GROUNDWATER MODEL OF THE MIMBRES BASIN, LUNA, GRANT, SIERRA AND DOÑA ANA COUNTIES, NEW MEXICO

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1. INTRODUCTION

A three-dimensional groundwater flow model of the Mimbres Basin has been developed to be used as a tool in water-use management and administration. This model is to be used to evaluate the availability of water and the effects of proposed water rights appropriations on existing groundwater rights.

The New Mexico Office of the State Engineer (OSE) has been using a numerical model developed by the OSE in the late 1970s for water rights administration in the Mimbres Basin. A subsequent model of the basin was developed by the U. S. Geological Survey (USGS) in 1994 but was never adopted by the OSE for use in water rights administration, primarily because of uncertainties in the historical pumping inputs to that model.

The model described in this report was developed to improve on several aspects of the existing model. These include:

- Basin geometry. Better basin geometry is available as a result of geophysical surveys conducted in the basin. The geophysical surveys provide a much more detailed configuration of the basin than was previously available.

- Basin geology. Recent work on alluvial basins in New Mexico has produced improved geological maps and cross sections of the basin-fill material which could be incorporated in a new model.

- Pumping history. Pumping rates from 1975 to 2005 were developed using Landsat imagery to estimate irrigated acreage from which pumping rates were calculated. This methodology provided pumping rates which are believed to be more accurate and span a longer period than the estimates provided by other records and thus enable a better calibration of the new model.

- Model accuracy. Faster computers and better software have enabled the construction of a new model with a finer grid, better calibration, and incorporation of available electronic data such as topography, rivers, geology, well locations and water levels.

2. HYDROGEOLOGY

The hydrogeology of the Mimbres Basin has been described by Hansen (1994) and the New Mexico Water Resources Research Institute (WRRI) et al. (2000). Trauger (1972) provided a detailed description of the geology and water resources of Grant County, New Mexico.

The basin, shown on Figure 1, is defined primarily as a surface water basin and covers parts of Luna, Grant, Sierra and Doña Ana counties in southwestern New Mexico and extends south into Mexico. The groundwater model extent corresponds to the watershed boundary. The OSE has defined an administrative basin, also shown on Figure 1, which corresponds closely with the watershed boundary except for an area on the east side of the basin towards Las Cruces. This area is not explicitly covered by the model presented in this report because it is outside the area of saturated basin-fill alluvium. The OSE administrative basin does not extend into Mexico, whereas the surface water and model boundaries do.

Reeds Peak is the northern-most and highest point in the basin. Southeast of Reeds Peak, the basin boundary passes through the Black Range and Mimbres Mountains to the Goodsight Mountains. The boundary extends northeast to the Sierra de las Uvas, then south to the West Potrillo Mountains. The basin extends into Mexico and includes the Los Muertos Basin. On the southwest, the basin is bounded by Sierra Alta, the Carrizalillo Hills and the Cedar Mountains. The boundary follows the Continental Divide northward across the Antelope Plains, the Big Burro Mountains and northeast through the Pinos Altos Range back to Reeds Peak. In all, the basin encompasses approximately 5,140 square miles, 4,410 of which are in New Mexico.

2.1. Geology

Figure 2 shows the area of basin-fill alluvium within the Mimbres Basin. The northern part of the basin contains a series of north northwesterly-trending mountains, including the Big Burro Mountains, the Pinos Altos Range, the Black Range, the Mimbres Mountains and the Cooke Range. These mountains consist of Precambrian intrusive and metamorphic rocks, Paleozoic sediments, and Cretaceous-Tertiary intrusive, volcanic and sedimentary rocks.

The southern part of the basin contains isolated exposures of the basin bedrock in the Cedar, Victorio, Black, Florida and Tres Hermanas Mountains. These mountains consist of Precambrian intrusive and metamorphic rocks, Paleozoic sediments, and Cretaceous-Tertiary intrusive, volcanic and sedimentary rocks. Some areas in the southern part of the basin, particularly in the West Potrillo Mountains and the area south of the Tres Hermanas Mountains are dominated at the surface by late Tertiary or Quaternary basalt flows which are interbedded with basin-fill alluvium.

The basin itself consists of a number of sub-basins filled with deposits of various geologic units, which in this report are collectively referred to as basin-fill alluvium. Figure 2 shows thickness contours of the basin-fill alluvium. The basin configuration shown on Figure 2 was largely derived by interpretations performed by Heywood (2002) using gravity surveys. The basin configuration was modified based on surface geologic mapping, cross-sections presented in WRRI et al. (2000) and lithologic logs from deep drill holes available from the New Mexico Oil Conservation Division. The basin fill has a maximum thickness of slightly over 4,000 feet near Deming. Other areas with significant thickness greater than 2,000 feet are southeast and southwest of the Florida Mountains and beneath the San Vicente Arroyo between Silver City and Deming.

For the purposes of this groundwater model, the basin-fill alluvium was divided into two units, an upper unit and a lower unit. The source of the upper and lower demarcation is from a technical completion report from the New Mexico Water Resources Research Institute (2000). The upper unit corresponds to sediments classified as Upper Gila Group, which is also referred to as the Upper Santa Fe Group, and various surface alluvial and fluvial deposits. The lower unit corresponds to sediments classified as Lower to Middle Gila Group also called the Lower to Middle Santa Fe Group. The primary difference between the upper and lower units is that the lower unit is more indurated than the upper unit.

2.2. Hydrology

Precipitation. Precipitation ranges from about 9 inches annually at the lower elevations (Deming and Columbus) to about 25 inches in the higher elevations of the Black Range. Table 1 presents average monthly temperatures and precipitation amounts for Columbus, Deming and Fort Bayard, near Silver City. Data in Table 1 were obtained from the Western Regional Climate Center website.

Surface Water. The only major perennial stream in the basin is the upper reach of the Mimbres River. The river starts in the Black and Pinos Altos ranges and flows south to Faywood at which point it emerges from the bedrock of the mountains and flows out onto the basin-fill alluvium. The river channel passes Black Mountain and ends about 10 miles east of Deming. The river is a losing stream after it passes Faywood and only rarely flows past Deming. After Faywood, losses from the stream to the aquifer occur by infiltration through unsaturated sediments. There is not a direct connection of the stream to the aquifer. The USGS maintained three stream gaging stations on the Mimbres River between October 1, 1963 and September 30, 1968. The locations of the gaging stations are shown on Figure 1. Flows during this period are summarized in Table 2.

Infiltration and recharge to groundwater in the basin fill takes place in the Mimbres River channel downstream from Faywood. The decrease in flows between Faywood and Spalding is a measure of the amount of recharge from the river to the groundwater in the basin-fill alluvium. The recharge between Faywood and Spalding is approximately 3,932 acre-feet/year or 394 acre-feet/year/mile given the distance between the two points of 9.98 miles. Between 1963 and 1968, flows were observed at Faywood on approximately 99.4% of the days and at Spalding on approximately 19.1% of the days.

The decrease in flows between Spalding and the Wamel Canal is also a result of infiltration of the river flows. However, the flows measured at Wamel Canal also include an additional contribution from flows in the San Vicente Arroyo which enter the Mimbres River during times of high surface water flows. More recharge is taking place between Spalding and the Wamel Canal than that indicated by the difference between the flows at Spalding and the Wamel Canal. The minimum amount of recharge between Spalding and the Wamel Canal is the difference between the two adjusted flows or 3,501 acre-feet/year. An estimated maximum recharge can be obtained by assuming that recharge takes place at the same rate downstream from Spalding as it does upstream from

Spalding (394 acre-feet/year/mile as calculated above). The distance from Spalding to the Wamel Canal is approximately 14.6 miles and a maximum recharge amount is approximately 5,752 acre-feet/year.

The flows measured at the Wamel Canal are a measure of the amount of recharge taking place in the Mimbres River channel downstream from the Wamel Canal because there are no major tributaries entering the river below the Wamel Canal. Flows measured at the Wamel Canal infiltrate over the reach of the river channel extending approximately 10 miles east of Deming. The recharge below Wamel Canal is approximately 2,794 acre-feet/year, or about 279 acre-feet/year/mile. Flows were measured at the Wamel Canal on approximately 8% of the days between 1963 and 1968.

The Mimbres River upstream from Faywood flows through a relatively narrow valley bounded by bedrock. Flow in the river is sustained by snowmelt and rainfall runoff and by inflows of groundwater. The river is believed to be in good hydraulic communication with the alluvium in the valley. No attempt was made to model groundwater in the alluvium upstream from Faywood due to the relatively small scale of the river valley and because this portion of the river, being bounded by bedrock, does not interact with the main portion of the Mimbres Basin. The net effects of the contributions by the Mimbres River on recharge to the main portion of the Mimbres Basin are combined in the streamflow measurements at the Faywood gage.

San Vicente Arroyo is the major drainage in the northwestern portion of the basin. The arroyo is an ephemeral stream for most of its length. The USGS maintains a stream flow gage on the arroyo near Silver City but has never had a gage near the confluence of San Vicente Arroyo and the Mimbres River. There are numerous tributaries to San Vicente Arroyo between the USGS gage and the confluence with the Mimbres River. As a result, no good measurements are available to estimate the amount of recharge to the groundwater system made by San Vicente Arroyo and its tributaries.

Evaporation. Net lake evaporation in the Mimbres Basin ranges from a maximum rate of 60 to 70 inches per year at the lower elevations to a minimum of 10 to 20 inches per year at the higher elevations (NM Interstate Stream Commission and OSE, 2002). Net lake evaporation is defined as gross lake evaporation minus annual precipitation.

2.3. Groundwater

In general, prior to development of the basin, groundwater in the Mimbres Basin was recharged by mountain-front recharge and recharge from the Mimbres River primarily in the northern portion of the basin. Groundwater flowed to the south. The basin was considered to be closed and groundwater losses from the basin occurred by evapotranspiration.

Figure 3 shows a predevelopment water level map of the basin indicating the generally southerly flow of groundwater. Water levels on Figure 3 were obtained from data presented in Darton (1916) and from the U.S. Geological Survey's Ground Water Site

Inventory database. The predevelopment water level map is based on water level measurements in wells completed in the upper 200 feet of the saturated zone. Water levels presented on Figure 3 were those measured prior to 1916, from Darton (1916), or were judged to represent water levels in an area prior to significant development.

Deflections in the predevelopment water level contours indicate that significant areas of mountain-front recharge are present on both sides of the San Vicente Arroyo, around the Cooke Range, around the Florida Mountains, and along the West Potrillo Mountains. Additional recharge takes place in the upper portion of White Rock Canyon on the western side of the basin.

Natural evapotranspiration takes place where groundwater levels are close to land surface, generally less than 40 to 50 feet. Prior to development of the basin, large areas of shallow groundwater were present south of Deming. The maximum rate of evapotranspiration in the basin equals the maximum net lake evaporation of 60 to 70 inches per year.

2.3.1. Aquifer Properties

A summary of aquifer tests of wells in basin-fill alluvium is presented in Table 3. These tests were performed as constant discharge tests of varying duration, primarily on production wells. Horizontal hydraulic conductivities were calculated from the transmissivities generally using the entire saturated thickness of alluvium observed at the well. The hydraulic conductivities were distributed approximately log-normally and the geometric mean of the conductivities was approximately 11 feet/day. The mean conductivity is probably significantly biased towards a high value relative to the true conductivity of the alluvium because:

- nearly all of the tests were performed on production wells which were installed preferentially in areas of high hydraulic conductivity,
- wells are screened only in zones of high productivity (although this factor was offset by using the entire saturated thickness to calculate conductivity from transmissivity), and
- wells were generally drilled only as deep as needed to obtain sufficient productivity.

As a result, the average of 11 feet/day probably represents an upper value of the conductivity of the basin fill. Kernodle (1992) suggests that typical basin-fill conductivities are in the range of 2 to 10 feet/day in closed-drainage basins, such as the Mimbres Basin.

No data were available regarding vertical hydraulic conductivities in the basin. Kernodle (1992) suggests that horizontal to vertical conductivity ratios vary from 200:1 to 1000:1.

An estimate of specific yield of 0.14 was provided by Hanson (1994) who estimated the consumptive use of water pumped between 1910 and 1970 and divided by the total volume of aquifer dewatered in that period.

2.3.2. Water Levels

Water levels measured in the Mimbres Basin were obtained from the U.S. Geological Survey's Ground Water Site Inventory. Water levels were used from wells which had sufficient construction information to assign them to a model layer. A database of water level measurements containing nearly 16,000 measurements from over 1400 wells was assembled. Measurements were collected between 1910 and 2006.

2.4. Groundwater Use

Groundwater pumped in the Mimbres Basin is used for agricultural irrigation, municipal and industrial uses and domestic water supplies. No attempt was made to quantify domestic pumping within the basin. Pumping in Mexico was quantified only for agricultural irrigation based on satellite imagery; no records were available for municipal, industrial or domestic uses.

