cell 27,29, and the remaining 33 percent from model cell 27,20, where well LV-311 is located. Pumping at the Pyramid Facility was divided equally between the two model cells (36,26 and 37,26) containing the wells.

4.7 RESULTS AND DISCUSSION

4.7.1 Lordsburg municipal wells

Drawdown calculated by the Lower Animas-Lordsburg model in the year 2020 near the Lordsburg East well field is about 50 feet. Drawdown in 2040 near the East well field is calculated to be about 63 feet (plate 8). Model calculated drawdown in 2060 near the East well field is about 75 feet.

Estimated drawdowns in the East well field wells based on adjusted model drawdowns are reported in table 4-3 for the years 2020, 2040, and 2060. By 2060 all the wells still have more than 100 feet of water column, and retain 60-70 percent of their initial water columns. The aquifer in the East well field area appears capable of meeting the City of Lordsburg's projected municipal demands until 2060.

4.7.2 Lordsburg area power plant wells

Maximum drawdowns calculated by the Lower Animas-Lordsburg model in the years 2020, 2040 and 2060 near the Lordsburg Power Plant well field are about 51 feet, 62 feet (plate 8) and 73 feet, respectively. Estimated drawdowns at the wells based on adjusted model drawdowns are reported in table 4-4 for the years 2020, 2040, and 2060. By 2060 all but one of the wells (LV-312) still have more than 100 feet of water column, retaining about 50-70 percent of their initial water columns. With management and scheduling of pumping among its existing wells the Lordsburg Power Plant should be capable of meeting its demands with the aquifer supplying these wells until 2060.

Maximum drawdowns calculated by the Lower Animas-Lordsburg model in the years 2020, 2040 and 2060 near the proposed Pyramid Facility well field are about 65 feet, 77 feet (plate 8) and 89 feet, respectively. Estimated drawdowns at the wells based on adjusted model drawdowns are reported in table 4-4 for the years 2020, 2040, and 2060. By 2060 all of the wells still have more than 100 feet of water column, retaining about 80 percent or more of their initial water columns. With management and scheduling of pumping among its existing wells the Pyramid Facility should be capable of meeting its demands with the aquifer supplying these wells until 2060.

4.7.3 Irrigation wells

The maximum drawdown calculated by the model in the Lordsburg Basin in 2020 is about 72 feet; average drawdown in the irrigated area is about 60 feet. The difference between water columns and average drawdown in the irrigated area in 2020 indicates that two wells could have less than 100 feet of water column. The maximum drawdown calculated in the Lordsburg Basin in 2040 is about 85 feet; average drawdown in the irrigated area is about 70 feet (plate 8). This indicates that two wells could have less than

100 feet of water column in 2040. The maximum drawdown calculated in the Lordsburg Basin in 2060 is about 98 feet; average drawdown in the irrigated area is about 80 feet. The difference between water columns and average drawdown in the irrigated area in 2060 indicates that 10 wells could have less than 100 feet of water column.

The average pre-development saturated thickness simulated in the Lower Animas-Lordsburg model in the Lordsburg Basin irrigated area is 360 feet, indicating that an average of about 300 feet of saturated material will remain by 2040 in the irrigated area. Hydrogeologic information indicates that this material consists of potentially productive upper Gila hydrostratigraphic units (Hawley and others, 2000), although productivity would vary with location. Aside from these local variations in aquifer productivity, most wells in the Lordsburg Basin affected by projected water-level declines within 40 years could probably be deepened to regain production.

Task 5: Animas Basin agricultural demands

5.1 PREVIOUS INVESTIGATIONS

Reeder (1957) predicted drawdowns in the Animas Basin due to irrigation pumping. O'Brien and Stone (1983) and Hawkins (1981) developed calibrated ground-water flow models of the Animas Basin, but did not predict pumping effects.

5.2 HYDROGEOLOGIC SETTING

Irrigation in the Animas Basin area occurs in the Lower Animas sub-basin (Hawley and others, 2000). The northern boundary is the topographic divide between the Animas and Gila River Basins. The southern boundary with the Upper Animas sub-basin is based on a change in average slope. The Animas River is perennial through part of the Upper Animas sub-basin, but is ephemeral in the Lower Animas sub-basin.

Hydrostratigraphic units of the upper and middle Gila Group comprise the principle aquifer within the Lower Animas sub-basin (Hawley and others, 2000). Younger basin-fill units that include piedmont, axial alluvial and basin-floor deposits overlie the Gila Group and are mostly above the water table (Hawley and others, 2000).

Mountain-front recharge occurs along the Peloncillo and Pyramid Mountains, and underflow from the Upper Animas sub-basin also contributes to flow in the Lower Animas sub-basin (Hawley and others, 2000; fig. 7-3). From these recharge areas ground water flows towards the central Lower Animas Valley, and then north down the valley, discharging as underflow to the Gila Basin, and ultimately the Gila River (plate 2).

5.3 DEMAND PROJECTIONS

Agricultural demands were assumed to remain at 1995 levels, when 7,322 acres were irrigated in the Lower Animas basin, and ground-water withdrawals for irrigation were estimated to have been 23,852 acre-feet (Wilson and Lucero, 1997; table 9).

5.4 CAPACITY IN RELATION TO DEMAND

Existing well capacity in the Lower Animas basin was assumed to be sufficient to have met irrigation demands in 1995, and because projected demands were assumed to remain at 1995 levels, existing well capacity should be sufficient to meet these demands.