2.4.1. Agricultural Irrigation

Irrigation began in the Mimbres Basin in the early 1900s. Significant expansion of the irrigated acreage occurred in the mid-1930s. Except for some occasional flood waters in the Mimbres River, all of the irrigation water in the main portion of the basin comes from groundwater pumping. Irrigation along the upper Mimbres River, upstream of Faywood, is primarily from surface water in the Mimbres River; however, the net effect of this water use is measured by the surface water gage at Faywood.

Table 4 presents estimated water consumption for irrigation between 1933 and 2005. The acreages in Table 4 for 1933, 1936 and 1940 came from maps published by White (1934), Theis (1939) and Conover and Akin (1942), respectively. Hydrographic survey maps from 1975 to 1982 provided the irrigated acreage for those years. The irrigated acreages were also estimated from satellite imagery analysis from 1975 to 2005. Irrigation pumping was determined from the irrigated areas identified by the Normalized Difference Vegetation Index (Bohannan Huston, 2006) and assumes that irrigation water was not pumped significant distances to the fields being irrigated. Satellite imagery was interpreted in conjunction with hydrographic survey maps that served to limit the potential areas evaluated for irrigation.

The consumptive irrigation requirements (CIRs) were calculated using software developed by the Office of the State Engineer (OSE) and documented by Wilson (1992). The program is based on the Soil Conservation Service modifications to the Blaney-Criddle method. Climate data used in the CIR calculations were based on the average of the Columbus and Deming data presented in Table 1. Additional climate data included the spring and fall days in which minimum temperatures were reached. These were based on data presented in Wilson (1992) for Deming.

The growing season information was input from file GS29 provided with the CIR program, corresponding to the Mimbres Basin in Luna County.

The percent daylight hours used in the CIR program is based on the latitude of the location for which CIRs are being calculated. A latitude of 32° 16’ corresponding to Deming was input to the program.

Individual crop acreages were obtained from the series of reports published by the Agricultural Experiment Station at New Mexico State University concerning irrigation water sources and cropland acreages (New Mexico State University, 1981). These acreages and the CIRs for years between 1939 and 2001 are presented in Table 5. The CIR used for administration is 1.6 acre-feet/acre, falling within the range of values given in Table 5. Two Farm Delivery Requirements (FDR) are used within the basin. From Township 18 South and north, the FDR is 2.7 acre-feet/acre; from Township 19 South and south, the FDR is 3.0 acre-feet/acre.

2.4.2. Municipal/Industrial Pumping

Municipal and industrial pumping was compiled from records maintained by the OSE-Deming office and, for the mines near Silver City, from a modeling report prepared by Hargis and Montgomery (1983). Municipal pumping records were obtained for Bayard, Columbus, Deming, Santa Clara, Silver City and Tyrone. The periods for which pumping records were available are summarized in Table 6. Generally, in earlier years, only total pumping from wellfields was available. In later years, meter readings for individual wells were available. Total pumping for municipal wellfield is summarized at five-year intervals in Table 7.

Industrial pumping is related to mining near Silver City. Pumping at individual wellfields is summarized at five-year intervals in Table 7.

2.4.3. Trends in Groundwater Use

As seen in Table 4, agricultural water use reached a maximum in the late 1970s and is currently only about 40 percent of its 1979 peak. Municipal and industrial use, shown in Table 7, increased until about 1990 and has remained relatively constant since then. Agricultural use has always exceeded municipal and industrial use. However, the gap has closed significantly due, primarily, to the decrease in agricultural use.

3. GROUNDWATER MODEL

The Mimbres Basin groundwater model was designed and run using Groundwater Vistas Version 5 developed by Environmental Simulations, Inc. Groundwater Vistas runs the U.S. Geological Survey MODFLOW 2000 code (Harbaugh et al., 2000).

3.1. Model Description

3.1.1. Model Dimensions

The extent of the model grid is shown on Figure 4. The north-south oriented grid contains 242 rows, 214 columns and three layers. The model cells are each 2,000 feet by 2,000 feet. The southwest corner of the grid is positioned at x=177,495.64 meters and y=3,483,603.78 meters in the NAD1983 UTM Zone 13N coordinate system and the Transverse Mercator projection.

The simulation runs through 16 stress periods. The first stress period, represents a predevelopment steady state. The subsequent 15 stress periods are each 5 years in length and represent a calibration period from January 1, 1931 through December 31, 2005.

The three layers of the model each vary in thickness. Layers have thicknesses greater than 0 only in areas where basin-fill alluvium is present. Bedrock is assigned as no-flow cells and is not simulated in the model. The total thickness of the model is based on the configuration previously shown on Figure 2.

The top of Layer 1was defined as the land surface elevation. The bottom of Layer 1 was defined as 200 feet below the predevelopment water table. In areas where the saturated alluvium was less than 200 feet thick, Layer 1 included the full thickness of the saturated alluvium. The total thickness of the combined saturated and unsaturated portions of Layer 1 ranged from 5 feet to 954 feet. Because Layer 1 was defined based on the location of the predevelopment water table, it crosses geologic contacts and included both the upper and lower units of the basin-fill alluvium. As described earlier, the upper unit of the basin-fill alluvium corresponds to sediments classified as Upper Gila Group, Upper Santa Fe Group, and various surface alluvial and fluvial deposits. The lower unit corresponds to sediments classified as Lower to Middle Gila Group or Lower to Middle Santa Fe Group.

The bottom of Layer 2 was defined as the deeper of:

- The bottom of the upper alluvium, or
- 200 feet below Layer 1 but not extending into the underlying bedrock.

Layer 2 ranged in thickness from 5 feet to 550 feet.

Layer 3, the bottom layer, included all the basin-fill alluvium below Layer 2. Because the bottom of Layer 2 was defined as including all the upper alluvium, if present, Layer 3 consisted entirely of lower alluvium. The thickness of Layer 3 ranged from 5 feet to 3,330 feet.

Figure 5 shows an east-west cross section along model row 97 through the City of Deming showing geologic units and model layers.

3.1.2. Boundary Conditions

Boundary conditions in the model included no-flow boundaries, mountain-front recharge, stream recharge, evapotranspiration and pumping wells.

<u>No-Flow Boundaries</u>. Model cells consisting of bedrock were assigned as no-flow cells. The basin is closed and is completely surrounded by no-flow cells. Additional no-flow cells were placed internally in the basin to simulate bedrock highs and mountains within the basin boundaries.

<u>Mountain-Front Recharge</u>

Locations of mountain-front recharge cells are shown, for Layer 1, in Figure 6. Mountain front recharge was simulated as constant flux cells using the recharge package. Recharge cells were located near the edges of the mountains in model Layer 1. In general, recharge cells were not placed immediately next to the mountain-front (no-flow cells) because the saturated thickness in these areas was small and the cells had a tendency to dry up during the model runs. This would lead to the recharge cells becoming inactive and prevent simulated recharge from taking place at that location.

Most mountain-front recharge takes place in the northern part of the basin. Flow rates for mountain-front recharge were initially obtained by calibrating a steady-state model to predevelopment water levels. These flow rates were revised after performing the transient calibration. Annual mountain-front recharge volumes are shown in Figure 6. The annual total simulated mountain-front recharge volume is 21,146 acre-feet.

<u>Mimbres River Recharge</u>

Locations of Mimbres River recharge cells are shown in Figure 6. Mimbres River recharge was simulated as recharge cells and only acted on Layer 1. Recharge rates were estimated based on the USGS stream gaging data described earlier in Section 2.2. The river was divided into four reaches:

1) from Faywood to Spalding,
2) from Spalding to Black Mountain
3) from Black Mountain to the Wamel Canal, and
4) from the Wamel Canal to about 10 miles east of Deming.

The annual simulated recharge volume from the Mimbres River to the basin-fill alluvium (downstream from Faywood) is 9,967 acre-feet.

The total model recharge of 31,113 acre-feet/year is about 1% of the average basin-wide precipitation. Recharge remains constant in the steady state and transient simulations.

Evapotranspiration

The potential for evapotranspiration was assigned to all active cells in Layer 1. Model cells with a simulated depth to water less than the assigned extinction depth of 40 feet could produce up to the maximum assigned evapotranspiration rate of 5 feet/year. This maximum evapotranspiration rate was based on the net lake evaporation rate determined by the New Mexico Interstate Stream Commission and the OSE (2002).

Pumping Wells

Agricultural irrigation, municipal and industrial pumping determined in section 2.4 of this report was assigned to model cells. Figure 7 shows groundwater pumping centers and simulated rates over the calibrated period of the model. Peak model pumping of 74,859 acre-feet/year occurs in 1976.

Irrigation pumping was assigned to model cells underlying the irrigated areas. The amount of pumping assigned to a cell was the product of the irrigated acreage within the cell and the CIR applicable to a particular stress period.

Municipal pumping was assigned to the model cells in which the production wells lay.

3.1.3. Calibrated Aquifer Properties

Figures 8 through 10 show the values of hydraulic conductivity assigned to the three layers of the calibrated model. The lower alluvium is assigned a single horizontal hydraulic conductivity of 1 feet/day. In most areas, the upper alluvium is assigned a horizontal hydraulic conductivity of 5 feet/day. A zone of hydraulic conductivity of 2 feet/day is assigned to the upper alluvium in an area northeast of the village of Columbus.

Hydraulic conductivities in the x-direction equaled those in the y-direction. The ratio of horizontal to vertical hydraulic conductivity was assigned a value of 200:1 based on the recommendation given in Kernodle (1992).

The calibrated zonation of the specific yield is shown in Figure 11. A specific yield of 0.10 is assigned for all of the lower alluvium. A large area of the upper alluvium is assigned a specific yield of 0.14. During model calibration, specific yield zones of 0.05 and 0.01 west and south of Deming were specified. A semi-confined storage of 0.001 is assigned east of the Village of Columbus. This area has been delineated as lacustrine in

Hanson and others (1994). A single specific storage of 1 x 10^{-6} ft^{-1} was assigned to the upper and lower alluvium.

3.1.4 Calibration Results

Figure 12 summarizes the steady state calibrated fit of simulated to observed water elevations. Calibration targets were largely taken from Darton (1916) and supplemented by water levels from the U.S. Geological Survey's Ground Water Site Inventory measured primarily in the 1950s. Some measurements in locations away from pumping areas were measured as recently as 1970. The model is generally well calibrated to steady state water elevations. Water elevations are better estimated away from the no-flow boundaries of the model.

Figure 13 shows the model cells with active evapotranspiration in the steady state simulation. In predevelopment, 31,113 acre-feet/year leaves the model area as evapotranspiration. Over the historical simulation, the areal extent and the rate of the evapotranspiration decrease. In 2005 the rate of evapotranspiration from the model is 12,911 acre-feet/year. Tables 8A and 8B summarize the model budget components for the steady state and the year 2005 simulation periods. Figure 14 shows the steady state and transient model flow components over the entire calibrated period.

Figure 15 shows the simulated depression of water levels from predevelopment in the year 1931 through the historical pumping period in 2005. In 2005 the depression has a depth of 120 feet in an area located 10 miles south of Deming.

Figure 16 shows the goodness of fit between observed and simulated water elevation hydrographs for selected wells. Calibration data for the transient simulation is from the U.S. Geological Survey's Ground Water Site Inventory. The priority of the transient calibration was simulating to the observed drawdown trends. This was coupled with a statistical evaluation of water elevations. For the 9949 observed transient water elevations, 50 % of the simulated values are within 20 feet of the observations and 89% are within 50 feet of the observations.

The model reasonably simulates the observed rate of drawdown in most areas of the model. There is some local variability. In a long-term well hydrograph 5 miles southwest of Deming, 24S.10W.12.341HRNA, drawdown is over-predicted in the simulation. Drawdown in other nearby wells is accurately simulated. Similarly, in the semi-confined area just west of Columbus, wells showing moderate rates of drawdown are interspersed with wells showing rapid rates of drawdown. The model is calibrated to the larger observed rates of drawdown.

The sensitivity of the calibration when model parameters are varied was examined. The most sensitive parameters are storage of the upper alluvial zone and recharge. Variations in these parameters by 20% change the average residual mean of the transient water elevations by 2 to 3 feet.

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TABLES

Table 1. Average Monthly Precipitation and Temperatures in the Mimbres Basin

	Meteorological Station					
	Columbus (292024) 1/1/1925 - 12/31/2005		Deming (292436) 1/1/1914 - 12/31/2005		Ft. Bayard (293265) 2/1/1897 - 12/31/2005	
Month	Precipitation (inches)	Temperature (°F)	Precipitation (inches)	Temperature (°F)	Precipitation (inches)	Temperature (°F)
January	0.48	43.7	0.44	41.8	0.87	38.7
February	0.44	48.0	0.53	46.2	0.87	41.5
March	0.38	54.3	0.38	51.5	0.70	46.0
April	0.24	62.2	0.23	59.0	0.39	53.1
May	0.22	70.7	0.25	67.5	0.47	61.0
June	0.44	79.9	0.45	76.8	0.78	70.3
July	2.00	81.5	1.78	79.7	3.20	72.5
August	1.85	79.1	1.96	77.6	3.30	70.8
September	1.31	73.9	1.25	72.0	2.05	66.0
October	0.89	63.5	0.88	61.5	1.25	56.6
November	0.50	51.2	0.48	49.4	0.76	46.0
December	0.64	43.7	0.73	42.1	1.04	39.2
	Total 9.39	Average 62.6	Total 9.36	Average 60.4	Total 15.68	Average 55.1

Table 2. Streamflows Along the Mimbres River

Station (USGS Station Number)	Measured Average Annual Flows 10/01/1963 – 9/30/1968 (acre-feet/year)	Adjusted Average Annual Flows[1] (acre-feet/year)
Faywood (8477500)	15,163	10,227
Spalding (8477530)	9,333	6,295
Wamel Canal (08478300 + 08478400[2])	4,143	2,794

[1] The long-term average flow at Faywood, measured from October 1930 to September 1955 and October 1963 to September 1968 (30 years), was 10,227 afy. Flows at Spalding and Wamel Canal were adjusted proportionally downward by 10,227/15,163 to compensate for the high flows that occurred during the 1963-1968 period.

[2] Flows measured in the Wamel Canal and the Mimbres River below the Wamel Canal were combined to yield an estimated total flow in the Mimbres River prior to any development.

Table 3. Summary of Aquifer Test Results

Test Date	Well Location[i]	Duration of Pumping (hours)	Pumping Rate (gallons per minute)	Drawdown (feet)	Well Depth (feet)	Static Water Level (feet below land surface)	Transmissivity ($feet^2$/day)	Hydraulic Conductivity (feet/day)[ii]	Source
---	18S.14W.12.313	4	11	89	320	167	5.7	0.04	Wilson & Company (2001)
May-79	19S.10W.27.234b	19	140	4	234	12	10,700	48	Geohydrology Associates (1979)
Oct-79	19S.14W.35.3	48	615	27	590	377	9,500	45	Water Resources Associates (1981)
Jan-05	20S.11W.7.334	2	830	26	255	65	17,900	94	Finch (2005)
Jul-05	20S.11W.7.413	8	165	12	294	84	14,600	70	Finch (2005)
Jul-05	20S.12W.12.134	17	150	41	400	52	700	2	Finch (2005)
Oct-80	20S.14W.1.1	24	700	26	1020	315	10,000	14	Water Resources Associates (1981)
Nov-51	24S.11W.11.211	48	280	50	202	108	670	7	Conover (1952)
Dec-51	24S.11W.12.324	48	374	21	200	102	4,300	44	Conover (1952)
Feb-51	24S.7W.4.421a	4	470	63	398	56	940	3	White and Guyton (1951)
Feb-51	24S.7W.9.241a	48	797	90	375	59	1,700	5	White and Guyton (1951)
Jun-42	24S.8W.6.11	24	450	7	235	48	14,000	75	Akin (1942)
Jun-42	24S.9W.1.21	24	400	8	235	54	15,600	86	Akin (1942)
May-42	24S.9W.1.22	24	365	81	234	49	1,500	8	Akin (1942)
May-41	24S.9W.6.431	14	465	43	1000	55	2,800	4 [iii]	Murray (1942)
Feb-53	25S.6W.5.311	48	540	65	230	74	1,900	12	Spiegel (1956)
Jan-54	25S.6W.8.112	48	650	95	1000	2	1,000	3 [iiii]	Spiegel (1956)
---	27S.8W.8.311	---	---	---	413	34	7,900	21	Blandford and Wilson (1987)
							Geometric Mean	11	

[i]Given as Township.Range.Section.1/4.1/4.1/4

[ii]Calculated using a saturated thickness of well depth minus static water level.

[iii]Calculated using a saturated thickness of alluvium of 790 feet.

[iiii]Calculated using a saturated thickness based on a screened interval of 375 feet.

--- = Unknown

Table 4. Estimated Consumption of Groundwater for Irrigation

Year	Acres Irrigated by Groundwater	Consumptive Irrigation Requirement (feet)	Acre-Feet of Groundwater Consumed
1933	5,894	1.59	9,371
1936	9,158	1.59	14,561
1940	12,295	1.59	19,549
1953	26,747	1.71	45,737
1975	41,123	1.64	67,442
1979	41,557	1.75	72,725
1986	22,676	1.75	39,683
1989	22,732	1.84	41,827
1995	23,319	1.82	42,441
2000	18,676	1.80	33,617
2005	15,650	1.80	28,170

Table 5. Irrigated Acreages by Crop and Consumptive Irrigation Requirement

	Year										
Crop	**1939**	**1949**	**1954**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2001**
Beans	4,600	2,937	6,211	1,000	350	2,200	1,180	360	0	0	784
Corn	400	170	1,186	500	1,500	3,000	4,400	1,500	900	2,500	1,920
Sorghum	2,300	1,219	3,404	12,700	18,000	26,000	9,400	5,600	2,500	2,100	2,297
Wheat	0	0	0	30	400	2,500	2,250	950	1,200	4,000	3,459
Spring Small Grains	150	330	344	2,050	3,600	4,500	1,870	2,200	1,400	1,180	1,110
Cotton	1,800	16,680	13,815	14,150	14,460	9,310	22,100	10,910	8,700	4,890	6,153
Vineyards	0	0	0	0	0	0	0	1,500	600	500	275
Planted Pasture	500	1,063	389	2,200	1,100	1,300	1,300	390	400	700	306
Onions	0	0	0	0	200	440	180	300	2,650	3,800	2,832
Chile	0	0	0	0	0	800	1,390	4,400	11,000	8,200	6,752
Misc Veges	750	30	205	130	1,950	150	50	350	700	1,900	3,574
Orchards	0	44	42	0	250	700	750	970	1,100	1,255	867
Alfalfa	0	315	1,272	1,400	1,800	2,200	1,600	1,700	2,300	2,700	1,888
Native Pasture	0	0	0	0	6,700	8,880	10,350	10,350	10,350	10,350	11,216
Total Acreage	10,500	22,788	26,868	34,160	50,310	61,980	56,820	41,480	43,800	44,075	43,433
Consumptive Irrigation Requirement (feet)	1.59	1.79	1.71	1.71	1.68	1.64	1.75	1.75	1.84	1.82	1.80

Table 6. Summary of Periods of Available Pumping Records

Municipal Pumping	
Town	**Period of Record**
Bayard	1983 - 2004 [1]
Columbus	1982 - 2004 [1]
Deming	1985 - 2005 [1]
Santa Clara	1978 - 2004 [2]
Silver City	1958 - 2004 [1]
Tyrone	1989 - 2004 [1]
Mine Pumping	
Wellfield	**Period of Record**
Apache	1952 - 1986[2], 1989 - 2004[1]
Baker	1952 - 1986[2], 1989 - 2004[1]
Bolton	1952 - 1986[2], 1989 - 2004[1]
Cron Ranch	1976 - 1983[2], 1993 - 2003[2]
Lower Whitewater	1952 - 1986[2], 1989 - 2004[1]
McCauley	1952 - 1986[2], 1989 - 2004[1]
McCauley 8	1983 - 1986[2], 1988 - 2004[1]
Moody	1979 - 1987[2], 1988 - 2004[1]
Stark	1952 - 1986[2], 1989 - 2004[1]
Warm Springs	1983 - 1986[2], 1989 - 2004[1]
Warm Springs 12	1983 - 1986[2], 1989 - 2004[1]
Yates	1988 - 2004[1]

[1] Meter records available for individual wells

[2] Records available for total wellfield only

Table 7. Municipal and Industrial Pumping

Year	Municipal Wellfields Annual Pumping (acre-feet)						Mine Wellfields Annual Pumping (acre-feet)												Total
Year	Bayard	Columbus	Deming	Santa Clara	Silver City	Tyrone	Apache	Baker	Bolton	Cron Ranch	Lower Whitewater	McCauley	McCauley 8	Moody	Stark	Warm Springs	Warm Springs 12	Yates	Total
1935																			
1940																			
1945																			
1950																			
1955	186.00			42.00			1,680.84		1,832.99						1,079.51				6,776.33
1960					622.37		1,977.89		2,369.12						652.05				7,581.42
1965	236.00			70.00	598.46	362.00	224.60	0.00	1,905.44						2,253.20				7,614.69
1970					1,122.78	368.00	1,992.38	470.93	2,274.93		0.00	0.00			1,912.68				10,111.69
1975	275.00				1,530.10	281.00	572.36	1,485.23	1,456.25		318.78	1,876.46		0.00	1,499.72				11,269.88
1980	275.00			238.01	1,486.19		710.01	1,188.18	1,238.90	199.62	391.23	1,506.96		1,028.79	1,036.04				11,278.92
1985	347.59	113.09	3,195.51	142.20	1,384.07		478.00	2,149.00	892.00		362.00	795.00	902.00	144.56	1,641.00	2,922.00	196.00		17,649.02
1990	305.37	125.75	3,282.27	241.74	1,881.53	2,050.11	1,135.64	1,150.98	1,122.53		338.78	1,644.92	3,257.43	1,923.97	1,109.57	2,719.76	118.15	705.16	25,103.66
1995	371.13	163.84	4,061.55	282.90	2,505.06	1,828.80	685.31	2,596.18	936.88	19.20	339.81	1,414.67	2,387.02	1,454.09	963.20	1,341.92	1.58	859.38	24,207.52
2000	356.69	213.76	4,101.67	245.17	2,020.41	1,438.15	787.41	1,305.18	623.96	16.68	274.54	2,387.80	2,186.92	1,518.65	1,151.86	2,119.45	472.79	862.21	24,083.30
2005			4,541.84																

Table 8A. Steady State Model Budget Components

Model In	Rate (acre-feet/year)
Mountain Front Recharge	21,146
Tributary Recharge	9,967
Total In	31,113

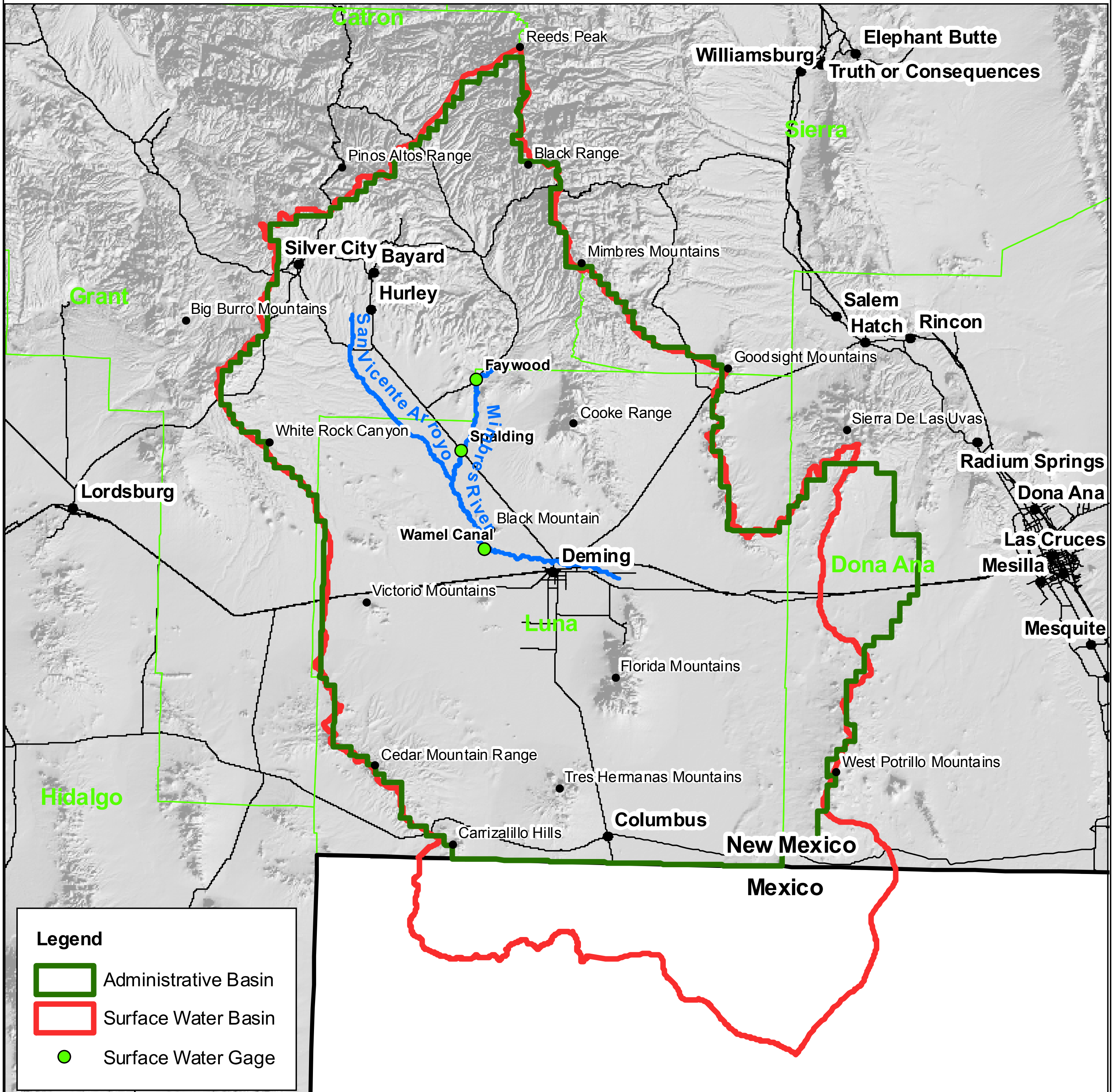
Model Out	Rate (acre-feet/year)
Evapotranspiration	31,113