5.5 WELL FIELD CONDITIONS

The OSE WATERS database lists 76 irrigation wells located in the Animas Underground Water Basin. Of these, 54 have information from which a water column can be calculated. The average irrigation well depth in the basin is 427 feet, and the average water column is 316 feet. Maximum water-level declines of almost 110 feet by 2000 were calculated by model simulation of historical irrigation pumping.

5.6 METHODS

5.6.1 Lower Animas-Lordsburg model

The Lower Animas-Lordsburg ground-water flow model briefly described in section 4.6.1 was used to estimate effects of pumping to meet projected irrigation demands in the Animas Basin.

5.6.2 Estimating drawdown in the wells

Water levels in irrigation wells are assumed to be approximately equal to the model-simulated drawdowns due to the variable nature of irrigation well usage. Irrigation well water columns were compared to the average drawdown in the irrigated area calculated by the model to estimate numbers of irrigation wells that may have less than 100 feet of water column in 2020, 2040, and 2060.

5.7 RESULTS AND DISCUSSION

The maximum drawdown calculated by the model in the Animas Basin in 2020 is about 133 feet; average drawdown in the irrigated area is about 100 feet. By 2020, 17 wells could have less than 100 feet of water column, and the water level in the area may be below the depths of 8 of these wells. The maximum drawdown calculated in 2040 is about 156 feet; average drawdown in the irrigated area is about 120 feet (plate 14). By 2040, 18 wells could have less than 100 feet of water column, and the water level in the area may be below the depths of 8 of these wells in 2040. The maximum drawdown calculated in the Animas Basin in 2060 is about 177 feet; average drawdown in the irrigated area is about 140 feet. By 2060, 20 wells could have less than 100 feet of water column, and the water level in the area may be below the depths of 8 wells.

The average pre-development saturated thickness simulated in the Lower Animas-Lordsburg model in the Animas Basin irrigated area is 470 feet, indicating that an average of about 350 feet of saturated material will remain by 2040 in the irrigated area. Hydrogeologic information indicates that this material consists of potentially productive upper Gila hydrostratigraphic units (Hawley and others, 2000), although productivity would vary with location. Aside from these local variations in aquifer productivity, most wells in the Animas Basin affected by projected water-level declines within 40 years could probably be deepened to regain production.

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TABLES

Table 1-1. Selected information on wells in the Town of Silver City's Franks well field. From State Engineer Office files; Trauger (1972; table 12); Gordon and others (1993; table 4).

State Engineer Office file/well number	**Location (T.R.S.qqq)**	**Year drilled**	**Casing diameter**		**Yield (gpm)**	**Well depth (feet)**	**Depth to water when drilled (feet)**	**Initial water column[a] (feet)**
			In.	**feet**				
GSF-1014	18.15.11.313	1945	12	1.00	--	597	207	390
GSF-1014-S	18.15.11.331	1945	12	1.00	400	547	240	307
GSF-1014-S-2	18.15.11.323	1945	12	1.00	--	558	220	318
GSF-1014-S-3	18.15.11.341	1945	12	1.00	--	580	237	360
GSF-1014-S-4	18.15.10.441	1954	12	1.00	325	659	192	467
GSF-1014-S-5	18.15.14.123	1974	12	1.00	500	865	323	542
GSF-1014-S-6	18.15.13.333	1982	12	1.00	800	1095	335	760
TOTAL (gpm)					2025			
TOTAL (afy)[b]					1961			

[a] Initial water column = well depth minus depth to water when drilled

[b] TOTAL (afy) = total yield in acre-feet per year (afy), assuming 60 percent production time. Only yields of those wells currently in operation included.

Table 1-2. Selected information on wells in the Woodward well field (M-2735 et al.), and the Anderson (M-2675) and Hayes (M-2903) wells, Town of Silver City. From: State Engineer Office files; Trauger (1972; table 12).

State Engineer Office file/well number	**Location (T.R.S.qqq)**	**Year drilled**	**Casing diameter**		**Yield (gpm)**	**Well depth (feet)**	**Depth to water when drilled (feet)**	**Initial water column[a] (feet)**
			In.	**feet**				
M-2735	18.14.30.324	1954	12	1.00	300	895	341	554
M-2735-S	18.14.30.312	1954	12	1.00	300	800	319	481
M-2735-S-2	18.14.30.343	1957	12	1.00	500	835	348	487
M-2735-S-3	18.14.30.432	1965	12	1.00	500	954	284	670
M-2735-S-4	18.14.31.213	1971	12	1.00	500	1030	359	671
M-2735-S-5	18.14.31.412	1972	12	1.00	500	1030	414	616
TOTAL (gpm)					2600			
TOTAL (afy)[b]					2517			
					Yield (afy)			
M-2675	19.14.06.410	1967	12	1.00	407.7	900	455	445
M-2903	18.14.28.141	1970	16	1.33	1433	680	260	420

[a] Initial water column = well depth minus depth to water when drilled

[b] TOTAL (afy) = total yield in acre-feet per year (afy), assuming 60 percent production time

Table 1-3. Selected information on wells in the Lone Mountain well field, Village of Santa Clara (formerly Central). From: State Engineer Office files; Trauger (1972; table 12)

State Engineer Office file/well number	Location (T.R.S.qqq)	Year drilled	Casing diameter		Yield (gpm)	Well depth (feet)	Depth to water when drilled (feet)	Initial water column[a] (feet)
			In.	feet				
M-3128	18.13.15.444	1954	18	1.50	20	387	44.8	342.2
M-3128-S	18.13.15.434	1954	12	1.00	60	472	167.6	304.4
M-3128-S-2	18.13.15.433	1961	10	0.83	120	401.5[b]	75.7	325.8
M-3128-S-3	18.13.15.334	1972	12	1.00	400	515	185	330
Average				1.08				325
TOTAL (gpm)[c]					600			
TOTAL (afy)[d]					581			

[a] Initial water column = well depth minus depth to water when drilled.

[b] Depth is cased depth of well; open hole to total depth of 555 feet.

[c] TOTAL (gpm) = total yield in gallons per minute (gpm).

[d] TOTAL (afy) = total yield in acre-feet per year (afy), assuming 60 percent production time.

Table 1-4. Selected information on wells in the City of Bayard's well field. From: State Engineer Office files; Trauger (1972; table 12).

State Engineer Office file/well number	Location (T.R.S.qqq)	Year drilled	Casing diameter		Yield (gpm)	Well depth (feet)	Depth to water when drilled (feet)	Initial water column[a] (feet)
			In.	feet				
M-2698	18.13.14.222	1942	8	0.67	45	300	65	235
M-2698-S	18.13.14.222	1948	12	1.00	45	220	65	155
M-2698-S-2	18.13.14.222	1950	12	1.00	85	250	65	185
M-2698-S-3	18.13.14.222	1950	8	0.67	5	80	65	15
M-2698-S-4	18.13.14.222	1950	8	0.67	40	300	65	235
M-2698-S-5	18.13.14.222	1956	8	0.67	30	650	65	585
M-2698-S-6	18.13.14.222	1965	10	0.83	60	700	65	635
M-2698-S-7	18.13.14.222	1965	12	1.00	90	982	65	917
M-2698-S-8	18.13.14.222	1970	8	0.67	115	500	70	430
M-2698-S-9	18.13.14.240	1954	10	0.83	116	274	46.4	228
M-2698-S-10	18.13.14.144	1985	10	0.83	140	380	52	328
Average				0.80				360
Total all wells					771			
TOTAL (gpm)[b]					636			
TOTAL (afy)[c]					616			

[a] Initial water column = well depth minus depth to water when drilled

[b] TOTAL (gpm) = total yield in gallons per minute (gpm) of wells S-2 and S-5 through S-10.

[c] TOTAL (afy) = total yield in acre-feet per year (afy) of wells S-2 and S-5 through S-10, assuming 60 percent production time.

Table 1-5. Reported and estimated diversions at Silver City's wells and well fields, in acre-feet (af) and as a percentage of total pumping (%), as simulated in the Silver City model (1946-2000)