Table 8B. Model Year 2005 Budget Components

Model In	Rate (acre-feet/year)
Mountain Front Recharge	21,146
Tributary Recharge	9,967
Storage Drawdown	23,371
Total In	54,484

Model Out	Rate (acre-feet/year)
Pumping (CIR)	33,916
Evapotranspiration	12,911
Storage Buildup	7,677
Total Out	54,505

FIGURES



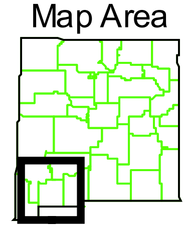
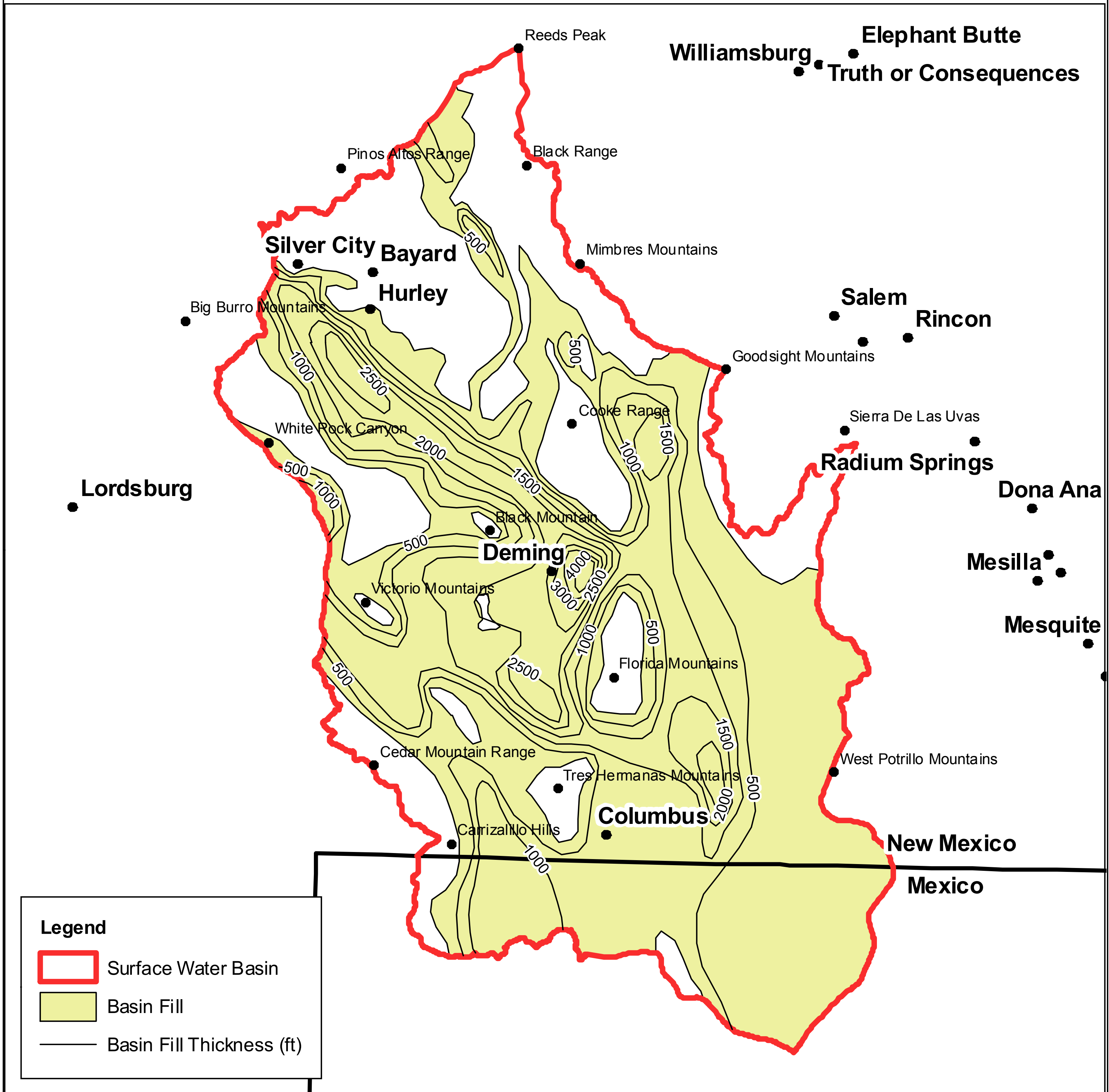


FIGURE 1
LOCATION OF THE MIMBRES BASIN

0 5 10 15 20 Miles

basin2.mxd



Contours of Thickness are modified from Heywood (2002)

The Contour Interval is 500-Feet

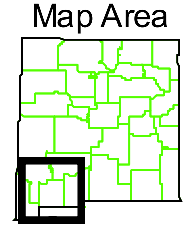
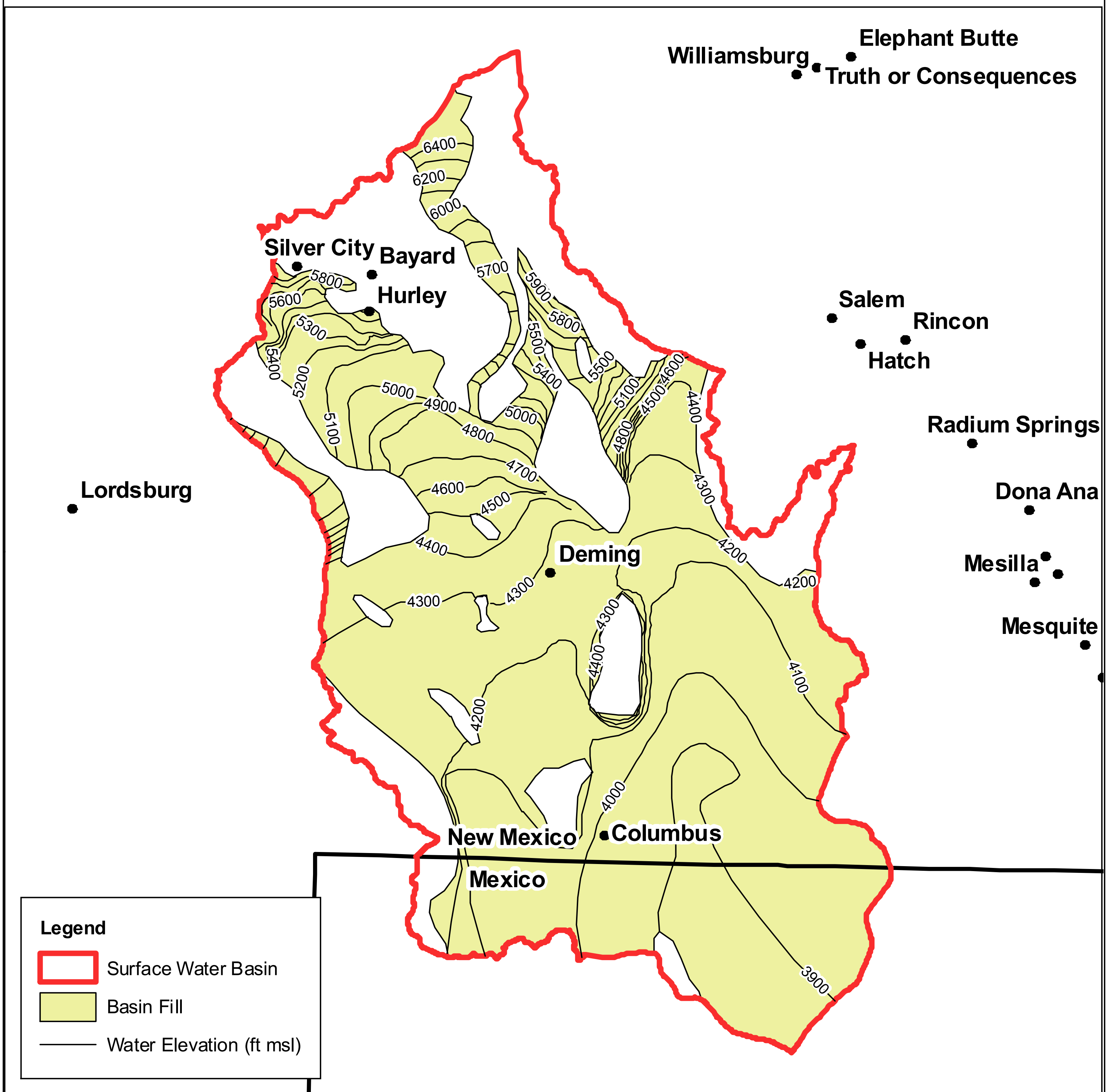