Year	Franks well field (1)		Woodward well field (2)		Anderson well		Hayes well		Total	Source
	Af	%	af	%	af	%	af	%		
1946	153.44	100	--	--	--	--	--	--	153.44	Trauger et al. (1980; table 2)
1947	543.19	100	--	--	--	--	--	--	543.19	Trauger et al. (1980; fig. 25)
1948	552.40	100	--	--	--	--	--	--	552.40	Trauger et al. (1980; fig. 25)
1949	521.71	100	--	--	--	--	--	--	521.71	Trauger et al. (1980; fig. 25)
1950	586.16	100	--	--	--	--	--	--	586.16	Trauger et al. (1980; fig. 25)
1951	611.02	100	--	--	--	--	--	--	611.02	Trauger et al. (1980; fig. 25)
1952	543.81	100	--	--	--	--	--	--	543.81	Trauger et al. (1980; fig. 25)
1953	621.45	100	--	--	--	--	--	--	621.45	Trauger et al. (1980; fig. 25)
1954	622.98	100	--	--	--	--	--	--	622.98	Trauger et al. (1980; fig. 25)
1955	605.18	100	--	--	--	--	--	--	605.18	Trauger et al. (1980; fig. 25)
1956	779.50	100	--	--	--	--	--	--	779.50	Trauger et al. (1980; fig. 25)
1957	637.41	100	--	--	--	--	--	--	637.41	Trauger et al. (1980; fig. 25)
1958	568.66	77	166.64	23	--	--	--	--	735.30	Trauger (1980; figs. 25 (1), 26 (2))
1959	341.87	44	428.11	56	--	--	--	--	769.98	Trauger (1980; figs. 25 (1), 26 (2))
1960	294.00	32	622.37	68	--	--	--	--	916.37	Trauger (1980; figs. 25 (1), 26 (2))
1961	294.31	35	551.17	65	--	--	--	--	845.48	Trauger (1980; figs. 25 (1), 26 (2))
1962	278.65	32	596.28	68	--	--	--	--	874.93	Trauger (1980; figs. 25 (1), 26 (2))
1963	324.69	35	598.13	65	--	--	--	--	922.82	Trauger (1980; figs. 25 (1), 26 (2))
1964	323.46	33	660.42	67	--	--	--	--	983.88	Trauger (1980; figs. 25 (1), 26 (2))
1965	361.67	38	598.46	62	--	--	--	--	960.13	Trauger et al. (1980; table 3)
1966	349.24	35	661.65	65	--	--	--	--	1010.89	Trauger (1980; figs. 25 (1), 26 (2))
1967	371.95	33	739.60	67	--	--	--	--	1111.55	Trauger (1980; figs. 25 (1), 26 (2))
1968	388.75	32	843.94	68	--	--	--	--	1232.69	OSE (1);Trauger(1980; fig. 26) (2)
1969	396.41	29	991.86	71	--	--	--	--	1388.27	OSE (1);Trauger(1980; fig. 26) (2)
1970	325.60	22	1122.78	78	--	--	--	--	1448.38	OSE (1);Trauger(1980; table 3) (2)
1971	380.20	24	1214.82	76	--	--	--	--	1595.02	OSE meter records
1972	385.40	24	1189.02	76	--	--	--	--	1574.42	OSE meter records
1973	336.39	20	1340.87	80	--	--	--	--	1677.26	OSE meter records
1974	301.50	17	1460.67	83	--	--	--	--	1762.17	OSE meter records
1975	282.60	16	1530.10	84	--	--	--	--	1812.70	OSE meter records
1976	278.81	14	1691.92	86	--	--	--	--	1970.73	OSE meter records
1977	430.27	22	1450.76	77	13.91	1	--	--	1894.94	OSE meter records
1978	512.67	27	1327.05	71	33.85	2	--	--	1873.57	OSE meter records
1979	485.84	23	1522.97	73	77.74	4	--	--	2086.55	OSE meter records
1980	671.06	31	1415.06	66	71.13	3	--	--	2157.25	OSE meter records
1981	726.10	31	1499.09	64	110.57	5	--	--	2335.76	OSE meter records
1982	804.37	34	1542.11	64	52.60	2	--	--	2399.08	OSE meter records
1983	881.40	35	1638.08	65	4.28	0	--	--	2523.76	OSE meter records
1984	449.70	20	1448.63	66	305.42	14	--	--	2203.75	OSE meter records
1985	981.21	41	1122.69	47	261.38	11	--	--	2365.28	OSE meter records
1986	749.68	30	901.99	37	85.82	4	725.19	29	2462.68	OSE meter records
1987	265.80	10	834.25	32	105.33	4	1404.08	54	2609.46	OSE meter records
1988	349.38	13	949.51	37	0.00	0	1284.19	50	2583.08	OSE meter records
1989	375.02	13	959.73	35	229.83	8	1218.76	44	2783.34	OSE meter records
1990	598.74	24	1018.73	41	62.62	3	800.18	32	2480.27	OSE meter records
1991	507.45	19	1137.83	43	107.63	4	896.87	34	2649.78	OSE meter records
1992	320.47	12	1208.97	45	181.09	7	979.50	36	2690.03	OSE meter records
1993	358.88	14	1267.67	47	189.83	7	860.16	32	2676.54	OSE meter records
1994	573.94	19	1074.94	36	214.59	7	1131.27	38	2994.74	OSE meter records
1995	442.49	15	1646.82	56	238.60	8	619.64	21	2947.55	OSE meter records
1996	817.81	29	944.48	34	126.85	5	895.56	32	2784.70	OSE meter records
1997	929.37	32	1228.32	43	0.42	0	726.70	25	2884.81	OSE meter records
1998	821.97	28	1595.43	55	0.00	0	496.85	17	2914.25	OSE meter records
1999	851.74	30	1569.42	56	0.02	0	395.38	14	2816.56	OSE meter records
2000	1032.76	34	1060.29	35	2.33	0	957.79	31	3053.17	OSE meter records
1986-2000 avg.		**21**		**42**		**4**		**33**		

Table 1-6. Reported and estimated diversions at the Santa Clara and Bayard well fields, in acre-feet, as simulated in the Silver City model (1946-2000).

Year	Santa Clara / Lone Mountain well field (1)	Bayard well field (1)	Santa Clara / Lone Mountain well field (2)	Bayard well field (2)	Source (1)	Source (2)
1946	28.98	144.89			Estimated for this study	
1947	28.98	144.89			Estimated for this study	
1948	28.98	144.89			Estimated for this study	
1949	28.98	144.89			Estimated for this study	
1950	28.98	144.89			Estimated for this study	
1951	28.98	152.14			Estimated for this study	
1952	28.98	159.38			Hargis & Montgomery (1983; table 2)	
1953	36.22	166.63			Hargis & Montgomery (1983; table 2)	
1954	36.22	173.87			Hargis & Montgomery (1983; table 2)	
1955	43.47	181.12			Hargis & Montgomery (1983; table 2)	
1956	43.47	188.36	42	185	Hargis & Montgomery (1983; table 2)	Trauger et al. (1980)
1957	50.71	195.60			Hargis & Montgomery (1983; table 2)	
1958	50.71	202.85			Hargis & Montgomery (1983; table 2)	
1959	57.96	202.85			Hargis & Montgomery (1983; table 2)	
1960	57.96	210.09			Hargis & Montgomery (1983; table 2)	
1961	57.96	217.34			Hargis & Montgomery (1983; table 2)	
1962	57.96	217.34			Hargis & Montgomery (1983; table 2)	
1963	65.20	224.58			Hargis & Montgomery (1983; table 2)	
1964	65.20	231.83			Hargis & Montgomery (1983; table 2)	
1965	72.45	239.07	70	236	Hargis & Montgomery (1983; table 2)	Trauger et al. (1980)
1966	86.94	246.32			Hargis & Montgomery (1983; table 2)	
1967	101.42	246.32			Hargis & Montgomery (1983; table 2)	
1968	115.91	246.32			Hargis & Montgomery (1983; table 2)	
1969	130.40	253.56			Hargis & Montgomery (1983; table 2)	
1970	144.89	253.56			Hargis & Montgomery (1983; table 2)	
1971	159.38	260.81			Hargis & Montgomery (1983; table 2)	
1972	181.12	260.81			Hargis & Montgomery (1983; table 2)	
1973	195.60	260.81			Hargis & Montgomery (1983; table 2)	
1974	210.09	260.81			Hargis & Montgomery (1983; table 2)	
1975	224.58	268.05			Hargis & Montgomery (1983; table 2)	
1976	311.52	268.05			Hargis & Montgomery (1983; table 2)	
1977	231.83	275.30			Hargis & Montgomery (1983; table 2)	
1978	206.47	275.30	206	275	Hargis & Montgomery (1983; table 2)	Trauger et al. (1980)
1979	260.81	275.30			Hargis & Montgomery (1983; table 2)	
1980	239.07	275.30	240	300	Hargis & Montgomery (1983; table 2)	Sorensen (1982)
1981	217.34	282.54			Hargis & Montgomery (1983; table 2)	
1982	222.25	296.41			Linear interpolation	
1983	227.17	310.27			Linear interpolation	
1984	232.09	324.13			Linear interpolation	
1985	237.00	338.00			Wilson (1986; table 5)	
1986	238.10	338.00			Linear interpolation	
1987	239.20	338.00			Linear interpolation	
1988	240.30	339.00			Linear interpolation	
1989	241.40	339.00			Linear interpolation	
1990	242.50	339.88			Wilson (1992; table 6)	
1991	250.58	350.90			Linear interpolation	
1992	258.66	361.92			Linear interpolation	
1993	266.74	372.94			Linear interpolation	
1994	274.82	383.96			Linear interpolation	
1995	282.90	394.98			Wilson and Lucero (1997; table 6)	
1996	280.52	387.40			Linear interpolation	
1997	278.14	379.80			Linear interpolation	
1998	275.76	372.20			Linear interpolation	
1999	273.38	364.60			Linear interpolation	
2000	271.00	357.00			Wilson (2001; table 6)	

Table 1-7. Ground-water withdrawals for mining in the Silver City model area compared to withdrawals for all of Grant County, in acre-feet (1975-2000). From OSE technical reports.

Year	Chino Mines-Hurley	Phelps Dodge-Tyrone		Cron Ranch/U.V. Industries	Model area total	Grant County total	Model area total as percentage of Grant County total
		Gila Basin	Mimbres Basin				
1975	5723.26	857.76	--	--	6581.02	11305.00	58.2
1980	4882.88	1609.03	--	199.62	6691.53	13842.00	48.3
1985	4168.00	1478.40	--	81.87[a]	5728.27	12797.00	44.8
1990	6964.00	962.43	2050.11	8.28	9984.82	30465.58	32.8
1995	4376.59	1142.83[a]	1828.80	19.20	7367.42	25848.11	28.5
2000	5225.58	1143.28[a]	1438.15	214.58[a]	8021.59	21458.00	37.4
1975-2000 average							41.7
1990-2000 average							32.9

[a] Estimated

Table 1-8. Ground-water withdrawals for mining in the Silver City model area as a percentage of total withdrawals for Grant County (1975-2000). From OSE files and technical reports.

Year	Chino Mines-Hurley	Phelps Dodge-Tyrone		Cron Ranch/U.V. Industries	Model area total as percentage of Grant County total
		Gila Basin	Mimbres Basin		
1975	50.6	7.6	0.0	0.0	58.2
1980	35.3	11.6	0.0	1.4	48.3
1985	32.6	11.6	0.0	0.6[a]	44.8
1990	22.9	3.2	6.7	0.0	32.8
1995	16.9[a]	4.4	7.1	0.1	28.5
2000	24.4[a]	5.3	6.7	1.0[a]	37.4
1975-2000 average	30.4	7.3	3.4	0.5	41.7
1990-2000 average	21.4	4.3	6.8	0.4	32.9
Percentage assumed for future demand	21.0	6.0	7.0	1.0	35.0

[a] Based on estimated withdrawal

Table 1-9. Estimated drawdowns in feet from projected pumping under Scenario 1 in the years 2020, 2040, and 2060 at wells in the Franks well field (Town of Silver City), and estimated remaining water columns in feet (ft) and as percentage of initial water column in the well (%).

Well number	**Estimated drawdown in well (ft)**			**Remaining water column (ft)**			**Remaining water column (%)**		
	2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
GSF-1014	143	195	244	247	195	146	63	50	37
GSF-1014-S	161	219	273	146	**88**	**34**	48	**29**	**11**
GSF-1014-S-3	156	212	265	182	126	**73**	54	37	**22**
GSF-1014-S-4	177	236	289	290	231	178	62	49	38
GSF-1014-S-5	185	248	305	357	294	237	66	54	44
GSF-1014-S-6	363	476	510	397	284	250	52	37	33
Wells with less than 200 ft water column				**2**	**3**	**4**			
Wells with less than 100 ft water column				**0**	**1**	**2**			
Wells with 50% or less water column							**1**	**5**	**6**
Wells with 30% or less water column							**0**	**1**	**2**

Table 1-10. Estimated drawdowns in feet from projected pumping under Scenario 1 in the years 2020, 2040, and 2060 at wells in the Woodward well field and the Hayes and Anderson (And.) wells (Town of Silver City), and at the Santa Clara and Bayard well fields, and estimated remaining water columns in feet (ft) and as percentage of initial water column in the well (%).