FIGURE 2
THE EXTENT AND THICKNESS OF THE BASIN FILL ALLUVIUM IN THE MIMBRES BASIN

Miles
0 5 10 15 20

basin_fill2.mxd

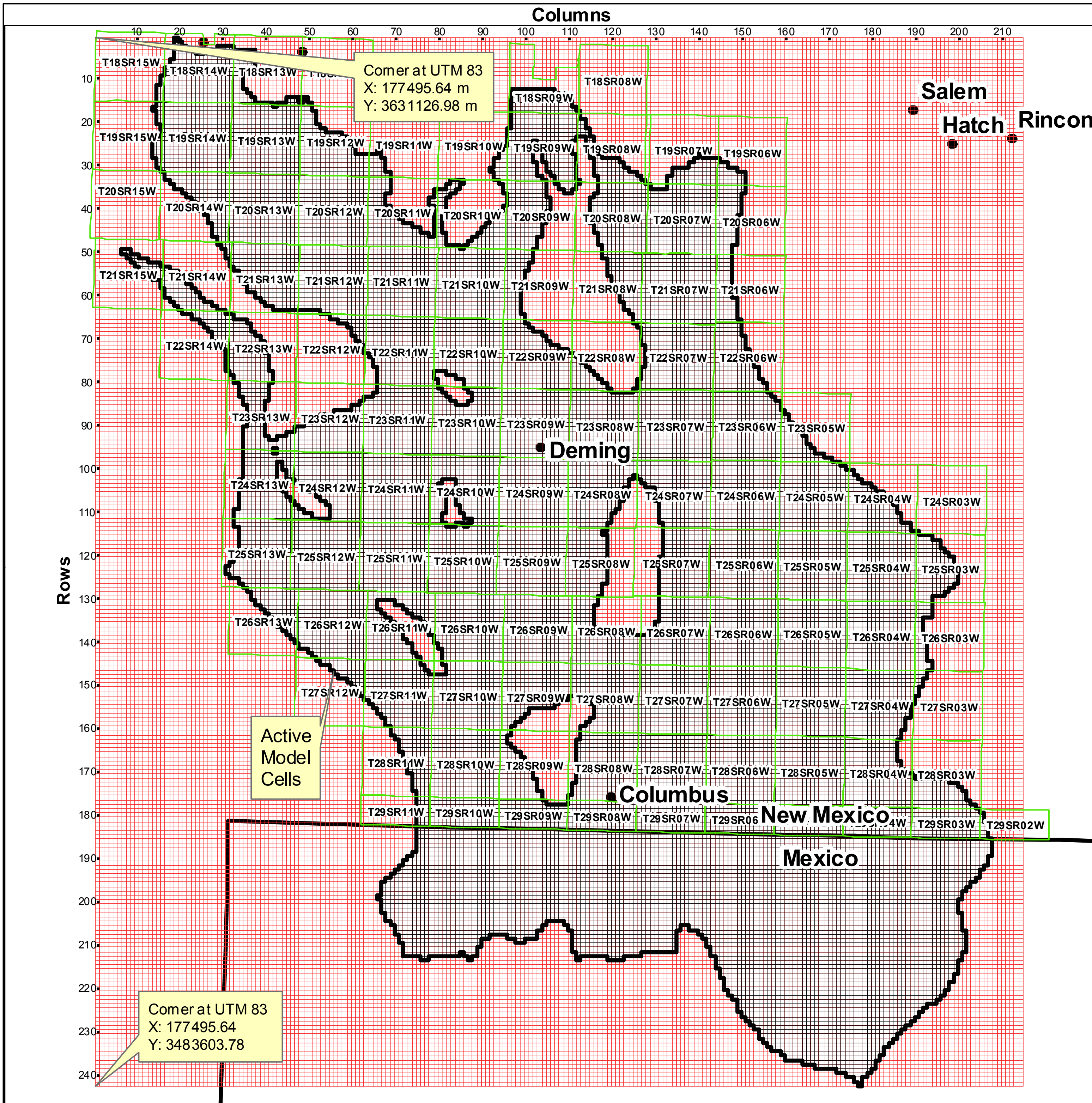


The Contour Interval is 100-Feet

FIGURE 3
PREDEVELOPMENT WATER ELEVATIONS IN THE MIMBRES BASIN

Miles
0 5 10 15 20

wl_predevel2.mxd



The model cell size is uniformily 2000 ft by 2000 ft
242 Rows and 214 Columns

Map Area

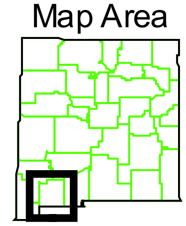
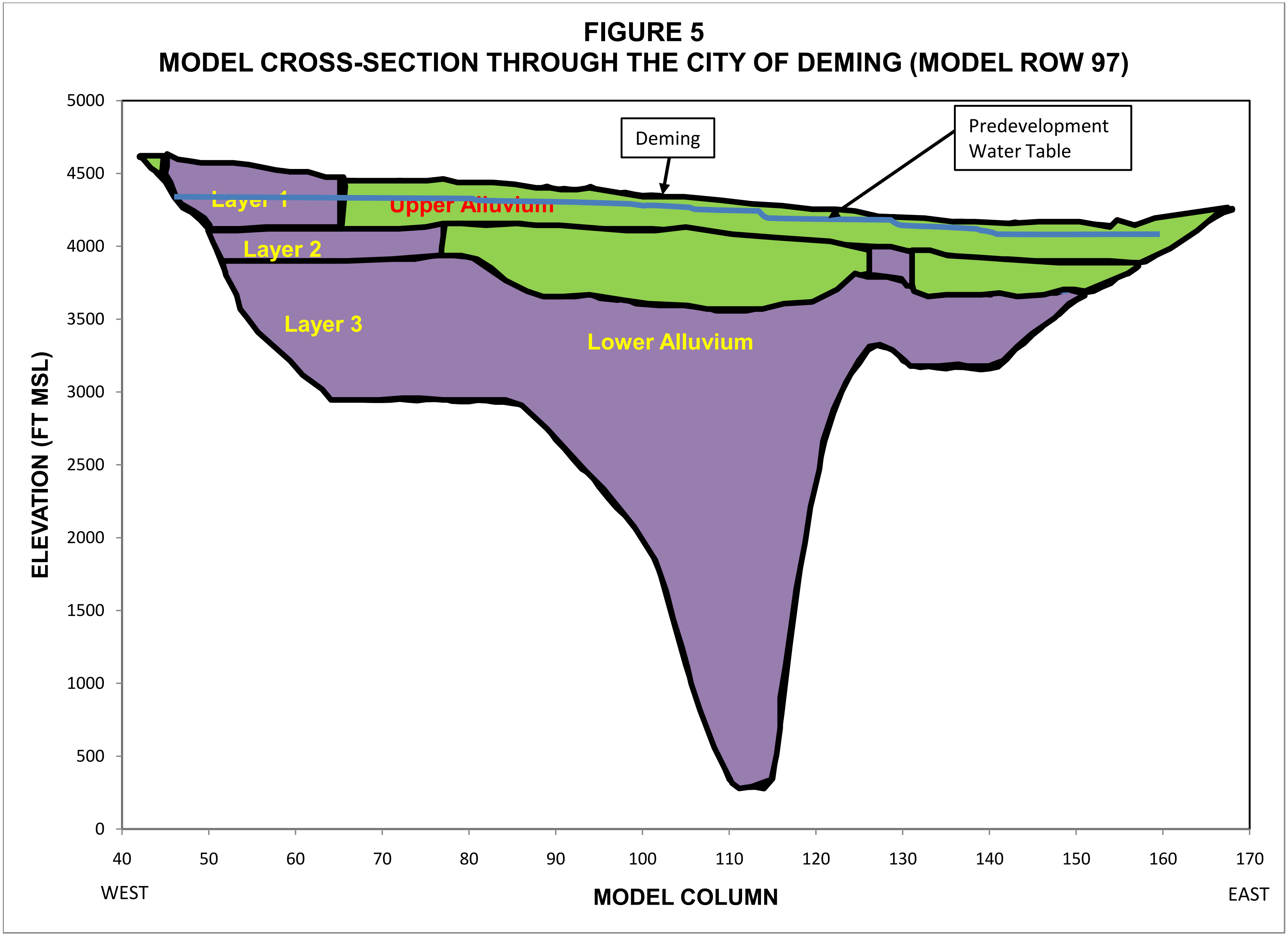


FIGURE 4
LOCATION AND EXTENT OF THE MIMBRES MODEL GRID

Miles
0 5 10 15 20

grid_extent2.mxd



row97_cross2.xlsx Chart2
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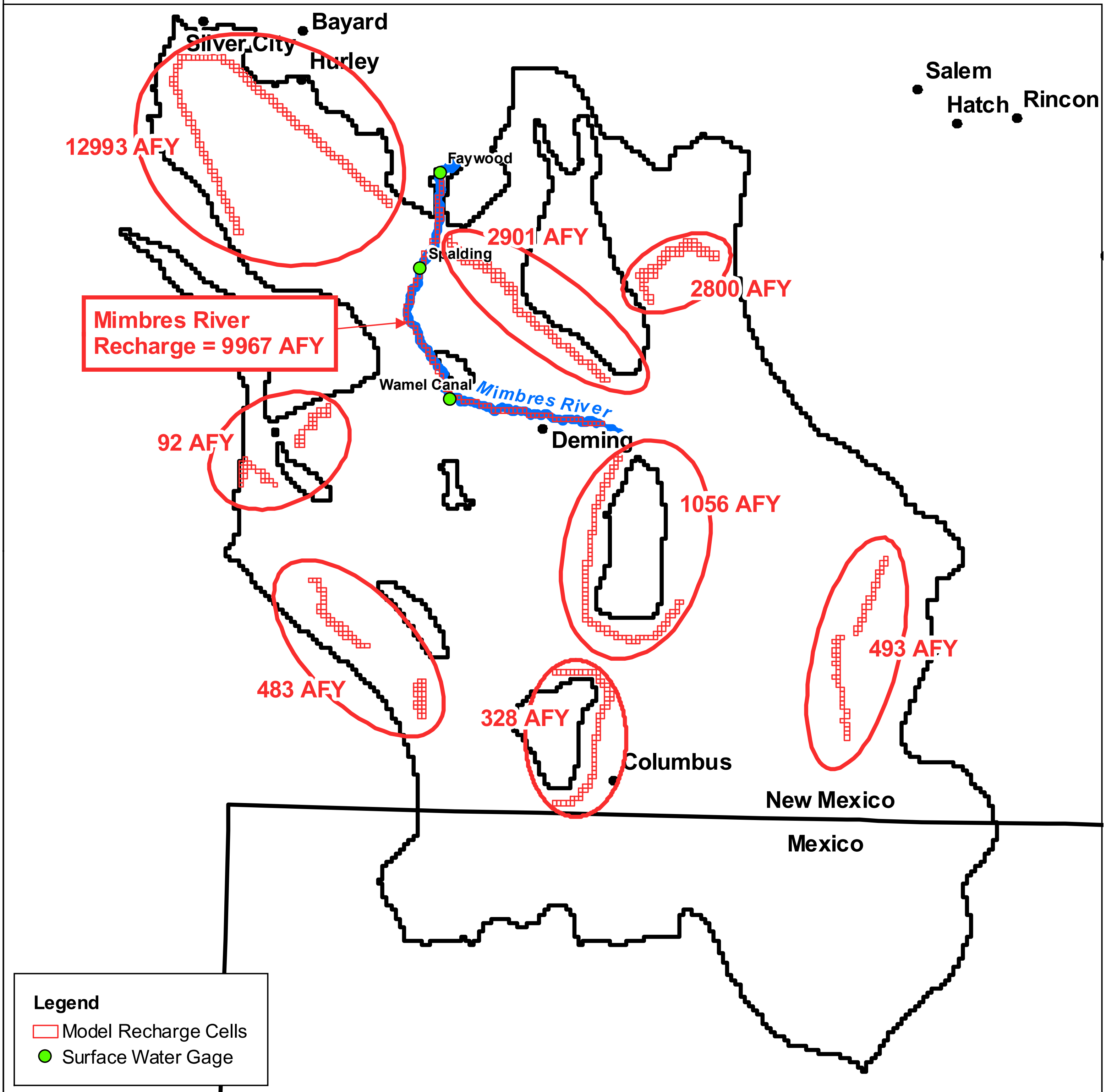
ejk



THE TOTAL SIMULATED RECHARGE EQUALS 31,113 AFY
FOR ALL MODEL STRESS PERIODS

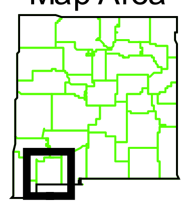
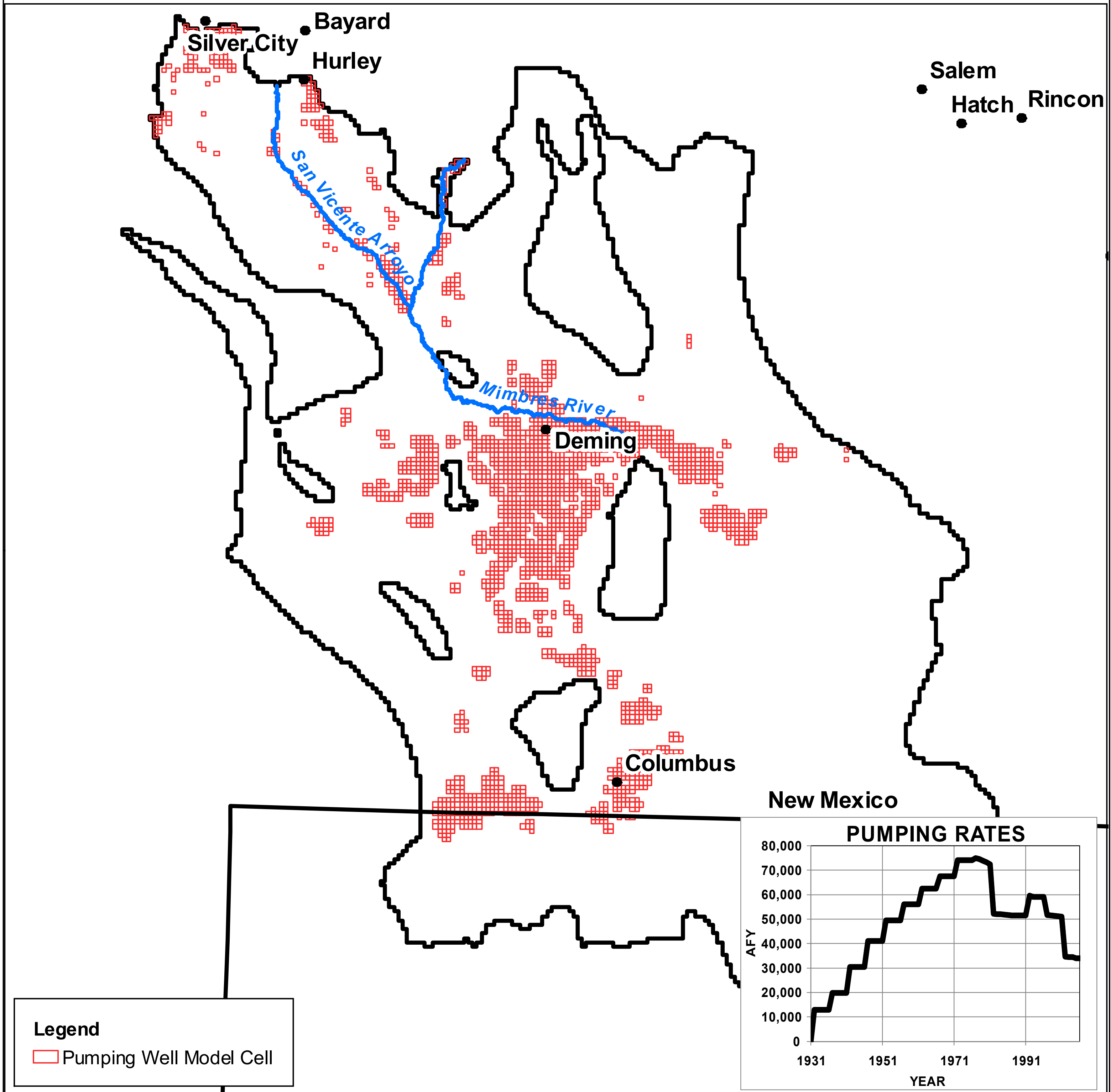