Well number	**Estimated drawdown in well (ft)**			**Remaining water column (ft)**			**Remaining water column (%)**		
	2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
M-2735	264	346	414	290	208	140	52	38	**25**
M-2735-S	272	358	430	141	**55**	**(-17)**	34	**13**	**0**
M-2735-S-2	297	391	467	190	**96**	**20**	39	**20**	**4**
M-2735-S-3	281	366	435	389	304	235	58	45	35
M-2735-S-4	283	369	439	388	302	232	58	45	35
M-2735-S-5	266	347	412	459	378	313	63	52	43
Wells with less than 200 ft water column				**2**	**2**	**3**			
Wells with less than 100 ft water column				**0**	**2**	**2**			
Wells with 50% or less water column							**2**	**5**	**6**
Wells with 30% or less water column							**0**	**2**	**3**
M-2675 (And.)	185	249	299	260	196	146	58	44	33
M-2903 (Hayes)	393	495	578	**25**	**(-77)**	**(-159)**	**6**	**0**	**0**
Santa Clara	197	244	295	128	**81**	**30**	39	**25**	**9**
Bayard	240	299	356	120	**61**	**4**	33	**17**	**1**

Table 1-11. Estimated drawdowns in feet from projected pumping under Scenario 2 in the years 2020, 2040, and 2060 at wells in the Franks well field (Town of Silver City), and estimated remaining water columns in feet (ft) and as percentage of initial water column in the well (%).

Well number	**Estimated drawdown in well (ft)**			**Remaining water column (ft)**			**Remaining water column (%)**		
	2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
GSF-1014	156	221	282	234	169	108	60	43	**28**
GSF-1014-S	178	249	316	129	**58**	**(-9)**	48	**19**	**0**
GSF-1014-S-3	172	242	306	166	**96**	**32**	49	**28**	**9**
GSF-1014-S-4	195	267	334	272	200	133	58	43	**28**
GSF-1014-S-5	205	283	355	337	259	187	62	48	35
GSF-1014-S-6	415	552	668	345	208	**92**	45	**27**	**12**
Wells with less than 200 ft water column				**2**	**3**	**6**			
Wells with less than 100 ft water column				**0**	**2**	**3**			
Wells with 50% or less water column							**3**	**6**	**6**
Wells with 30% or less water column							**0**	**3**	**5**

Table 1-12. Estimated drawdowns in feet from projected pumping under Scenario 2 in the years 2020, 2040, and 2060 at wells in the Woodward well field and the Hayes and Anderson (And.) wells (Town of Silver City), and at the Santa Clara and Bayard well fields, and estimated remaining water columns in feet (ft) and as percentage of initial water column in the well (%).

Well number	**Estimated drawdown in well (ft)**			**Remaining water column (ft)**			**Remaining water column (%)**		
	2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
M-2735	301	404	489	253	150	**65**	46	**27**	**12**
M-2735-S	311	418	508	102	**(-5)**	**(-95)**	**25**	**0**	**0**
M-2735-S-2	341	458	556	146	**29**	**(-69)**	**30**	**6**	**0**
M-2735-S-3	321	427	515	349	243	155	52	36	**23**
M-2735-S-4	324	431	519	347	240	152	52	36	**23**
M-2735-S-5	303	403	485	422	322	240	58	44	33
Wells with less than 200 ft water column				**2**	**3**	**5**			
Wells with less than 100 ft water column				**0**	**2**	**3**			
Wells with 50% or less water column							**3**	**6**	**6**
Wells with 30% or less water column							**2**	**3**	**5**
M-2675 (And.)	207	285	346	238	160	**99**	53	36	**22**
M-2903 (Hayes)	451	580	684	**(-33)**	**(-162)**	**(-266)**	**0**	**0**	**0**
Santa Clara	105	91	89	220	234	236	68	72	73
Bayard	130	114	105	230	246	255	64	68	71

Table 2-1. Selected information on wells in the City of Deming and Village of Columbus municipal well fields, Luna County. From: State Engineer Office files; Leedshill-Herkenhoff (1997; table 6).

State Engineer Office file/well number	Well name or no.	Location (T.R.S.qqq)	Year drilled	Casing diameter (inches)	Yield (gpm)	Well depth (feet)	Depth to water (feet)	Water column[a] (feet)
Deming								
M-299-S	Well 06	23.09.34.324	1954	--	500	400	99	301
M-299-S-2	Well 03	23.09.35.422	1966	--	400	571	140	431
M-299-S-4	Well 11	23.09.35.343	1963	--	650	484	126	358
M-299-S-5	Well 05	23.09.27.412	1979	--	400	400	55	345
M-299-S-6	Well 01	23.09.33.222	1977	--	600	569	129	440
M-299-S-7	Well 02	23.09.27.134	1966	--	500	493	109	384
M-299-S-8	Well 07	23.09.34.312	1966	--	400	500	106	394
M-299-S-10	Well 10	24.09.01.142	1960	--	600	500	119	381
M-299-S-11	Well 08	24.08.06.111	1985	--	500	597	110	487
M-299-S-12	Well 09	23.09.35.133	1980	--	300	500	97	403
M-299-S-13	Well 12	23.09.36.213	1951	--	400	445	105	340
M-299-S-15	Well 04	23.09.25.324	1968	--	650	500	86	414
TOTAL (gpm)[b]					5900			
TOTAL (afy)[c]					5710			
Columbus								
M-584	North	28.08.27.411	1964	12	NR* 85	310	149.5	160
M-1420	South	28.08.34.243	1970	10	NR* 103	655	109	546
M-1420-S	South	28.08.34.424	1995	12	350	832	138	694
TOTAL (gpm)[b]					538			
TOTAL (afy)[c]					520			

[a] Water column = well depth minus depth to water.

[b] TOTAL (gpm) = total yield in gallons per minute (gpm).

[c] TOTAL (afy) = total yield in acre-feet per year (afy), assuming 60 percent production time.

NR* = no reported well yield, estimated yield from maximum reported diversion.

Table 2-2. Estimated drawdowns and remaining water columns at 2020, 2040, and 2060 in municipal wells of the City of Deming and Columbus under projected diversions for irrigation, commercial, industrial, and municipal use (remaining water column is derived from measured water level or model drawdown, which ever is greater)

OSE well/file number	**Well No.**	**Well Depth (ft)**	**Estimated drawdown in well (ft)**			**Remaining water column (ft)**			**Remaining water column (%)**		
			2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
Deming											
M-299-S	Well 06	400	182	222	287	119	**48**	**(-52)**	40	**16**	**0**
M-299-S-2	Well 03	571	131	161	202	300	270	229	70	63	53
M-299-S-4	Well 11	484	157	186	231	201	172	109	56	48	**30**
M-299-S-5	Well 05	400	99	116	141	246	210	171	71	61	50
M-299-S-6	Well 01	569	167	202	251	273	238	164	62	54	37
M-299-S-7	Well 02	493	183	225	292	201	138	**36**	52	36	**9**
M-299-S-8	Well 07	500	163	194	237	231	180	109	59	46	**28**
M-299-S-10	Well 10	500	141	175	217	240	206	160	63	54	42
M-299-S-11	Well 08	597	139	173	216	348	314	258	71	64	53
M-299-S-12	Well 09	500	144	172	214	259	212	142	64	53	35
M-299-S-13	Well 12	445	126	154	191	214	186	125	63	55	37
M-299-S-15	Well 04	500	138	172	217	276	224	154	67	54	37
Wells with less than 100 ft water column						**0**	**1**	**2**			
Wells with 30% or less water column									**0**	**1**	**4**
Columbus											
M-584		310	300	362	446	**(-189)**	**(-290)**	**(-427)**	**0**	**0**	**0**
M-1420		655	303	365	450	153	**52**	**(-86)**	34	**12**	**0**
M-1420-S		832	367	492	662	266	102	**(-121)**	42	**17**	**0**
Wells with less than 100 ft water column						**1**	**2**	**3**			
Wells with 30% or less water column									**1**	**3**	**3**

Table 3-1. Estimated drawdowns and remaining water columns at 2020, 2040, and 2060 in existing irrigation wells with water use planned for the proposed Duke Energy Luna Energy Facility under projected diversions for irrigation, commercial, industrial, and municipal use (remaining water column is derived from measured water level or model drawdown, which ever is greater)

OSE Permit Number	Well Depth (ft)	Estimated drawdown in well (ft)			Remaining water column (ft)		
		2020	2040	2060	2020	2040	2060
DUKE ENERGY							
M-454	550	164	192	215	210	181	158
M-460	300	164	193	216	**(-15)**	**(-44)**	**(-67)**
M-462-A	745	160	189	212	427	398	375
M-545	409	161	190	212	102	**73**	**51**
M-486	205	157	183	204	**(-118)**	**(-144)**	**(-165)**
M-526	500	179	212	239	147	113	**87**
M-526-A	398	180	213	240	**47**	**14**	**(-13)**
M-448	370	233	269	300	**(-7)**	**(-68)**	**(-120)**
M-480-A	475	110	137	160	285	244	205
M-480	210	156	191	218	**(-53)**	**(-112)**	**(-158)**
M-483	445	161	195	223	128	**94**	**66**
M-531	401	183	220	250	**93**	**30**	**(-21)**
M-532	200	183	220	250	**(-137)**	**(-174)**	**(-222)**
M-456	315	203	243	275	**(-54)**	**(-94)**	**(-145)**
M-455	480	179	215	245	163	125	**74**
M-533	315	172	208	238	**(-20)**	**(-56)**	**(-86)**
M-478	500	179	218	249	201	135	**82**
M-166	280	143	166	190	**11**	**(-12)**	**(-36)**
M-1649	475	108	133	154	269	244	219
M-1715	372	104	128	150	183	157	120
Wells with less than 100 ft water column					**10**	**12**	**15**

Table 4-1. Selected information on wells in the East well field, City of Lordsburg. From: State Engineer Office files; Gordon (1994; table 3)