FIGURE 6
MOUNTAIN FRONT AND STREAM RECHARGE CELLS
IN THE MIMBRES MODEL

Miles
0 5 10 15 20

Recharge2.mxd



MODEL PUMPING CELLS SHOWN
ARE USED IN SOME BUT NOT ALL STRESS PERIODS

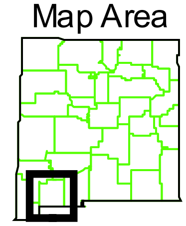
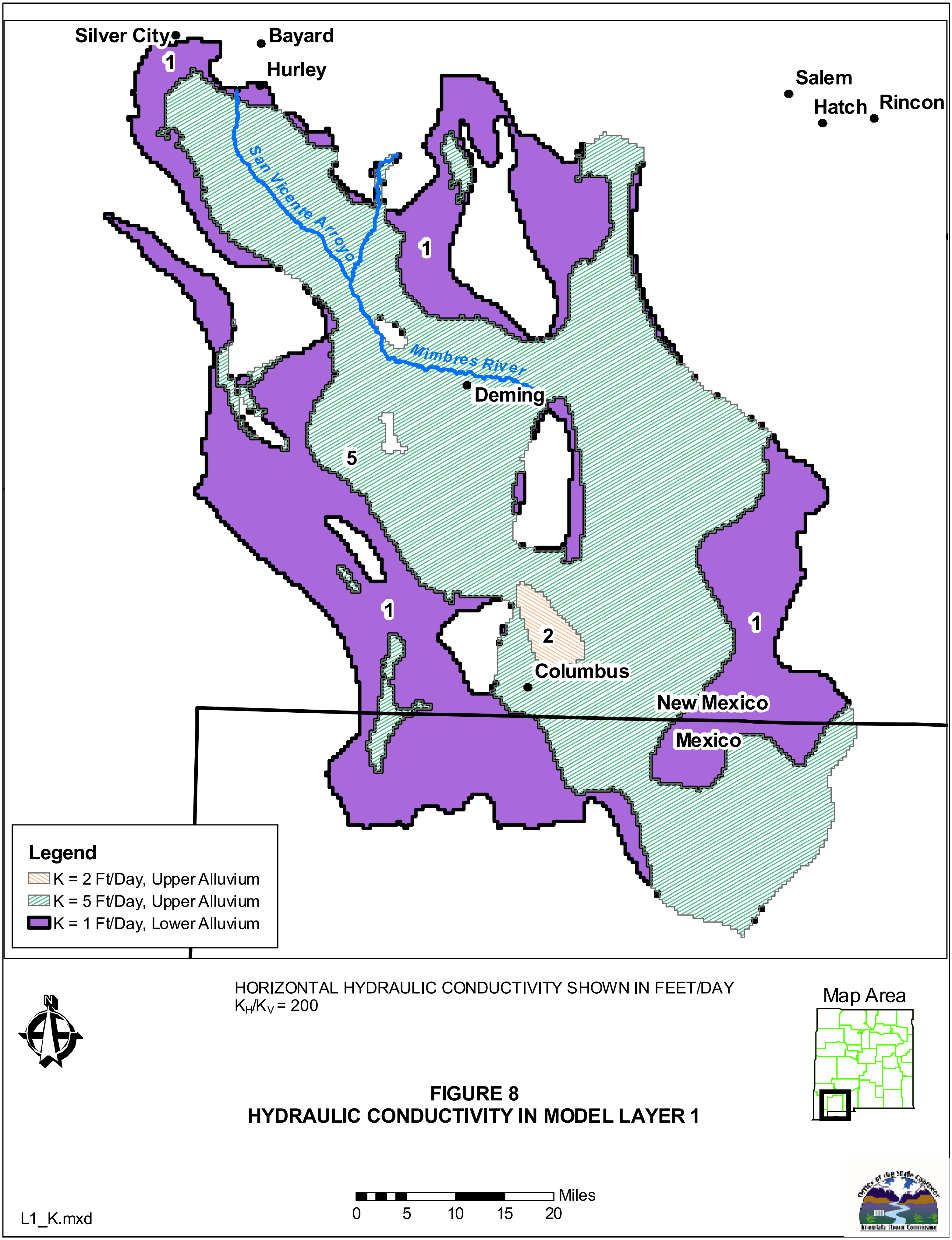


FIGURE 7
PUMPING CELLS IN THE MIMBRES MODEL

Miles
0 5 10 15 20

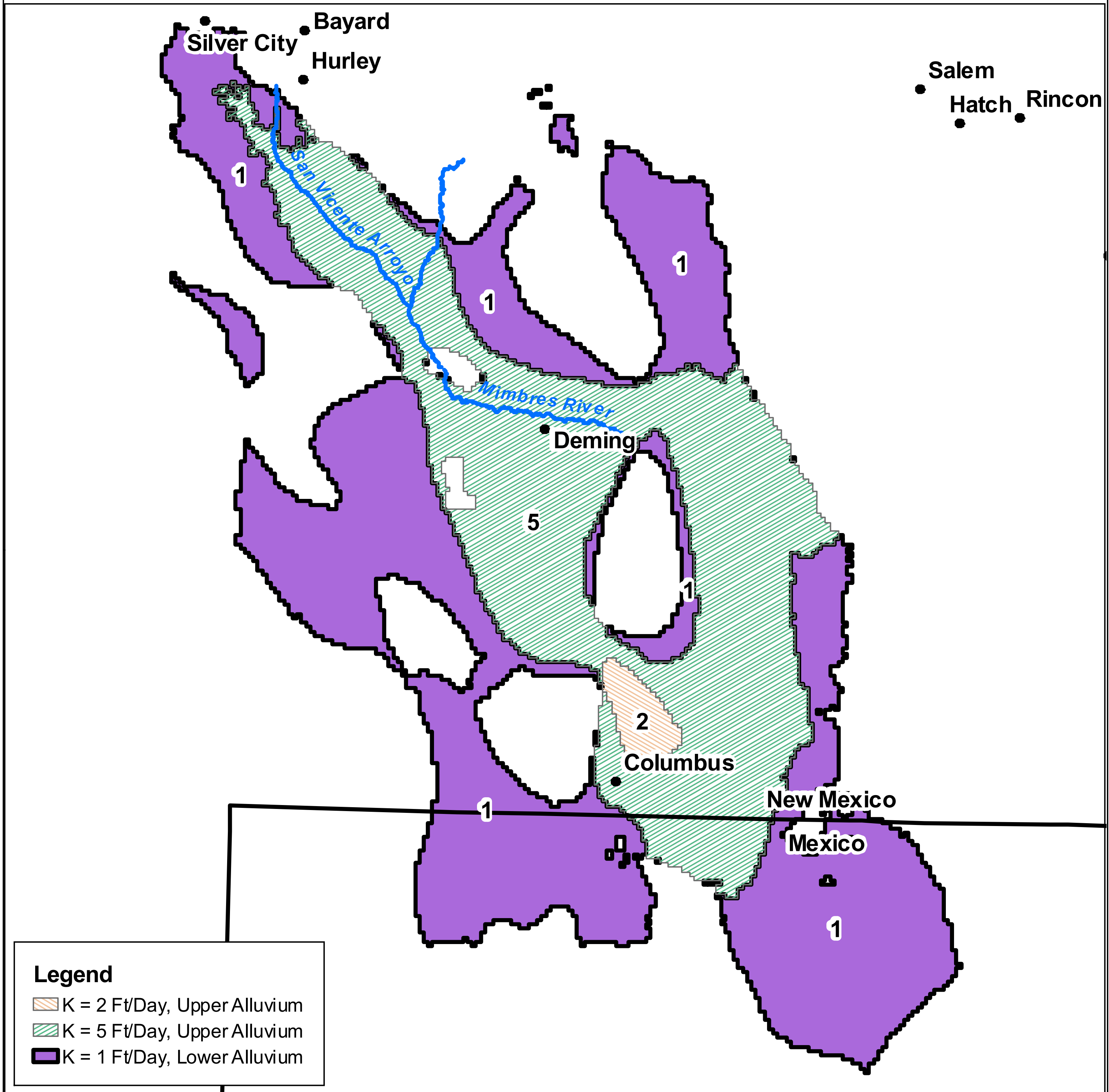
Pumping2.mxd



HORIZONTAL HYDRAULIC CONDUCTIVITY SHOWN IN FEET/DAY
$K_H/K_V = 200$

FIGURE 8
HYDRAULIC CONDUCTIVITY IN MODEL LAYER 1

L1_K.mxd



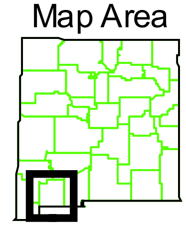
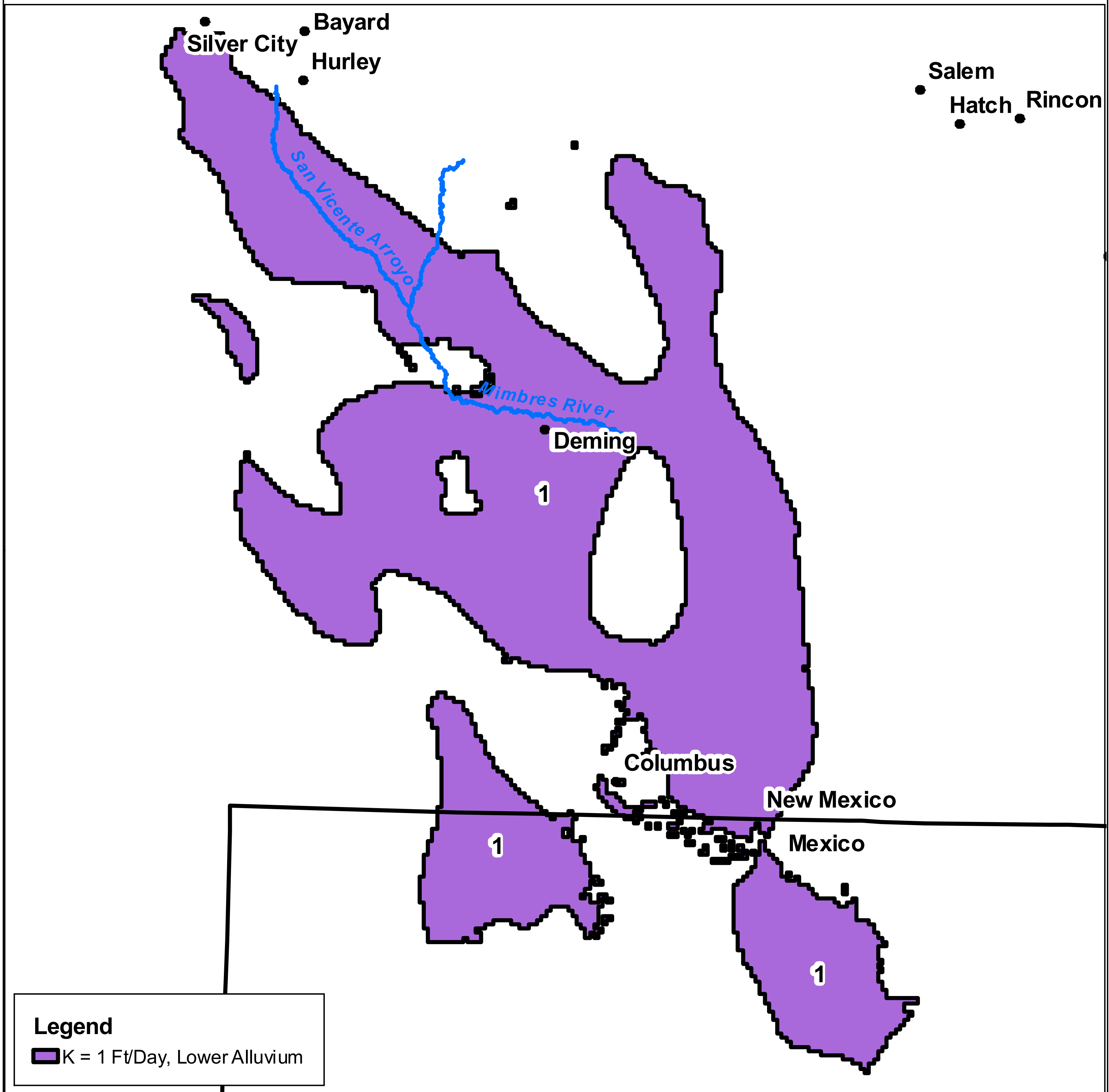


FIGURE 9
HYDRAULIC CONDUCTIVITY IN MODEL LAYER 2

L2_K.mxd



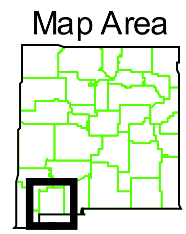


FIGURE 10
HYDRAULIC CONDUCTIVITY IN MODEL LAYER 3

L3_K.mxd

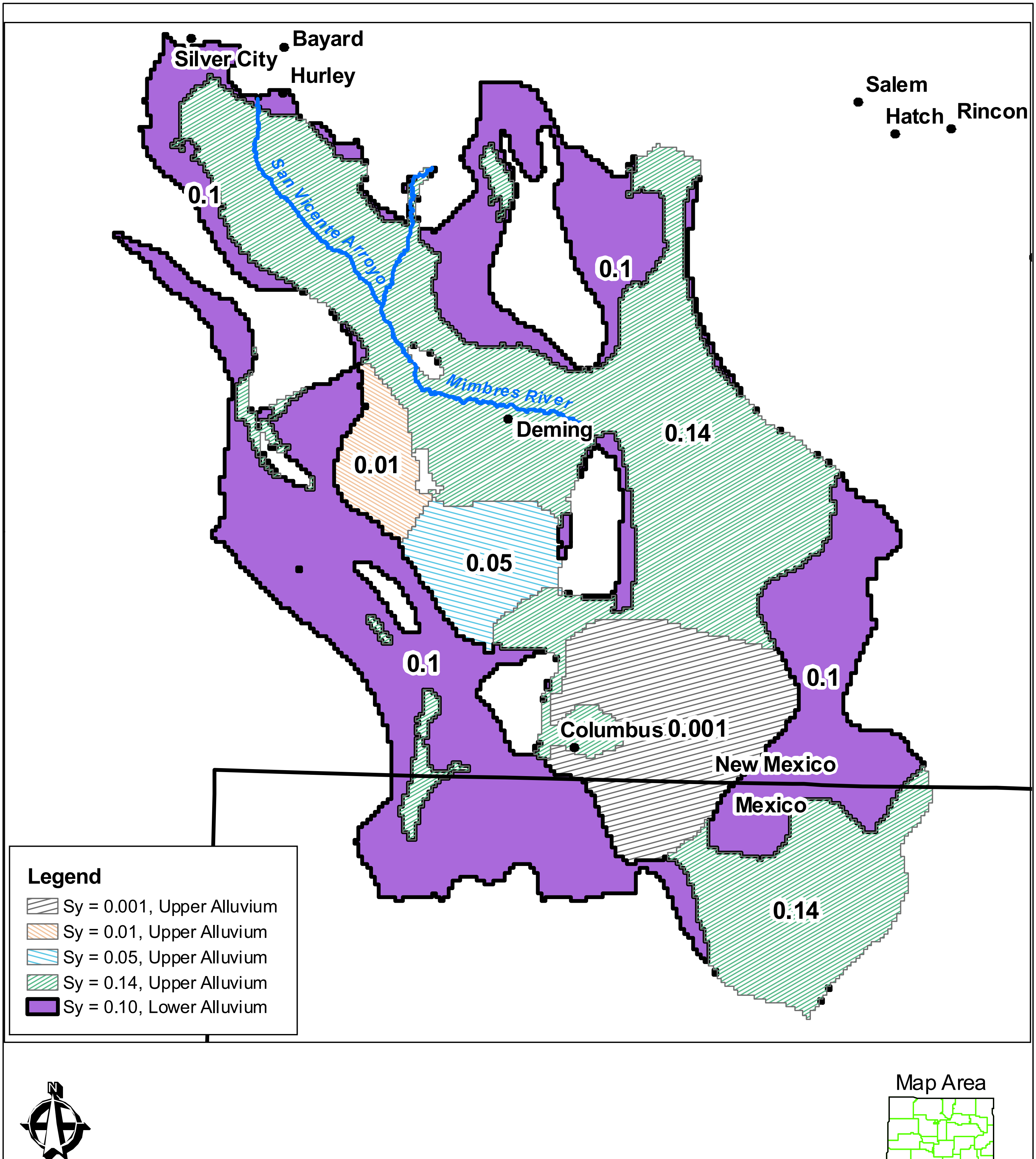
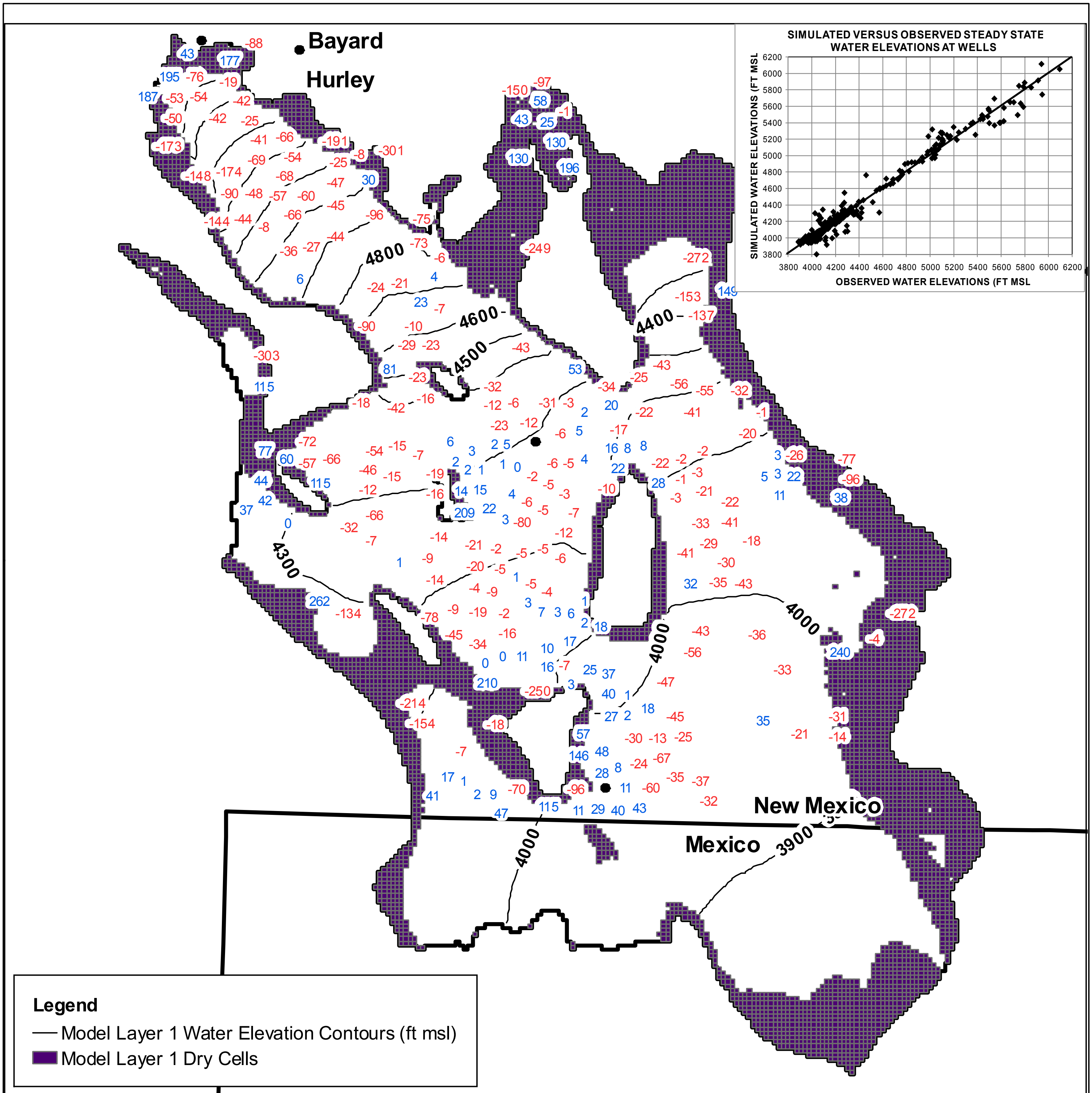


FIGURE 11
SPECIFIC YIELD IN THE MODEL

Miles
0 5 10 15 20

Sy.mxd



The contour interval is 100-feet
The residuals are posted as observed - simulated water elevation in feet
Negative red values represent the amount that the model overpredicted steady state water elevations

Map Area

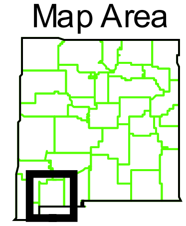
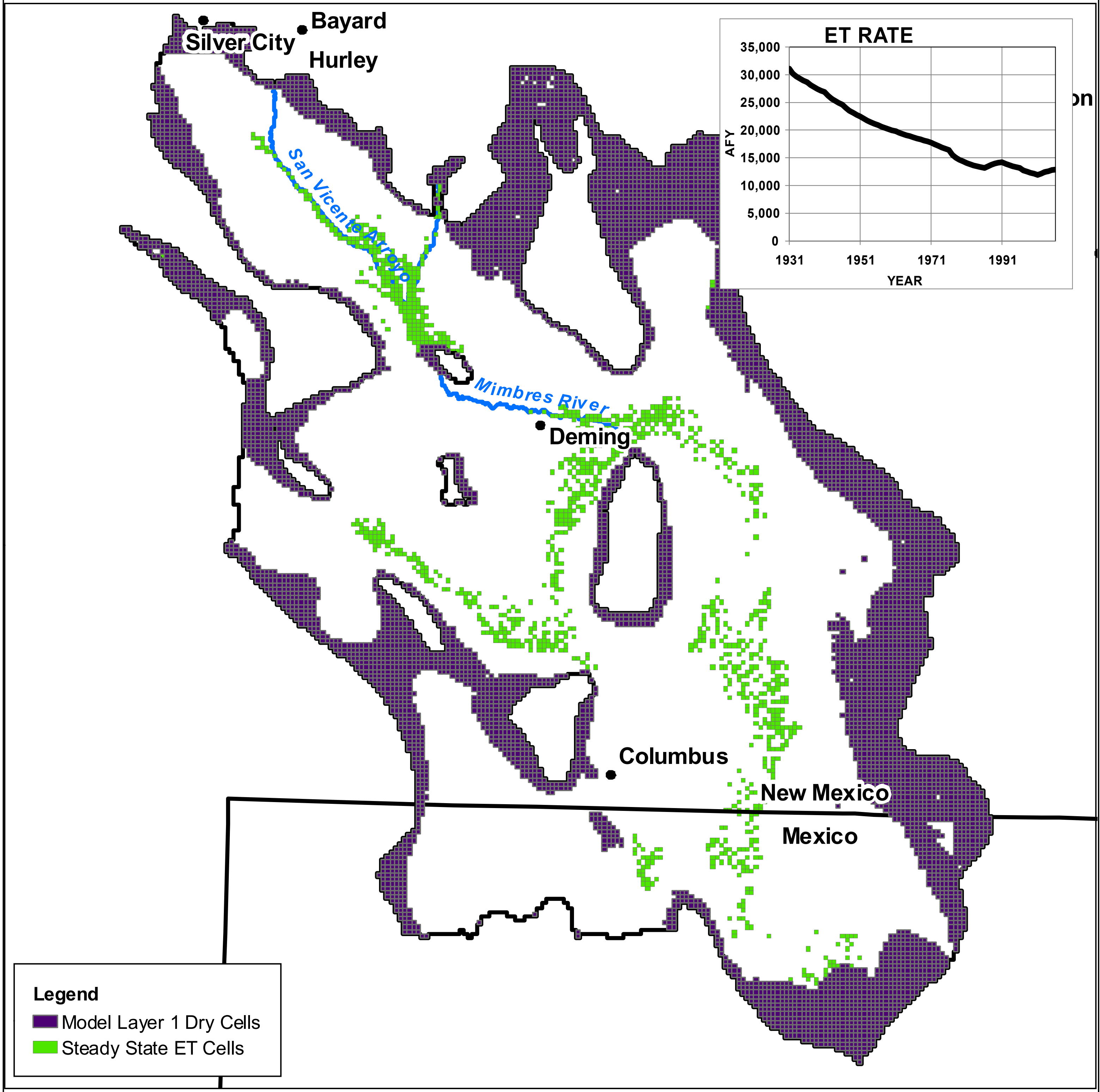