State Engineer Office file/well number	Location (T.R.S.qqq)	Year drilled	Casing diameter		Yield (gpm)	Well depth (feet)	Depth to water when drilled (feet)	Initial water column[a] (feet)
			In.	feet				
LV-269-S	23.18.02.22	1943	16	1.33	350	420	90[b]	330
LV-269-S-2	23.18.02.222	1973	14	1.17	585	410	117.4	293
LV-269-S-3	23.18.02.22	1973	14	1.17	735	500	128.85	371
LV-269-S-4	23.18.02.22	1998	14	1.17	830	525	141	384
TOTAL (gpm)[c]					2500			
TOTAL (afy)[d]					2420			

[a] Initial water column = well depth minus depth to water when drilled.
[b] Estimated water level in area from Morgan and others (1942).
[c] TOTAL (gpm) = total yield in gallons per minute (gpm).
[d] TOTAL (afy) = total yield in acre-feet per year (afy), assuming 60 percent production time.

Table 4-2. Selected information on wells at the Lordsburg Power Plant and the Pyramid Facility. From: State Engineer Office files.

State Engineer Office file/well number	Location (T.R.S.qqqq)	Year drilled	Casing diameter (inches)	Yield (gpm)	Well depth (feet)	Depth to water when drilled (feet)	Initial water column[a] (feet)
Lordsburg Power Plant							
LV-310	22.18.34.1231	1967	16	500[b]	374	123	251
LV-311	22.18.34.1241	1967	16	585[b]	440	115	325
LV-312	22.18.34.1113	1949	16	395	290	90[c]	200
LV-313	22.18.34.1113	1953	16	457	297	90[c]	207
TOTAL (gpm)[d]				1937			
TOTAL (afy)[e]				1875			
Pyramid Facility							
LV-8	24.17.11.2444	1955	8	240[f]	917	85	832
LV-9	24.17.11.2242	1960	16	240[f]	801	90	711
LV-40	24.17.13.1422	1955	10	300	694	100	594
LV-40-S	24.17.13.1244	1965	12	300[g]	1015	105	910
LV-282	24.17.12.1422	1966	12	500[f]	880	85	795
LV-282-S	24.17.12.3422	1966	12	500[f]	895	80	810
TOTAL (gpm)[d]				2080			
TOTAL (afy)[e]				2010			

[a] Initial water column = well depth minus depth to water when drilled.
[b] Estimated based on 1992 production records.
[c] Estimated water level in area from Morgan and others (1942).
[d] TOTAL (gpm) = total yield in gallons per minute (gpm).
[e] TOTAL (afy) = total yield in acre-feet per year (afy), assuming 60 percent production time.
[f] Estimated minimum yield from amount of water right, assuming 60 percent production time.
[g] Estimated based on comparison with well LV-40.

Table 4-3. Estimated drawdowns in feet from projected pumping in the years 2020, 2040, and 2060 at wells in the East well field (City of Lordsburg), and estimated remaining water columns in feet and as percentage of initial water column in the well.

Well number	**Estimated drawdown in well (feet)**			**Remaining water column (feet)**			**Remaining water column (percent of initial water column)**		
	2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
LV-269-S	76	91	106	268	253	238	78	74	69
LV-269-S-2	76	92	107	254	238	223	77	72	67
LV-269-S-3	75	91	107	217	201	185	74	69	63
LV-269-S-4	74	91	107	296	280	264	80	75	71
Wells with less than 200 ft water column				**0**	**0**	**1**			
Wells with less than 100 ft water column				**0**	**0**	**0**			
Wells with 50% or less water column							**0**	**0**	**0**
Wells with 30% or less water column							**0**	**0**	**0**

Table 4-4. Estimated drawdowns in feet from projected pumping in the years 2020, 2040, and 2060 at wells Lordsburg Power Plant and the Pyramid Facility, and estimated remaining water columns in feet (ft) and as percentage of initial water column in the well (%).

Well number	**Estimated drawdown in well (ft)**			**Remaining water column (ft)**			**Remaining water column (%)**		
	2020	**2040**	**2060**	**2020**	**2040**	**2060**	**2020**	**2040**	**2060**
Lordsburg Power Plant									
LV-310	76	92	107	175	159	144	70	63	57
LV-311	77	94	109	248	231	216	76	71	66
LV-312	74	90	105	126	110	**95**	63	55	48
LV-313	74	90	105	133	117	102	64	57	49
Wells with less than 200 ft water column				**3**	**3**	**3**			
Wells with less than 100 ft water column				**0**	**0**	**1**			
Wells with 50% or less water column							**0**	**0**	**2**
Wells with 30% or less water column							**0**	**0**	**0**
Pyramid Facility									
LV-8	91	109	126	741	723	706	89	87	85
LV-9	91	109	125	620	602	586	87	85	82
LV-40	95	113	130	499	481	464	84	81	78
LV-40-S	95	113	130	815	797	780	90	88	86
LV-282	91	109	125	704	686	670	89	86	84
LV-282-S	95	113	130	715	697	680	88	86	84
Wells with less than 200 ft water column				**0**	**0**	**0**			
Wells with less than 100 ft water column				**0**	**0**	**0**			
Wells with 50% or less water column							**0**	**0**	**0**
Wells with 30% or less water column							**0**	**0**	**0**

PLATES