FIGURE 12
STEADY STATE WATER ELEVATION AND RESIDUALS IN THE MIMBRES MODEL

Miles
0 5 10 15 20

ss_resid2.mxd



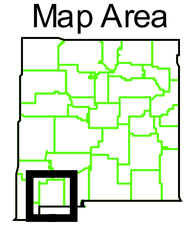
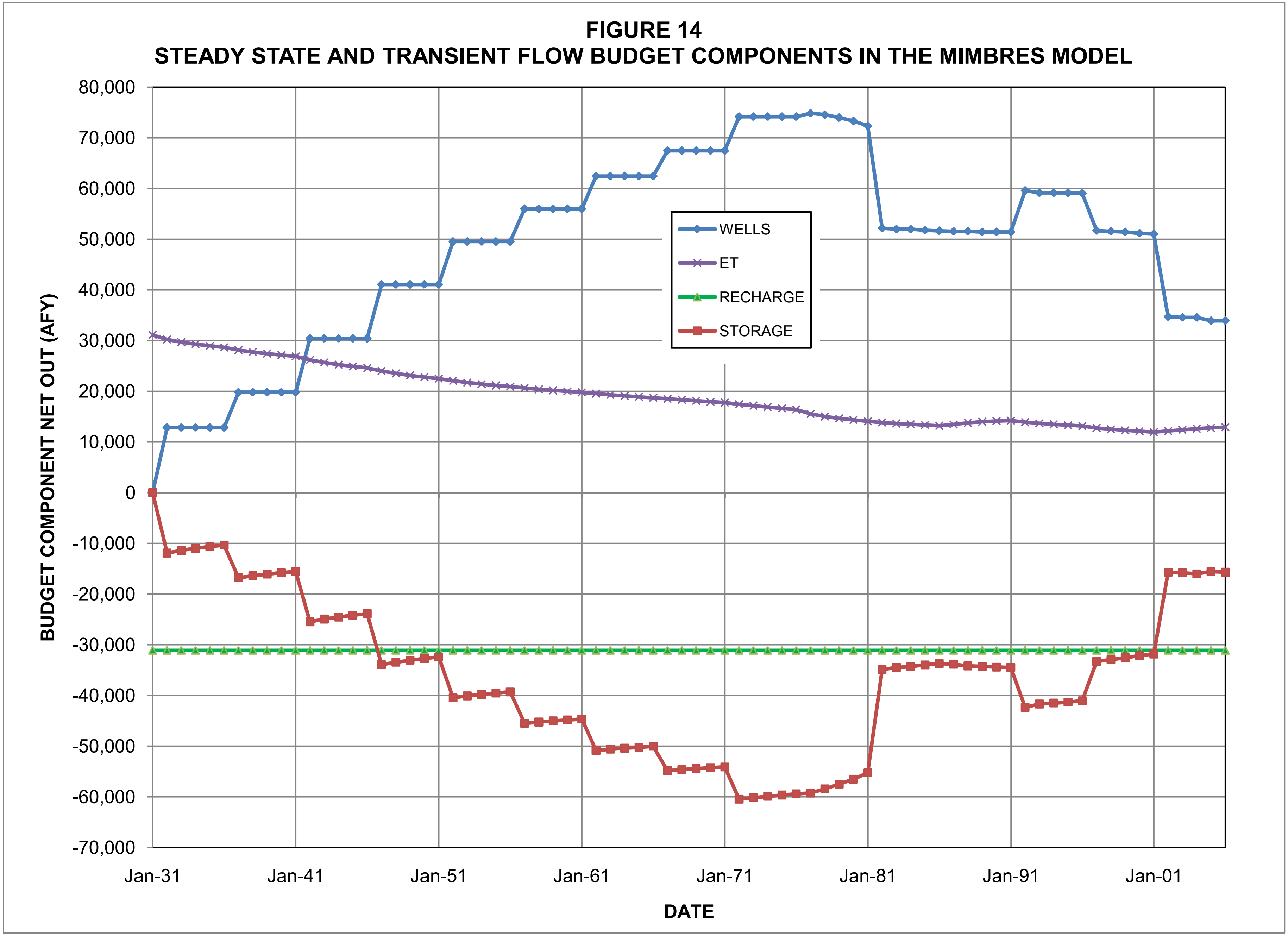


FIGURE 13
THE LOCATIONS OF ACTIVE EVAPOTRANSPIRATION IN THE STEADY STATE MIMBRES MODEL

Miles
0 5 10 15 20

et2.mxd



budget.xlsx Chart1
ejk
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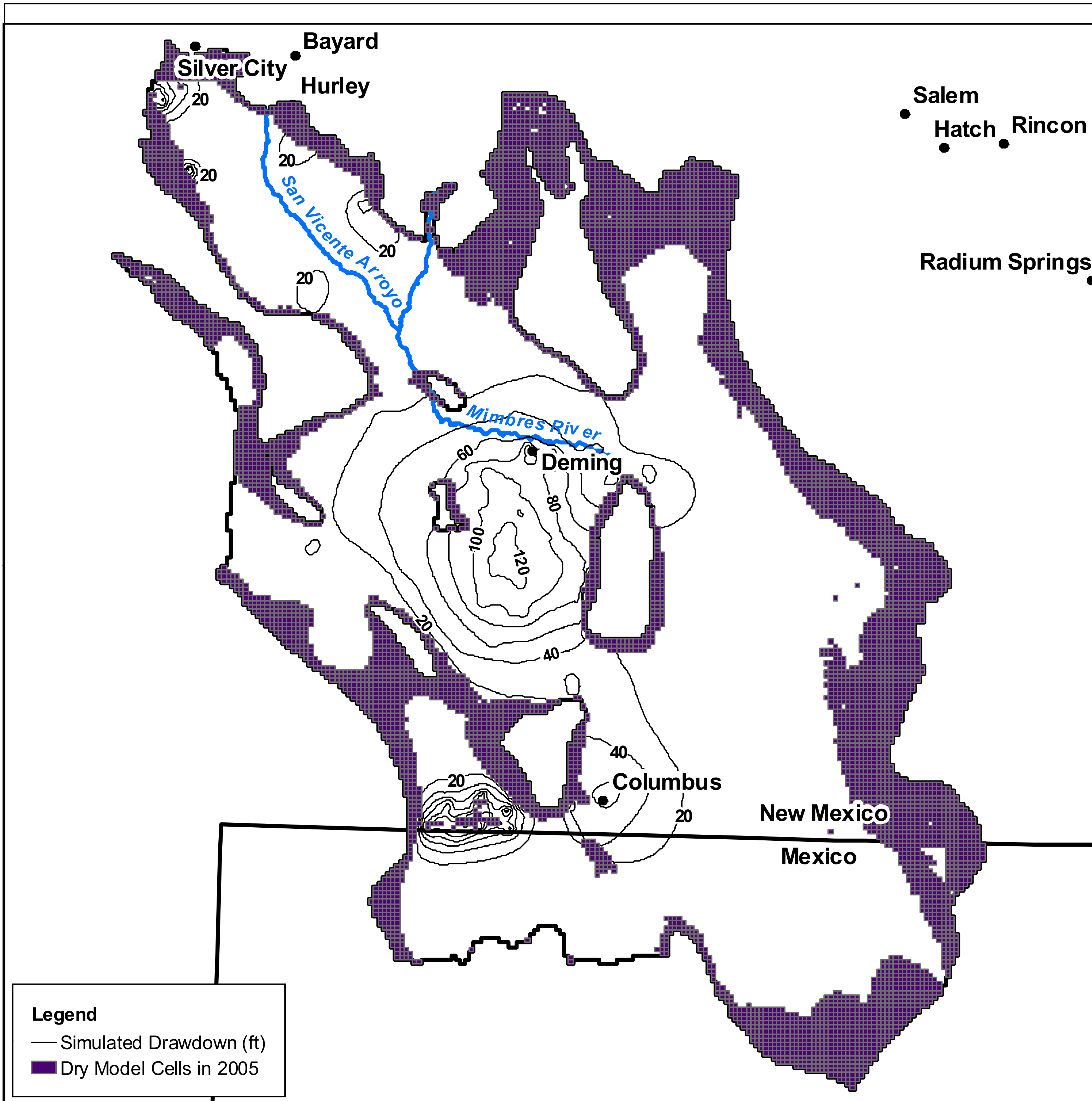


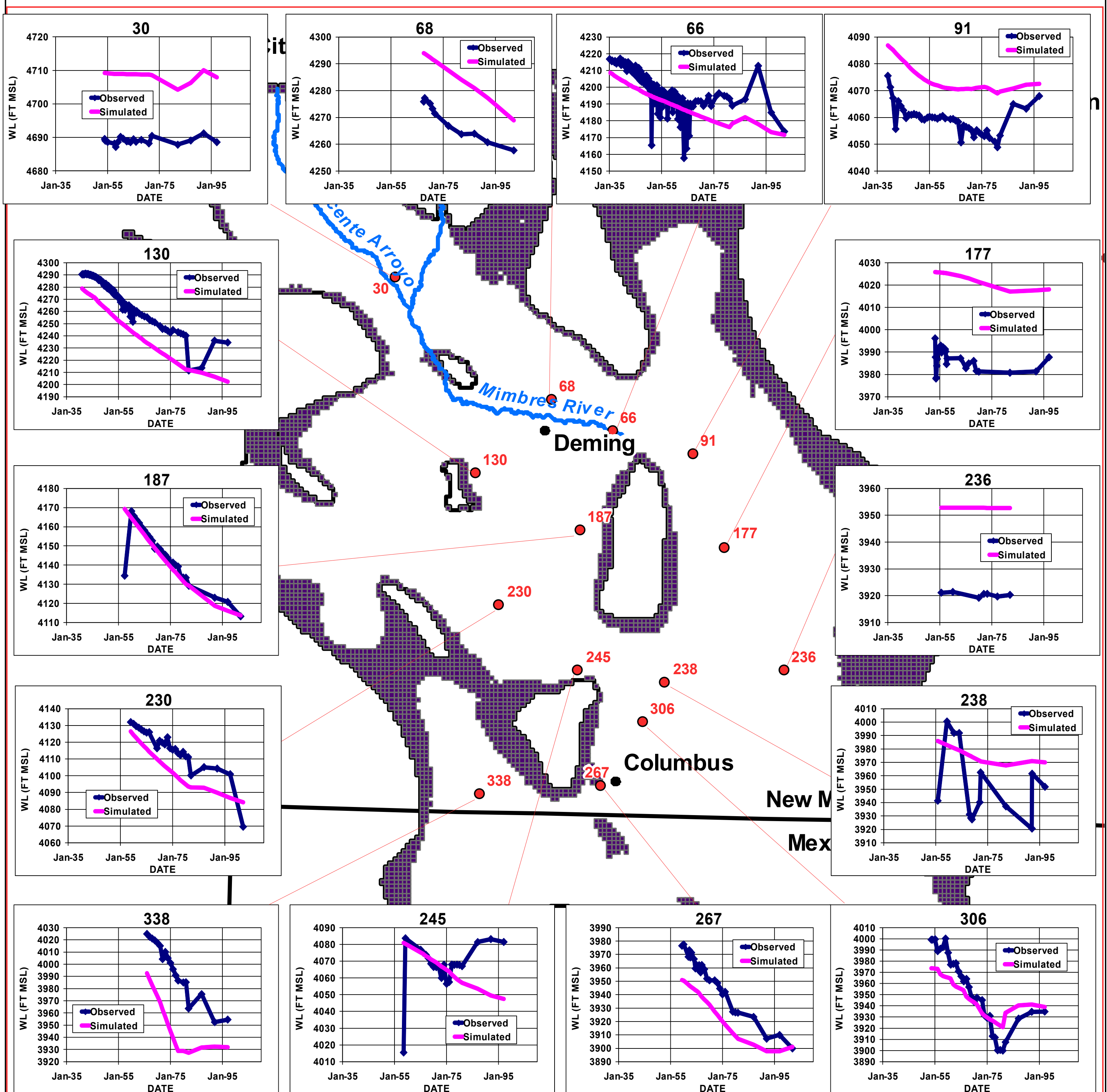
The Contour Interval is 20-feet

Map Area

FIGURE 15
SIMULATED DRAWDOWN
FROM PREDEVELOPMENT TO THE YEAR 2005
IN THE MIMBRES MODEL

Miles
0 5 10 15 20

dd_2005.mxd



Legend
- Hydrographs
- Model Layer 1 Dry Cells

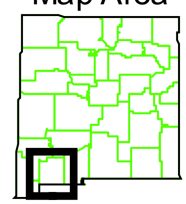


FIGURE 16
COMPARISON OF OBSERVED AND SIMULATED HYDROGRAPHS IN THE MIMBRES MODEL

Miles
0 5 10 15 20

hydrographs2.mxd